# Symbolism, knowledge and management of soil and land resources in indigenous communities: Ethnopedology at global, regional and local scales

*(Symboliek, kennis en beheer van bodem- en landhulpbronnen in inheemse gemeenschappen: etnopedologie op wereld-, regionaal en lokaal niveau)*

## VOLUME I

*by*

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*Quiero dedicar mi esfuerzo a*

*Todos los topos de esta larga, obscura y entristecida noche*
*A los esforzados miopes, por no haber perdido el rumbo de la mirada*
*A los sin cara, a los sin nombre*
*A todos los desterrados en su propia tierra*
*Al emigrante, que siempre lleva en el puño un migajón de su terruño*

To Victor Manuel Toledo Manzur

# Preface

The type of work done by a PhD student is quite similar to the one carried out by a monk or nun apprentice confinement of his/her cell, or by a spider that spins its cobweb in the highest corner of the roof. Most of all, such tasks require a great deal of concentration, a profound conviction about the goals to be fulfilled (even as in the case of the arachnid's survival strategy), and an enormous isolation to consciously and carefully spin what will support arguments, faith or home. This is how I have built the architecture of my thesis during these long years, despite knowing that it could collapse during the process. However, even if these tasks require a great deal of isolation, individuals simply cannot carry out them alone. Students form part of the academic institution, monks and nuns belong to the church, and spiders do their work for their population maintenance, thus they cannot do it alone.

It is commonly assumed that a PhD dissertation is an individual responsibility, which demonstrates the individual's capability to conduct independent research. At last, this individual may become a doctor, or even a professor, if the requirements are completely fulfilled according to the authority of science. Monks and nuns may become father or mother superiors, or even bishops, if 'God' allows it; and spiders may maintain their population, if the fate of nature is benevolent to them. During my PhD *passage* ritual, I carried out my tasks always knowing that I was the only responsible of my academic acts, and most of the time I felt that I was conducting them lonely or isolated, without enough support. Today, while writing these paragraphs, I found that I was never alone. On the contrary, I was accompanied by or connected with several institutions, researchers, farmers and friends, during the whole journey. Maybe this finding forms part of the ritual: I had to experience loneliness and isolation, while crossing to the other side of the academic bridge during the trance; thus I like to acknowledge that I learnt from this, and that I was wrong. The fact is that lots of support came from many sources.

First of all, I am in debt with my two promoters for tirelessly reading multiple versions of my 24 long chapters. It must have been terrible, I am afraid. However, I want to thank my professors Alfred Zinck and Eric Van Ranst for encouraging me to go my own way, even if at times it seemed that I was radically departing from the subject matter. They also gave me freedom to work according to my disciplinary background (social anthropology and cultural geography). I deeply thank them for letting me preserve my academic identity.

Alfred Zinck had an enormous and kind patience during these long years, always encouraging me to go deeper into my topic, since I met him in Mexico in 1992. To my surprise, he had already read an old article written in Spanish about my early findings on the Purhépecha ethnopedology. Since then, I received support, even during tense and controversial moments. From the many things I learnt from him, the most important one is that good and founded relationships lead to success. My respect for him goes beyond professional matters as I consider him as a good friend. I also acknowledge the work done by Prof. Eric Van Ranst, who carefully read several draft versions of my thesis, providing me with observations and criticism.

I was hosted by ITC in the Netherlands during most part of my doctoral research. Impressing for me was to work and take advantage from what the ITC building infrastructure offered me. Many ITC specialized areas and colleagues offered advice and help. I especially acknowledge the cooperation received from Marga Koelen and Carla Gerritsen, who always rapidly and kindly responded to my bibliography requests. I made full use of the library facilites. In my opinion, the ITC library runs as the best place I found in that institution. However, I found out that not everybody was aware of the advantages of having such an efficient working area, which is a pity, in fact.

I also received support from the staff members of the former Soil Science Division, where I was appointed as a PhD researcher. I thank Abbas Farshad, Dhruba Shrestha, Robert Hennemann, David Rossiter and Wouther Siderius from their support and criticism. Abbas Farshad encouraged and helped me to learn about Andisols, to interpret soil laboratory data, and to spatially correlate local and technical soil classifications using the ILWIS software package. During this process, Abbas became a friend. I enjoyed those evenings at his home, while sharing excellent Persian food in the company of Sonia and their sons.

I also benefited from constant advice and friendship from several ITC staff members, including Mike McCall, Marion Pierik, Robert Albricht and Wim Bakker. Mike McCall helped me in many ways, encouraging me during harsh moments, providing me with very useful information and offering me research advice, but most of all friendship. I enjoyed those evenings at the McCall's, where we shared thoughts about what is now happening on our planet, while enjoying some of the best world music.

I also received invaluable technical assistance from Benno Masselink, Job Duim and our cluster manager, Gerard Leppink. Roelof Schoppers always offered me professional attention and strategic help. I thank them for their attention.

The directorate of the Instituto de Ecología, A.C., in Mexico, offered me the possibility to carry out doctoral studies in the Netherlands, as part of its internal academic formation support program. I acknowledged this by adding the name of the institute in all published articles, book and papers presented in 11 international conferences and meetings. I want to express special thanks to Professor Gonzalo Halffter for encouraging me to conduct my research. I also appreciate the work done by Lourdes Cruz at the Laboratory of Soils and thank Margarita Soto for her support in this matter.

During the course of my studies I have exchanged ideas, information and scientific advice with many individuals. My gratitude goes to all of them, but I would like to mention in particular those who made observations on chapter drafts or commented on papers in progress. Antoinette WinklerPrins became the closest colleague, while and after spending a year at ITC as a post-doctoral researcher. She made insightful comments, observations and criticism on most chapters of the thesis, published papers and the annotated bibliography on ethnopedology that was co-authored with J.A. Zinck and published at ITC in 2000. Since then, Antoinette and I constructed a professional partnership, which was materialized by co-authored papers, scientific meetings organization and forthcoming joint research projects in Mexico. I thank her for all that, but mostly for her friendship and care.

So far, few researchers are conducting studies similar to mine or are interested in the topic. Among them, I took advantage from exchanging ideas and information with David Niemeijer, Mike McCall, Abbas Farshad, Paul Richards, Pim Jungerius, Antoine Cleef, Piet van Reeuwijk, Klaas-Jan Beek and Robert Albricht in the Netherlands; Roger Langohr in Belgium; Jonathan Sandor, Susan Hecht, Luisa Maffi, David Harmon, Dan Klooster, Chris Fisher, Joe Tabor, Deirdre Birmingham and the late Mike Warren in the USA; Darrel Posey and Paul Sillitoe in UK; Romualdo Rengifo and Mario Tapia in Peru; Rhodora Gonzalez in the Philippines; Garth Harmsworth in New Zealand; and Victor M. Toledo, Gerardo Bocco, Carlos Ortiz Solorio, Pedro Alvarez-Icaza, Citlalli Lopez, Cesar Carrillo, Claudio Garibay, Lorenzo Vázquez and Marco Barrera in Mexico. I appreciate special contributions and friendship from David Niemeijer and Victor M. Toledo. That is why I dedicate this voluminous thesis to the latter.

I benefited from several fellowships and grants to conducting my research in the Netherlands and Mexico. Mexican fellowships came from the SEP and CONACYT. SEP provided me with an allowance fellowship during the first three years, while ITC provided me with a research fellowship that included tuition fees and a research budget during the same period. I would like to thank Professors Klaas-Jan Beek and Victor Arredondo for their support. CONACYT granted me a full doctoral scholarship during the last period of my stay in the Netherlands. I like to acknowledge that I received support from CONACYT with no delays and with efficient attention. I thank Debra Haber and Guadalupe Intriago for their professional and transparent help.

Grants and institutional support to conduct my research fieldwork in the indigenous community of San Francisco Pichátaro, Michoacán, Mexico, came from SEMARNAP, the Instituto de Ecología, A.C., and the Instituto de Geografía, UNAM. Fieldwork was carried out during almost two years, divided in three periods.

I want to express my gratitude to Julia Carabias, Pedro Álvarez-Icaza, Alberto Rojas Zamorano, José Luis Palacio, Gerardo Bocco and Sergio Guevara.

I received financial support, help and information from the following NGOs: the Friedrich Ebert Stiftung (Mexican section), CESE, A.C., and GIRA, A.C. Financial support was used for the organization of two participatory workshops held in the study area during a two-week period, with the active participation of some 60 local residents, authorities, researchers an technicians. The involvement of some staff members from CESE, A.C., was critical to the conduction of these workshops. For that, I want to thank Leonardo Meza, Joaquin Esteva, Jorge Odenthal, Omar Masera and Marta Astier.

I had the opportunity to share ideas and conduct fieldwork in the study area with Dutch students from the Department of Anthropology of Utrecht University. I benefited from the experience and information gathered by Liza de Laat, Martijn ter Heegde and David Pollack, who conducted a two-month fieldwork as part of their undergraduate studies. With them I also shared friendship while being in the Netherlands. I am in debt with Martijn ter Heegde for his help while conducting a socio-economic census in Pichátaro and for his assistance in developing the bibliographic database of this thesis, but mostly for his warm friendship and constant care.

Crucial were the support and advice from Luc van Sleen, Citlalli Lopez, Abbas Farshad, Lourdes Cruz, Piet van Reeuwijk and Alfred Zinck for the local geopedologic survey, taking into account that, as an anthropologist and a geographer, I only had general knowledge about volcanic soils before conducting my research fieldwork. I greatly appreciate them introducing me into the soils worldand soilscapes. I also express gratitude to Rafael Antunez and Daniela Esparza, who assited me in the last edition and formatting of the thesis. Special mention goes to Daniela for her kind support and help.

My kindliest appreciate goes to *Pichatareños*, from whom I always received warm support during almost two years of frequent visits and obsessive questioning about local soil and land resources, crops, agricultural practices, and the like. I simply cannot forget smiles and attention, even after long journeys of participative work from which I collected the bulk of my ethnopedological information. During these long conversations with them, they started acknowledging that I was not just wasting my time (*matando el tiempo*) with local matters, as *Pichatareños* do not consider the wisdom about local soil and land resources that they possess as special, but as part of the livelihood that they carry on. From the beginning, local participation was encouraged by the importance given to my inquiries by old residents, agriculturalists, local technicians and professionals, and authorities. At the end, this was testified by the active participation of 50 local residents during the participatory workshops.

Working in the village was not only an interesting academic exercise, but it also involved all sorts of other aspects that form part of our lives. Long and effervescent political discussions about the country, participation in everyday life duties such as working with them in their agricultural parcels, or participating in the local *fiestas* or household celebrations and in the after-dinner conversations about Pichátaro and *Pichatareños*, all that contributed to making strong friendship ties. I want to express my deepest gratitude to the Tellez family, who offered me shelter and food; to Heriberto Rodríguez, a young and bright local agronomist, and political leader who offered me advice and information and introduced me to the most notable agriculturalists, artisans and foresters of the village. He worked with me as a fieldwork research assistant, covering all sorts of duties and gathering valuable information. Cecilio de la Cruz, Rafael Arriaga (by then, the acting head of the village), Simon Nicolas, Pablo and Julian Tellez, Rogelio Rodriguez, Leovegildo Rodriguez and the late Francisco Diego, offered me wisdom, time and help.

ITC proved to be a trans-cultural fascinating scenario where one can easily make friends. I benefited from that circumstance and had the chance to build strong friendship ties. First of all, I want to express my deepest gratitude to Karin Schmidt (Namibia), who offered me sincerity and the best a friendship can offer: feelings, luminous conversation and care. Karin, Amon Murwira (Zimbabwe) and myself undertook biking through the forests surrounding Enschede as a pleasant weekend duty. Those were the best moments of my lonely weekends during years. Biking was always accompanied with long conversations and discussion, a nice meal, an ice cream, or a few beers. I had the best time while sharing the plenty of life with Wilbur Ottichilio and Wilson Khaemba (Kenya). Being with my African friends offered me the opportunity to learn about the beauty of that huge continent, but also made me more sensitive and aware about the impacts of colonialism that they suffered until just a few decades ago. Besides, sharing time with them I had the chance to enjoy and get closer to the lovely and rhythmic African music. Maria Bastidas, Memo and the 'kids' (Venezuela) embraced me with warm and unforgettable friendship. I thank them for listening to my complaints and deceptions, and for helping me to forget sadness and enjoy happiness. I also want to thank Eduardo (Dudu) Guimaraes and Ivan Bacic and family (Brazil), Jamshid Farifteh (Iran), Eulogio Chacón (Venezuela) and Silvia Giada (Italy) for their lovely company and support, including my anonymous friends from the Het Bolwerk café.

Very special for me were the moments I spent with Mathias Spaliviero (Italy) and Alejandra Fregoso (Mexico). The three of us have many things in common: professional activities, strong character, dreams, experience, although not the age. I hope our friendship stays long, despite geographic distance.

Last but not least, I express my enormous gratitude for the maintenance of strong ties with Victor M. Toledo, Lucero Binnquist, Marco Barrera, Cristina King, and Mathias Barrera King, Maria de Jesus Luna and Cesar Carrillo. Janna (Iceland) accompanied me during these last two years as my closest friend, with whom I traveled to far and exotic places and shared views about tender, care, respect; opinions and feelings that will last even if being geographically apart.

**Postdata**

Después de poco más de tres años de haber defendido esta tesis, decidí abocarme a la tarea de realizar las correciones pertinentes para su publicación en dos volúmenes dentro de la series de disertaciones que publica el ITC. El objetivo fué formalizar más de 9 años de trabajo en un libro que tendrá, espero, una mayor circulación que la propia tesis y, así, culminar con la meta que me planteé a mediados de 1995. Todo ello no hubiera sido posible sin el apoyo recibido por parte del Instituto de Geografía de la UNAM, mi hogar académico desde el 2003 y de sus autoridades y cohabitantes. En especial hago mención de Alejandro Velázquez y Gerardo Bocco. Un especial agradecimiento merece el apoyo técnico recibido de Pedro S. Urquijo, quien revisó cuidadosamente el documento final para su publicación. Aun así, soy totalmente responsable de ésta. Agradezco tambien el apoyo financiero y logístico otorgado a través del proyecto PAPIIT (IN 306806).

I also would like to thank ITC for giving me the oportunity to fulfill this goal, by providing logisitics and facilities during a short stay at Enschede in March 2007. I specially would like to thank Alfred J. Zinck, Abbas Farshad, Martin Hale, Loes Colenbrander, Benno Masselink, Job Duim and Andries Menning for assisting me during this period at ITC. A special mention goes for my good friends Alfred (France), Abbas (Iran), Diana (Colombia), Jamshid (Iran), Alejandro (Cuba), Graciela (Colombia), and Henk (The Netherlands) for offering a smile, sweetness and friendship. Mike and Margaret McCall have always been supportive and close friends since long time. Thanks to them I was comfortable, warm, smiling and well fed, during this last stage. Muchas gracias... !

Enschede, The Netherlands, March 16, 2007

# Abstract


Extensive work is still needed to fully understand and value local symbolism, knowledge, classification and management of soil and natural resources, which are still practised by a great number of rural peoples, especially from the Third World. In fact, many specialists, policy makers and developers tend to neglect or undervalue these knowledge systems. In contrast, ethnopedological studies increasingly reveal cases of adequate natural resource management, evolved and adapted over hundreds or even thousands of years. Research findings show that many local land-use and land management systems are rooted in detailed knowledge of soils, including soil properties, behavior, processes and dynamics, as well as spatial variability and heterogeneity of the soil cover. Local soil classification systems, water and soil conservation measures, soil fertility conservation, and management of soil, land and landscape resilience provide evidence of the knowledge about these resources that farmers apply in their parcels. Moreover, diverse symbolic representations and perceptions of soil and land reveal the strategic role given to these domains in local cosmovision, as they are the basis for sustaining agriculture and other production activities.

Many of the principles that structure social theories of soil and land resources, are similar to those that nowadays are promoted, on a scientific basis, by the paradigm of sustainable management of natural resources; thus both theories show the possibility for synergies related to the maintenance of biological, agricultural and cultural diversity. However, ethnopedology is still in its early days as a scientific discipline. The latter is critical if considering that land degradation tends to increase in many parts of the world, but especially in the inter-tropical belt of our planet. Current and potential contribution of ethnopedological studies aim to halt or even revert environmental degradation. This requires to make ethnopedological studies robust and useful. To do so, there is a need to link ethnopedological with scientific findings, to contrast them and find their synergies, and to encourage the maintenance of local knowledge, adapting it to the conditions that nowadays prevail in the world's rural context.

This thesis contributes to progress in ethnopedology as a hybrid discipline and as an interdisciplinary approach in several ways. First, it develops an integral research approach, which includes the symbolic (Kosmos), cognitive (Corpus) and management (Praxis) dominions of social theories about soil and land resources, here referred to as the K-C-P complex or model. It also argues that ethnopedological studies must put emphasis on the political, cultural, economic and ecological context of the social actors, as they are the prime producers and users of social theories about soil and land. This would allow ethnopedology to go beyond the limited technical analyses, which focus exclusively on comparing local soil classifications with scientific classifications.

Secondly, this thesis develops an integral methodological research framework, by the application of a set of techniques to store, retrieve, systematize, co-validate and analyze social theories about soil and land resources. This systemic approach and applied techniques offer the possibility to include information provided by anthropology, geopedology, agronomy and geography, including data processing in GIS environment. This approach sustains the hybrid character of ethnopedology and its transdisciplinary research approach.

The third contribution of this thesis consists in the use of a multi-scale approach, which provides information from global to regional and local levels, and conversely. This approach allows to evaluate multiple and diverse aspects of ethnopedological information, such as the links between local soil knowledge and the maintenance of biological, agricultural and cultural diversities at regional and global levels. It also permits to evaluate and compare ethnopedological findings for practical and theoretical purposes, contributing to enrich studies on nature-humans-culture relations.

The fourth contribution of the thesis consists in demonstrating the pertinence of linking ethnopedological findings with information derived from environmental history, landscape archaeology and political economy, using a political ecology framework. These relationships allow to evaluate, in an ample perspective, the current vitality, efficiency and limitations of local knowledge practice. In this way it seems possible to reach endogenous development with the full participation of the local actors.

# Samenvatting

Er is nog steeds heel wat onderzoek vereist opdat de lokale symboliek, kennis, en classificatie en ook het beheer van de bodem en andere natuurlijke hulpbronnen door een belangrijke landbouwbevolking, zeker in de Derde Wereld landen, volledig begrepen en gewaardeerd kan worden. Het is echter zo dat heel wat specialisten, politici en ontwerpers van plattelandsontwikkelingsprojecten deze lokale kennis onderwaarderen of zelfs negeren. Nochtans, tonen etnopedologische studies in toenemende mate aan dat de lokale bevolking in de loop der jaren een geschikt beheer van de natuurlijke hulpbronnen ontwikkelt en naderhand bijstuurt. Onderzoek toont verder aan dat de lokale landbeheerssystemen niet enkel steunen op een gedetailleerde kennis van de bodemeigenschappen en hun gedrag, de bodemprocessen en -dynamiek, maar ook gebaseerd is op een goed inzicht in hun ruimtelijke variabiliteit en heterogeniteit. Lokale bodemclassificatiesystemen, water- en bodembeschermingsmaatregelen, bodemvruch tbaarheidcontrole en het beheer van de bodem-, land- en landschapsveerkracht, illustreren hoe de boeren deze kennis effectief toepassen op hun landbouwpercelen. Gecombineerd met dit, laten de verscheidene symbolische representaties en lokale percepties betreffende deze hulpbronnen het strategische karakter zien, toegeschreven aan een kosmologische visie, welke de basis vormt voor landbouw activiteiten in het alomvattende geheel.

Veel van de principes die aan de basis liggen van de sociale theorieën van bodem- en landbeheer, zijn gelijkaardig aan deze die hedendaags worden gepromoot, steunend op wetenschappelijke criteria, in het paradigma van duurzaam beheer van natuurlijke hulpbronnen. Beide theorieën bieden bijgevolg mogelijkheden aan voor een synergie in de voorstellen voor het behoud van biologische, landbouwkundige en culturele diversiteit. Desondanks bevindt de etnopedologie zich nog steeds in de beginfase als wetenschapsveld, en dit terwijl alarmerende processen van landdegradatie overal ter wereld, maar vooral in de intertropische zone van onze planeet, worden vastgesteld. Wanneer de etnopedologische studies kunnen worden gebaseerd op robuuste onderzoek- en toepassingsprincipes, kunnen zij een middel vormen om de degradatie van het milieu te stoppen en zelfs te corrigeren. Dit veronderstelt een confrontatie en vergelijking van de etnopedologische en wetenschappelijke onderzoeksresultaten, en de bevordering van de lokale kennis zodat die zich kan aanpassen aan de dominerende stromingen in de huidige mondiale agrarische context.

Dit proefschrift draagt op verschillende wijzen bij tot de bevordering van de etnopedologie als hybride discipline en als transdisciplinaire activiteit. In eerste plaats wordt er een integrale onderzoeksstrategie ontwikkeld (het K-C-P-model) dat de analyse van de symbolische (Kosmos), cognitieve (Corpus) en praktische (Praxis) domeinen van de sociale theorieën met betrekking tot de hulpbronnen bodem en land omvat. Hierbij wordt de nadruk op de socio-politieke, culturele, economische en ecologische context van de sociale actoren, vermits zij juist de sociale theorieën voor bodem- en landgebruik produceren en praktiseren. Dit brengt deze etnopedologische studie een belangrijke stap verder dan de pure technische vergelijkende studies van lokale en wetenschappelijke bodemclassificatiesystemen.

Op de tweede plaats stelt dit proefschrift een methodologisch integraal raamwerk voor door toepassing van verschillende technieken om de sociale theorieën met betrekking tot de hulpbronnen bodem en land te organiseren, beheren, systematiseren, valideren en analyseren. Deze systematische aanpak en toegepaste technieken laten toe om informatie uit verschillende disciplines zoals antropologie, geopedologie, agronomie en geografie te verwerken in een geografisch informatie systeem. Deze aanpak bevordert het hybride karakter en de transdisciplinaire onderzoeksaanpak van de etnopedologie.

De derde bijdrage van dit proefschrift bestaat uit het toepassen van een meerschalige analyse van de informatie van globaal, regionaal tot lokaal niveau, en omgekeerd. Dit laat toe om diverse aspecten van etnopedologische informatie, zoals bijvoorbeeld de banden tussen de lokale kennis van de bodems enerzijds en het behoud van de biologische, landbouwkundige en culturele diversiteit op regionaal en globaal niveau anderzijds, te evalueren. Verder laat het toe om verschillende etnopedologische resultaten te evalueren en vergelijken voor praktijken en wetenschappelijke doelstellingen waardoor een bijdrage kan worden geleverd tot de studies betreffende mens-cultuur-natuur relaties.

De vierde bijdrage van dit proefschrift laat het belang zien van het samenbrengen van etnopedologische studieresultaten met informatie uit disciplines zoals milieugeschiedenis, politieke economie, landschapsarcheologie en etno-ecologie, aan de hand van een politiek- ecologisch raamwerk. Dit laat toe de vitaliteit, de efficiëntie, de beperkingen en het potentieel van de toepassing van lokale kennis in een wijde context te plaatsen. Alleen op deze wijze lijkt het mogelijk een endogene ontwikkeling met de totale deelname van de lokale actoren te realiseren.

# Resumen


El simbolismo, el conocimiento, la clasificación y el manejo local de los recursos suelo y tierra que aun poseen y utilizan muchos pueblos rurales, especialmente en el Tercer Mundo, han sido hasta ahora poco valorados e inclusive negados en el ámbito científico-técnico y en proyectos de desarrollo rural. Sin embargo, el creciente pero aun modesto numero de estudios etnopedológicos demuestra, en muchos casos, un manejo adecuado de estos recursos localmente adaptado a lo largo de muchos años por estos pueblos. Los resultados demuestran además que el uso y manejo de las tierras se basan en un detallado conocimiento sobre los suelos, que incluye sus propiedades, comportamientos, procesos y dinámicas, así como su variabilidad y heterogeneidad espacial. Las clasificaciones pedológicas locales dan cuenta de ello, así como las estrategias empleadas por los campesinos para la conservación de agua y suelos, el manejo de la fertilidad de las tierras y el manejo de la resiliencia de suelos, tierras y paisajes. Aunado a ello, las variadas representaciones simbólicas y percepciones locales sobre estos recursos demuestran el carácter estratégico que se les ha asignado en la cosmovisión por constituir la base sobre la cual se sustentan las actividades agrícolas, entre otras.

Más aun, muchos de los principios que sustentan las teorías sociales sobre los recursos suelo y tierra, resultan similares a aquellos que, basados en criterios científicos, promueven el manejo sustentable de los recursos naturales. Por lo tanto, ambas teorías presentan sinérgias en las propuestas para el mantenimiento de la diversidad biológica, agrícola y cultural. A pesar de ello, la etnopedología aun se encuentra en sus fases iniciales como disciplina científica. Esto contrasta con los alarmantes procesos de degradación de tierras, especialmente en la franja inter-tropical del planeta, según diversos especialistas. De allí la urgencia de promover el avance de los estudios etnopedológicos, de contrastar sus resultados con aquellos de tipo científico e impulsar los conocimientos locales adecuándolos a los procesos en el contexto agrario mundial actual. La etnopedología podria así informar sobre posibles y localizadas propuestas para mitigar el deterioro ecológico y cultural que hoy impera.

Esta tesis contribuye de diversas formas al avance de la etnopedología como disciplina híbrida y, por lo tanto, como quehacer trans-disciplinario. En primer lugar, propone realizar estudios integrales que incluyan el análisis de los dominios simbólico, cognitivo y práctico de las teorías sociales sobre los recursos suelo y tierra (el complejo K-C-P). Esto incluye además, poner énfasis en el contexto socio-político, cultural, económico y ecológico de los sujetos sociales, quienes son los que producen y practican dichas teorías. Solo así se podrá rebasar el carácter limitado de los estudios técnicos, enfocados exclusivamente a comparar las clasificaciones locales y científicas.

En segundo lugar, esta tesis propone un marco metodológico integral mediante la aplicación de diferentes técnicas para la captura, sistematización, co-validación y análisis de las teorías sociales sobre los recursos suelo y tierra. El enfoque es sistémico y su implementación incluye técnicas adaptadas para su abordaje antropológico, geopedológico, agronómico y geográfico, incluyendo el procesamiento de datos en SIG. Esto se sustenta en el carácter híbrido y el enfoque interdisciplinario de los estudios etnopedológicos.

La tercera contribución de esta tesis consiste en analizar y articular los conocimientos etnopedológicos de manera multi-escalar, pasando de lo global a lo regional y a lo local, y en sentido inverso. Este aporte multi-escalar permite discernir diversos aspectos de las sabidurías pedológicas locales en relación con la diversidad biológica, agrícola y cultural a nivel regional y global. Permite además, valorar y comparar diversos resultados etnopedológicos con fines prácticos y teóricos, esto ultimo visto desde la perspectiva de los estudios sobre las relaciones hombre-cultura-naturaleza.

La cuarta contribución de esta tesis es demostrar la pertinencia de vincular los estudios etnopedológicos con disciplinas tales como la historia ambiental, la economía política, la arqueología del paisaje y la etnoecología, entre otras, mediante el enfoque propuesto por la ecología política. Esto permite contextualizar ampliamente la vitalidad, la eficiencia, las limitantes y el potencial de los usos sociales de los conocimientos locales. Solo así parece posible alcanzar un desarrollo endógeno con la plena participación de los actores locales.

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APPENDIX 2

# Chapter one

## Introduction

So far, not much has been done to fully understand and value local perceptions, symbolism, knowledge and management of soil and land resources that are still practiced by a great number of rural societies, especially from the Third World. In fact, many specialists, policy makers and developers tend to undervalue or neglect the local well-fitted and accurate knowledge about natural resources that many farmers still possess. In contrast, ethnopedological studies increasingly reveal cases of adequate land management, evolved and adapted over hundreds or even thousands of years.

Many local land-use and land management systems are rooted in a detailed knowledge of soils, including soil properties, behavior, processes and dynamics, as well as spatial variability and heterogeneity of the soil cover. Local classification systems, water and soil conservation measures, soil fertility conservation strategies, and management of land resilience provide evidence of the knowledge about these resources that farmers apply in their parcels. Diverse and sometimes contrasting symbolic representations and perceptions about soil and land reveal the strategic role given to these domains as they sustain life. Many of the principles, that structure the social theories about soil and land as perceived dominions and as resources, are similar to those that are nowadays promoted, on a scientific basis, by the paradigm of sustainable management of natural resources, thus showing the possibility for synergies related to the maintenance of genetic, biological, agricultural and cultural diversity. However, ethnopedology, or "the knowledge of soil properties and management possessed by people living in a particular environment for some period of time" (WinklerPrins, 1999), is still in its early days as a scientific discipline. Much work has to be done to make it more robust and applicable.

Ethnopedology can contribute to the idea that there are other different ways of knowing soils besides modern soil science, and that the long-term experience of rural societies with resource use and management, including successes and failures, can help evaluate land-use in relation to soil quality and sustainable agriculture. Ethnopedology can also offer important long-term insight about human responses to environmental change, acknowledging that information from the past and contemporary local cultures is relevant to prevent, halt or even reverse current environmental degradation processes. The latter is critical if considering that land degradation tends to increase in many parts of the world, especially in the inter-tropical belt of our planet (Zinck, 2003).

Ethnopedology can contribute to the maintenance of cultural, ecological, biological and agricultural diversity at global, regional and local scales. Documenting local soil knowledge reinforces cultural viability of rural societies that are still attached to land; otherwise, displacement and disconnection from land may translate into the loss of cultural heritage. The maintenance, reinforcement and adaptation of local soil knowledge are linked to the cultural survival of social subjects that have been subordinated and continue resisting modern transformations, nowadays controlled by globalization. Ethnopedology provides dialogical bridges between farmers and scientists, technicians and developers in a more respectful way for farmers and their livelihoods, making rural development more successful in the long term. The maintenance and adaptation of the cultural heritage are inextricably linked to the reinforcement of rights and protection of the subordinated peoples.

Local knowledge studies have demonstrated that many rural societies base their livelihoods on complex, multi-purpose natural resource management strategies, where soil and land resources are perceived and manipulated as basic, strategic and fragile domains. Adaptive management helps counteract environmental, economic and political uncertainties in fragile landscapes, where multi-cropping and agro-forestry systems house a great diversity of species, cultivars and agronomic practices as ways to overcome scarcity, calamity and forced changes. The maintenance of healthy soils contributes to the health of plants and humans, thus of the whole food chain. That is why local soil knowledge and practice prevent the loss of genetic, biological and agricultural diversity as part of self-subsistence livelihood strategies, which acknowledge that diversity maintenance is critical to the conservation and protection of cultural and natural resources.

Current and potential contribution of ethnopedological studies requires making this hybrid discipline robust and useful. To do so, there is a need to link ethnopedological with scientific findings, to contrast them and find their synergies. There is also a need to fully understand the local realities of peoples, especially of those farmers and villages who are prime knowledge producers and users. By the same token, ethnopedology can contribute to find ways to reverse some of the negative conditions that prevail in the world's rural context nowadays. This thesis contributes to progress in ethnopedology in several ways. The thesis was guided by three main research questions referring to the assessment of ethnopedology at global, regional and local levels, respectively:

(1) Which is the state-of-the-art in indigenous soil knowledge at global level?
(2) How did symbolism, knowledge and management of soil and land resources evolve in Middle America since the pre-Columbian times until today?
(3) How soil and land resources are currently perceived, classified, used and managed in an indigenous mountain community of central Middle America?

To answer these questions, the thesis intends to fulfill four main objectives. First, it proposes to develop an integral and holistic ethnopedological approach, which includes the symbolic (Kosmos), cognitive (Corpus) and practical (Praxis) dominions of social theories about soil and land resources, here referred to as the K-C-P complex or model. It also argues that studies of local environmental knowledge must put emphasis on the political, socio-cultural, economic and ecological context where knowledge is produced, innovated and practiced. Contextual studies go beyond the technical analysis, that evaluates local soil classifications and contrasts them against scientific classifications to unilaterally validate and formalize them as the main and only research objective. More than understanding and validating local soil knowledge, there is a need to answer how and why social theories about soil and land resources are put into practice, adapted and/or innovated, and why they are limited by the effects of external forces and processes, such as the neoliberal policies controlled by globalization, transnationalization and cultural assimilation.

Secondly, this thesis proposes to develop a systemic methodological research framework, that operates at various space and time scales by the application of a set of techniques to store, retrieve, systematize and analyze social theories of soil and land resources. This systemic approach and applied techniques offer the possibility to include information provided by social and natural sciences, such as history, archaeology, anthropology, economy, pedology, ecology and geography, including data processing in GIS environment. The application of a multiplicity of techniques is sustained by the 'hybrid' nature of ethnopedology and the need to frame it through an interdisciplinary approach.

The third objective of this thesis consists in the use of a multi-scale approach, which provides information at global, regional and local levels. This approach allows evaluating multiple and diverse aspects of ethnopedological information, such as the links between local soil knowledge and the maintenance of genetic, biological, agricultural and cultural diversity at various scales. Earlier findings show, for example, that preservation of global diversity depends in great proportion on the maintenance and reinforcement of the local environmental knowledge systems. Multi-scale análisis also permits to compare ethnopedological findings for practical and theoretical purposes. This contributes to enriching the academic debate concerning the nature-humans-culture relations, from both the natural and social sciences perspectives. This debate includes the human-induced historical land degradation issue.

The fourth objective of the thesis consists in linking ethnopedological findings at local level with information derived from environmental history, landscape archaeology, agro-ecology, ethnoecology and political economy, using a political ecology framework. These relationships allow evaluating, in an ample perspective, the current vitality, efficiency and limitations of the social theory about nature adopted and practiced by indigenous farmers of a mountain village in central Mexico since hundreds of years ago. The local soil knowledge will be addressed, including aspects of its hybridization and the impacts caused by the ongoing neoliberal policies in the Mexican rural context. This provides guidelines for an endogenous local development, according to the current political ecology of land-use and land management in the central highlands of Middle America.

The thesis is divided into three main parts, which address the three main research questions. Each part is subdivided into chapters, where the analysis was guided by secondary research questions. Most of the research questions are indicated in the introduction to each chapter, allowing the reader to get located within the whole dissertation. This procedure helped structure and maintain the research road map, taking into consideration the multi-scale and multi-facetted research approach applied.

**Part One** of the thesis (Chapters Two to Six) conceptualizes the social subjects, which are the main producers and users of social theories about soil and land resources, the content of the social theories about nature, and ethnopedology as a hybrid and integrative discipline. This part assesses these findings at worldwide level and links ethnopedological findings with areas of biological and cultural megadiversity, including the main centers of origin of plant domestication.

Chapter Two is dedicated to the analysis of the social subjects. It includes main political vindications of indigenous peoples as subordinated subjects in resistance, as some of these vindications are directly linked to the maintenance, protection and reinforcement of the local theories of soil and land resources (the K-C-P complex). It is acknowledged that a first step to be considered in ethnopedological studies is recognizing who are the soil knowledge producers and where they stand within the socio-economic and cultural relations at global, regional and local levels. Thus, the analysis of local knowledge must be driven by an actor-oriented approach.

The intimate relations between cultural, biological and agricultural diversities are discussed in Chapter Three. The main objective of this chapter is to analyze the historical role that indigenous peoples and small farmers played in the construction, maintenance and enhancement of the world's bio-cultural diversity. The consequences of the ongoing loss of this historical legacy are emphasized, and the social theories about soil and land resources, which are inextricably linked to the maintenance of diversity at global, regional and local levels, are proposed to be reinforced through promoting sustainable local endogenous development.

Chapter Four discusses the ways nature is conceived, represented, known and managed among indigenous peoples and small farmers, as part of their cultural and economic rationality. It also discusses the concept of 'social theory about nature' as a complex cultural ensemble of beliefs (Kosmos), cognition systems (Corpus), and management practices (Praxis), paying attention to how environment and culture are constituents of the same worldview and world life. Finally, it addresses the false opposition between social theories about nature and science according to conventional positivist views and proposes an alternative conceptualization of the relations between social theories about nature and science.

Chapter Five is dedicated to conceptualize ethnopedology as a hybrid discipline using an integral research methodology. Different research approaches in ethnopedology are discussed and it is proposed to insert ethnopedological studies within a broader political ecology research framework to fully understand how peoples make use of their repertory of cognitive domains, skills and theories about the soil and land resources.

In Chapter Six, the state of knowledge in ethnopedology is analyzed from an extensive literature review. Relevant research topics are recognized and findings of ethnopedological studies (EPS), carried out around the world during the $20^{th}$ century, are analyzed. EPS are located within different agro-ecological zones and countries having high linguistic, biological and agricultural diversities. The chapter attempts to evaluate the imbalances of ethnopedological studies, using the K-C-P complex as a research framework that reflects the holistic view of local peoples about nature.

**Part Two** of this thesis (Chapters Seven to Thirteen) is dedicated to the analysis of past and present Middle American ethnopedology, taking into account that Middle America (or Mesoamerica) is considered one of the regions of the world having high biological and cultural diversity. Mesoamerica is also one of the main centers of origin of plant domestication and agriculture based on maize-bean-squash (*milpa*) cropping, as a result of the development of one of the most sophisticated civilization cores in the history of humankind. Ethnopedological findings are discussed in a regional perspective, giving emphasis to the analysis of change and permanence processes of various social theories about soil and land resources. Comparative analysis demonstrates that the Middle American ethnopedology constitutes a pedologic meta-culture shared by different indigenous peoples and *Mestizo* small farmers, who base their livelihood on maize cropping as a cultural matrix.

Chapter Seven focuses on pre-Columbian Middle American beliefs and symbolic representations of the soil and land resources (the Kosmos domain). Land and crops are analyzed using ethnohistorical and archaeological information and related to the Middle American cosmology.

Chapter Eight is dedicated to the analysis of the pre-Columbian Middle American soil and land knowledge (the Corpus domain). It traces the ways soil and land resources were understood, named and classified in central Middle America during the Post-Classic Period (A.D. 900-1521), by analyzing 16th century ethnohistorical documents, such as pictorial representations, soil glyphs, toponyms and written documents. It also explores relationships between pre-Hispanic soil knowledge and tributary policies implemented at the eve of the Spanish conquest.

Chapter Nine describes pre-Columbian land management techniques (the Praxis domain), aimed at improving soil fertility and land productivity for maize cultivation in Middle America. Special attention is given to fragile lands, such as sloping and inundated fields in semi-dry temperate highlands and humid tropical lowlands. Agricultural terraces in hilly landscapes, drained fields in flooded highlands, and raised-bed fields in tropical low-lying wetlands are analyzed, specifically in relation to soil, water and relief management.

Chapters Ten, Eleven, Twelve and Thirteen together are dedicated to the analysis of contemporary Middle American ethnopedological knowledge and practice. Chapter Ten provides an overview of the major historical trends, which reshaped the pre-Columbian Middle American landscapes, peoples, livelihoods, and land resources knowledge systems in many different ways. Permanence, change, innovation, enrichment and loss of local soil knowledge systems constitute major processes, which permit to fully understand contemporary local ethnopedologies. The chapter shows that indigenous and *Mestizo* farmers and communities were never isolated and played active and contrasted roles with other social actors involved in rural activities during the last 500 years.

Chapter Eleven presents contemporary soil and land resources knowledge systems of several rural communities living in five different agro-ecological zones of Middle America. It contrasts information from Mexico, Belize and Guatemala, covering 13 ethnic groups. The K-C-P model is used to frame ethnopedological evidence.

Chapter Twelve presents the Maya ethnopedology within the K-C-P model. Contemporary soil and land perception, symbolism, knowledge and management among Maya farmers from the Yucatan Peninsula have been best studied in Middle America. The very well documented Maya experience allows explaining how and why they still maintain efficient agro-ecological knowledge systems, highly symbolized and ritualized in syncretic ways, and sophisticated in their practical uses.

A discussion about similarities and differences of the varied Middle American ethnopedological information is provided in Chapter Thirteen. Richness and constraints of local ethnopedologies as part of longstanding and adapted agro-ecological systems are highlighted. The chapter concludes that it is possible to establish a general framework of perception, knowledge and management of soil and land resources in Middle America, that co-evolved since ancient times as practically all local ethnopedologies were and are still linked to the *milpa* production and shared a common cosmovision. Within this, a general framework falls the ethnopedological case study carried out at local level in the sub-humid temperate highlands of Mexico, among the Purhépecha of San Francisco Pichátaro in the Patzcauro Lake Basin, Michoacán.

**Part Three** of the thesis (Chapters Fourteen to Twenty-four) is dedicated to the local case study. This part is divided into several chapters, including an introductory chapter (Chapter Fourteen) that explains the research framework and the methods applied at local level. This helps understand how data were acquired and analyzed at local level, taking into account that Part Three is mainly based on fieldwork information and other primary data handled through the application of GIS techniques. However, Part Three also includes data acquired from secondary sources, such as archival documents, bibliographic references, and previously published and non-published information from the author of this thesis, covering the last 20 years. The term 'local' is used to differentiate this approach from the worldwide ethnopedological analysis at global scale, presented in Part One, and from the Middle American ethnopedological analysis at regional level, carried out in Part Two of the thesis.

Chapters Fifteen to Seventeen deal with the Pátzcuaro Lake Basin (PLB), the natural and cultural territory where San Francisco Pichátaro, the village study area, is located and interacts with. Chapter Fifteen analyzes the PLB as a natural region. Chapter Sixteen introduces the PLB from the socio-cultural point of view and analyzes the historical relations between nature, culture and society. The chapter provides a socio-political framework to understand the environmental degradation events that occurred within the last 4,000 years, assuming that socio-political factors have been prime movers of environmental change since the early occupation of the basin.

The aim of Chapter Seventeen is threefold. It analyzes land degradation events occurred in the PLB during the last 4,000 years. It confronts different interpretations about the causes leading to human-induced land degradation and contrasts them with the ecological knowledge that the Purhépecha people possessed at the end of the 20$^{th}$ century. The main objective is to discuss how the long occupation by populations relying on agriculture on marginal and fragile lands like the PLB led to an accretion of adaptive land management systems. These adaptive land management systems served to overcome natural and economic uncertainties, although the full implementation was limited by political agendas, inducing land degradation during the long span.

Chapters Eighteen to Twenty-two offer a comprehensive analysis of the village level, including ethnopedological findings, while Chapter Twenty-three links the current status of perception, knowledge and management about soil and land resources (the K-C-P complex) with the political ecology of the indigenous community. This link helps understand why, how and by which ecological, economic, socio-cultural and political processes, the local theory of soil and land resources has been readapted to gain-loss circumstances during the last 20 years.

Chapter Eighteen describes the biophysical setting of San Francisco Pichátaro, the local study area, and provides an environmental framework that is compared to the local environmental knowledge system in Chapters Twenty-one, Twenty-two and Twenty-three, with special attention to soil and land resources. Chapter Nineteen reconstructs the history of the village, placing emphasis on local territorial conformation, land-use evolution and cultural changes since the pre-Hispanic times until today. Changes that occurred in the community during the last 60 years in aspects such as demographic structure, access to natural resources, local institutions and economic activities, are analyzed. Main objective is to demonstrate how and why this small indigenous community was never isolated since pre-Hispanic times and was capable to adapt to colonial and modern traditions under adverse circumstances, without losing its Middle American grassroots.

Chapter Twenty analyzes how soil and land resources are perceived, symbolized, recognized, named and managed in San Francisco Pichátaro. The K-C-P conceptual approach is used for the interpretation of ethnopedological information. The chapter addresses the ways *Pichatareños* perceive and symbolize land as a polysemic dominion, as a polyvalent resource and as a living being with its own organization, giving insights about the social theory that *Pichatareños* developed to understand and assess the soil and land resources.

Chapter Twenty-one emphasizes the relations between soil knowledge, worldview and land management, with special reference to the *milpa* production system. Connections between land symbolism, agricultural practice and rituals are explained to reveal the communion between mind and matter. Together with Chapter Twenty, this chapter articulates the local theory about nature.

Chapter Twenty-two compares technical and local soil knowledge systems using GIS techniques to cross soil maps resulting from the geopedological and ethnopedological surveys. Spatial correlation is analyzed at three different levels: (a) at high taxonomic level, (b) at low taxonomic level, and (c) at topsoil property level.

Chapter Twenty-three concludes Part Three of the thesis by discussing how socio-political and economic relations, historical and environmental conditions, and external factors such as policies, academic research implementation and technological change, are shaping the local theory of soil and land resources (the K-C-P complex). Discussion is organized according to the political ecology research framework.

Conclusion in Chapter Twenty-four pulls together the analytical framework drawn in Part One of the thesis (Chapter Five) and the evidence presented at global, regional and local levels (Chapters Six, Thirteen, Twenty-one, Twenty-two and Twenty-three). It argues that ethnopedological research findings from the local to the global levels present some similarities, making it is possible to assert that small farmers and indigenous communities use, for example, similar sets of soil properties to assess soil quality, monitor soil fertility and classify soils. Social theories about soil and land are complex and holistic, but the different elements of the K-C-P model are adapted to the local environmental, economic and political contexts, and are framed according to highly diverse worldviews, world lives and cosmovision. Ethnopedological findings from San Francisco Pichátaro share strong similarities with other Middle American ethnopedological findings as local soil and land knowledge, in all cases, is specialized for *milpa* production. However, contextual studies demonstrate that the way the social theory about soil and land resources was adopted and adapted is quite unique to each community and hardly repeatable.

# Part One

## Concepts and global perspective

# CHAPTER TWO

## INDIGENOUS PEOPLES AS SOCIAL SUBJECTS

### 2.1. INTRODUCTION

Chapter Two conceptualizes indigenous peoples as social subjects in search for their self-determination as peoples. It also identifies indigenous peoples' distinctive features, which differ from those of other social groups and especially from those of the western society. Finally, a comprehensive definition of indigenous peoples, based on their self-determination as subordinated cultural minorities and on their status as emergent social subjects is discussed.

The main purpose of Chapter Two is to recognize the outstanding features and current conditions of indigenous peoples as these are central to the topic of this thesis, that is the study of knowledge of local populations about soils and their management. Even if ethnopedology is not restricted to indigenous soil knowledge systems and also includes modern soil knowledge systems (Barrera-Bassols and Zinck, 2000), the former play a fundamental role in understanding theories about soils different from those developed by modern science. Three relevant aspects highlight the importance of indigenous and traditional ethnopedologies:

(1) some 80% of the global cultural diversity is related to the presence of 4 to 5 thousand indigenous societies (Gray, 1999);
(2) some 80% of the non-industrialized world's population still relies on traditional agricultural systems (Posey, 1999a, 1999b);
(3) traditional multicropping systems provide as much as 20% of the world's food supply (Altieri, 1999).

The recognition of the current indigenous peoples' conditions and the recognition of the differences that they maintain with western societies constitute two central and inseparable elements. These elements explain (1) the ways how indigenous environmental knowledge systems evolved and are displayed, innovated, adapted or are vanishing, and (2) the ways how these systems are implemented according to diverse local subsistence strategies and according to diverse sets of relations that are, forcedly or not, established with western societies. This thesis assumes that it is not possible to disentangle these two elements when analyzing indigenous knowledge systems, because knowledge depends on whom produces, adopts, adapts and displays it in relation to a given context. It is also assumed that knowledge systems cannot be properly evaluated when isolating their technical elements from the social institutions that build them up and implement them according to certain cultural values and specific material needs, and in relation to a certain environmental context.

This exploration allows answering the following questions: Who are indigenous peoples? What are the underlying conditions that allowed the development of indigenous knowledge and management of nature? What is the current role of indigenous knowledge systems and their producers? How do indigenous peoples define themselves and how do they contrast themselves from other social subjects? Finally, by answering these questions, it is possible to demonstrate the importance of cultural diversity as a human resource and to recognize the important role indigenous environmental knowledge systems can play in the search for sustainable endogenous development.

The chapter is divided in five sections. Section 2.2 defines the indigenous condition and shows the estimated indigenous population of the world on the basis of language differences, as a single cultural element characterizing the indigenous condition. It also shows why this quantitative approach is limited and static; its combination with a qualitative analysis permits to fully recognize the current status of indigenous peoples. Section 2.3 discusses the concepts of cultural dimension, ethnic identity and identity project as central to the understanding of indigenous peoples as social subjects and as emergent multicultural movements in response to the mainstream cultural homogenization at global level. Section 2.4 analyzes indigenous peoples' self-identitarian projects from their own point of view. The background and implications of their demands are discussed when analyzing their own definition as indigenous peoples. Section 2.5 shows that cultural diversity is inextricably linked to biological and genetic diversity at global scale. The intimate relations of these three phenomena constitute one of the most important legacies of indigenous peoples, which is discussed in Chapter Three.

## 2.2. The indigenous condition

### 2.2.1. Placing the problem

There are contrasting conceptualizations of indigenous peoples among schools, scholars and practitioners (Levi-Strauss, 1962; Geertz, 1973; Malinowski, 1965; Burguer, 1990; Verhelst, 1990; Bonfil, 1991a; Smith, 1999; among others). Similar contrasting conceptualization exists among development institutions, social institutions and national policies (ILO, 1989; UNCED, 1992; World Bank, 1993; UNESCO, 1996; IUCN, 1997; IWGIA, 1999; IDRC, 1998; among others). These contrasting views also reflect the variable and complex realities among indigenous peoples (Burguer, 1990; Durning, 1992; Davis, 1993a and b; Toledo, 1994; Appadurai, 1996; Daes, 1996).

Non-western societies have been given different labels, including indigenous peoples (Alcorn, 1994; Simpson, 1997), grass-roots peoples (Verhelst, 1990), first peoples (Burguer, 1990), Fourth-World peoples (Latouche, 1993), pre-modern societies (Toledo, 1995a and b), traditional societies (Marglin, 1990; Klee, 1996), and ecosystems' peoples (Dasman, 1975). Their polymorphic historical development has been strongly influenced by the processes of domination/subordination and resistance/hybridization, that took place during the last 500 years of human history (Wolf, 1982).

Even if it is not possible to disentangle the 'indigenous condition' from that of western society, as both form part of the modern world, it is pertinent to recognize the differences that distinguish them. One of these differences is the way knowledge and practice are constructed and implemented. Indigenous peoples' knowledge is enriched by a cosmological symbolism, that guides practice as an ancient experience, through intimate and contextual engagement with the environment. Nature is conceived as an ontological part of the social, and the social is conceived as an ontological part of nature, both being parts of the same world (Croll and Parkin, 1992a; Descola, 1996; Hornborg, 1996). The dimension of indigenous environmental knowledge is not local but universal, expressed in local terms (Posey, 1999b). Science is constructed from the secularization of knowledge. Its formalization and institutionalization lie on the universalization of its postulates and laws, and on the separation between social and natural sciences (Knorr-Cetina, 1981; Latour, 1993; Pretty, 1995). These differences are rooted in two ways of constructing the worldview. Western society looks backward and forward in time to obtain a sense of place in history, while indigenous peoples look around themselves thinking more in a spatial way than in a temporal way (Suzuki and Knudtson, 1992). Indigenous worldviews require one to be native to a place (placeness) and live with nature (connectedness), in contrast to the western worldview which assumes humans live above, separated from or in opposition to nature (Pierotti and Wildcat, 1999). Indigenous worldviews can be considered eco-centric, placing humans in nature, so that nature and culture are not separated, while western worldview can be considered ethnocentric, separating culture from nature (Horigan, 1988; Croll and Park, 1992b; Lloyd, 1992; Torrance, 1992). These worldviews shape contrasting livelihoods, production systems and social relations between indigenous peoples and the western society.

The indigenous condition originated directly from the external and internal colonization over time. Indigenous peoples have not only structural identity, but also an increasing significance in a globalizing world (Stavenhagen, 1990; Escobar, 1995; Smith, 1999). Their struggle for political, economic and cultural emancipation and development is one of the most relevant social phenomena of the 20th century (UNESCO, 1996). A growing number of indigenous peoples look for recognition as social subjects historically neglected, excluded and exploited, but with rights as peoples that confront new challenges in a globalizing and excluding world (Arizpe, 1997). The right to be culturally different and the right to self-determination as peoples are part of their claim (IWGIA, 1999).

### 2.2.2. Estimated indigenous population according to linguistic criterion

A conventional way to estimate the worldwide indigenous population is based on the linguistic criterion, one of the cultural elements that define the indigenous condition. Global indigenous population measured by statistical procedures range from 250 million (Burguer, 1990) to 600 million (Durning, 1993), corresponding to 5-11% of the total world population. Indigenous population is distributed over some 70 countries, constituting 31% of the countries having linguistic information, mainly from the Third World (Grimes, 1996). About 5,000 different indigenous peoples are recognized, making up 70 to 80% of the global cultural diversity, based on the existence of 6,000 cultural groups all around the world (IUCN, 1997).

Continental distribution is variable. Some 200 million indigenous populations are estimated to live in Asia, including the countries of the ex-USSR (Durning, 1993). Approximately 30 millions live in Latin America (CADAL, 1981), which are represented by some 400 ethnic groups (Bonfil, 1991a) corresponding to 10% of the subcontinental population. Despite the difficulties to estimate the African indigenous peoples or tribal peoples due to specific forms of colonization, some estimates give more than 25 millions (Burguer, 1990). Estimates from Oceania report 2.5 million indigenous inhabitants. In contrast, only 0.1% of the European population is considered indigenous (Toledo, 1994).

North America is a good example of unequal regional distribution of the indigenous population. Official estimates from Mexico give some 9 million indigenous population, divided into 56 ethnic groups, corresponding to 10% of the Mexican population (Toledo, 1994; INI/World Bank, 1998). But, non-official estimates from the same country, that take into consideration other cultural criteria besides the linguistic one, give higher proportions ranging from 12 to 23 million autochthonous population (Wauchope, 1973). In contrast, less than 5% of the Canadian population and about 1% of the population in the USA are indigenous.

Estimates of indigenous population considering only one cultural element is reductionist and limited, even if language is one of the most important human resources to elaborate, maintain, develop and transmit knowledge, beliefs and values, although not all of them can be linguistically codified (Maffi, 1997, 1998). Besides, linguistic data acquired by national censuses often offer distorted information because of the historical rejection of the native languages by the dominant sectors of the national societies and the neglect shown by governments towards subordinated peoples' cultures. Consequently, indigenous peoples commonly hide the use of their native languages when being surveyed during a census. Also, official statistics underestimate indigenous population, because they do not count individuals younger than five years as native language speakers, while this group usually accounts for a large part of the population in many Third-World countries (Valdéz, 1995). Besides, a vast number of indigenous populations lost control and use of their languages due to the imposition of national languages promoted by the dominant educational programs in multi-ethnic countries. Nevertheless, many still consider themselves indigenous and consciously control and display other cultural elements such as beliefs, customs, knowledge, social institutions and subsistence strategies, as part of their local livelihoods. So far, there are no official statistics providing the real size of the indigenous population of the world. There is a need to define other qualitative theoretical concepts that are central to the understanding of these social groups as peoples possessing distinctive cultures, ethnic identities and socio-cultural projects, to go beyond the linguistic definition of indigenous peoples.

## 2.3. CULTURE AND ETHNIC IDENTITY

### 2.3.1. Cultural dimension as a concept

Cultural manifestations, self-ascription identities and cultural production-reproduction are fundamental characteristics to qualify the 'indigenous' condition in relation to other societies. There is a need to answer some basic questions when exploring these characteristics. What is culture? What is ethnic identity? What are the conditions needed for cultural production-reproduction? What is cultural movement or identity project? How it is possible to distinguish indigenous self-identitarian projects?

Anthropologists and sociologists have extensively debated about the concept of culture. The concept is used from distinct angles, some of them being irreconcilable (Geertz, 1973; Clifford and Marcus, 1988; Barth, 1989; Hannerz, 1992; Escobar, 1995; Appadurai, 1996; Tucker, 1998; among others). Culture is recognized to be a wide, open and complex concept (Hannerz, 1992). As culture means diverse aspects for different people, it is probably one of the most difficult concepts to define, being "one of the two or three most complicated words in the English language" (Proctor, 1998). Nevertheless, social scientists admit that the recognition of differences is not held to weaken the authority of science (Redclift, 1998). This apparent contradiction appears to be a theoretical weakness and conceptual fuzziness, but paradoxically constitutes the basis of social science richness and potentiality.

While culture as a noun carries associations with some sort of substance in ways that appear to conceal more than reveal, the adjective 'cultural' suggests a realm of differences, contrasts and comparisons (Appadurai, 1996). The recognition of differences is probably the most enriching aspect when analyzing 'cultural' as a contrastive property. Difference "is a useful heuristic that can highlight points of similarity and contrast between all sorts of categories: classes, genders, roles, groups, and nations" (Appadurai, 1996). Cultural differences are the base for the mobilization of collective identities. Therefore, 'cultural' is a heuristic tool to recognize and explain cultural differences.

The concept of cultural dimension allows researchers to address the differences in relation to something local, embodied, and significant. As just another layer of the human phenomenon, the cultural dimension cannot be analyzed independently from other human dimensions (Proctor, 1998). Cultural production, that is the production and reproduction of meanings, symbols and knowledge, cannot be disentangled from the political and economic transformations of societies. Cultural production embodies the full fabric of human experience (Tucker, 1998). It includes material, organizational, cognitive, symbolic and emotive elements, which function as a dynamic totality within historic and spatial contents revealing the self-ascription, meaning of being, knowing and performing of certain social group in relation to the 'others'. The cultural dimension operates as a resource and as a social process, always situated and mobilized to signify and negotiate the limits between the 'self' and the 'others' (Skelton, 1996).

Culture is a social construction and constitutes a way of looking at things, producing knowledge and structuring meaning. Culture is a way of looking at the world, a way of knowing it and a way to analyze reality. Reality is multiple, is constructed but contested and negotiated. Culture is not fixed or static and the cultural dimension is always dynamically present as a reference, ever-changing through time and space. The cultural dimension operates according to past, present and future social realities and concrete political needs. Some cultural elements and meanings are re-organized and negotiated through generations, others vanish and transform, while others are created as a result of collective innovation and inter-cultural relations.

### 2.3.2. Ethnic identity as a process

Identity is the source of collective meanings and experience. Identity is constructed by means of a conscious and reflexive selection of a set of cultural categories recognized by a community as having priority over its total cultural elements because they were auto-sustained over time and space (Castells, 1997). Cultural elements such as origin, history, language, territory, cosmovision, customs and institutions, identify, organize and re-organize a community (Bonfil, 1982, 1991a and b). This is recognized as ethnic identity and is constructed by social subjects to objectify their agency according to some social determinants and cultural projects rooted in their own social structure, temporally and spatially bounded (Bonfil, 1991a).

Ethnic identity is based on power relations inside the social group and interactions with other social subjects. Age, gender, sexual, professional, neighborhood and religious relations contribute to forging a particular identity. A common past and origin are recognized, certain cosmovision and values system are shared, a territorial ascription is recognized, and a system of signs, symbols and meanings is collectively codified. Only with this auto-ascription it is possible to aspire to a common future, and these are the bases for the self-recognition of 'us' and the referent to distinguish 'us' from 'them' (Bonfil, 1991a).

Two general tendencies of cultural domain appear on the current global scenario in apparent contradiction, but they are mutually inter-dependent, organizing, driving and shaping the deconstruction of the ethnic identities of historical peoples. On the one side, the global tendency to integration implies a strong impulse towards cultural homogenization when re-organizing localities and displacing cultural boundaries of local peoples (Geschiere and Meyer, 1998). On the other side, as a counter-response to the former, there is a growing tendency towards the defense of cultural differences in complex, conscious and emphatic ways by a growing number of social subjects, including indigenous peoples (Castells, 1996a).

Global social mobilization and displacements are also producing a pervasive cultural hybridization process (Appadurai, 1991; Garcia Canclini, 1990). National states and transnational policies frame this process and activities, which intend to assign a fixed and closed set of cultural categories to social minorities as forced consumption goods and commodities. As a response, political identities of local communities are mobilized to resist and, if possible, revert global cultural transformations and displacements, contributing to the crisis of the modern national states originated by the own process of globalization (Appadurai, 1996).

This culturalism appears as a counter-national and meta-cultural movement in the form that cultural differences tend to take in the era of mass mediation, migration and globalization. Culturalist movements are self-conscious of their own identities and heritage, and both premises form a deliberate vocabulary of vindication, as a primordial battlefield against national states that oppress and limit them. Appadurai (1996) argues that these culturalist movements "are the most general form of the work of imagination and draw frequently on the fact or possibility of migration and secession". This ample and complex phenomenon radically transformed the classical anthropological view of the world as a conglomerate of separated and internally homogeneous cultures, each one having its own essence, and where inter-cultural contacts were recognized as a loss of cultural autenthicity (Geschiere and Meyer, 1998).

The study of these complex tensions and their consequences is framed in an academic debate guided to the deconstruction of the supposed opposition between the universalism/particularism analytical constructions. These analytical constructions are traditionally bounded by dual and exclusive views as analytical objects, civilization subjects, discourses, and meta-languages or representations (Wallerstein, 1996). The discussion centers on the recognition of the pertinence and reality of a pluralist universalism as an alternative and inclusive project with the advent of the network society, by deconstructing this pervasive dualism. What is of interest here is schematizing diverse forms of construction of ethnic identities and recognizing the diverse cultural projects or multicultural movements, precisely at the advent of the network society (Castells, 1996b).

### 2.3.3 Identity construction

There are several forms of identity construction, expressing different outcomes on societies (Castells, 1996b). These constructions are intimately linked, as some of them are constructed as a response to the displaying of others, but all are related with their historical contexts and power relations that control their cultural dynamics. Identity dynamics are framed by the pervasive roles of domination/subordination and resistance/hybridization relations. There are three main identity constructions:

(1) Legitimizing identity is introduced by dominant social institutions aiming to extend and rationalize their domination, by building a civil society which reproduces, albeit sometimes in a conflictive manner, the identity that rationalizes the sources of structural domination. When legitimizing identity is imposed, it becomes a normalized identity constructed from the negation of the identity of the subordinated and culturally marginalized communities. The construction of this identity form prevails as the dominant acculturation process in modern national states by the homogenizing policies of national identities, especially in multi-ethnic and multi-cultural countries.

(2) Subordinated communities construct resistance identity as a counter-response to the imposition of legitimizing identity. The construction of resistance and survival trenches, based on principles opposed to those of the dominant social institutions, allows the emergence of political identities (Banuri, 1990). This form of identity gives rise to the building of communities and probably is the most important form of identity construction in current societies. Identity construction on the basis of resistance to the dominant institutions and ideologies operates by inverting the judgment values of these institutions and reinforcing the identity boundaries of the communities through organized political action. In this case, collective action is determinant. Two forms of identity resistance are the negation of dominant or normalized identities and the reconfiguration of subordinated identity boundaries through communitarian organization.

(3) When social actors build new identity forms from any available set of cultural elements to redefine their position within the dominant society, the construction of an identity project occurs. The central aim of identity projects is the search for a transformation of the overall social structure. The construction of such projects produces communities where social subjects reach a comprehensive meaning of the collective experience. Identity projects start from the re-construction of resistance identities organized on communal principles. These new social subjects build up new identity projects –as the indigenous peoples projects- when displaying their political identities seeking to change the prevailing social structure, thus helping the making of a new pluralist universalism. Those are the ideological and political grassroots of multicultural movements.

## 2.4. Self-identity projects of indigenous peoples

This section aims to interpret the cultural and identity categories discussed above from the indigenous people's own discourse, based on their self-determination as subordinated cultural minorities and on their status as emergent social subjects. This interpretation is supported by the analysis of an ample and comprehensive definition of indigenous peoples given by the Cobo Study (Cobo, 1986). This study understands indigenous communities, peoples and nations as:

*"Those which, having historical continuity with pre-invasion and pre-colonial societies that developed on their territories, consider themselves distinct from other sectors of the societies now prevailing in those territories, or parts*

*of them. They form at present non-dominant sectors of society and are determined to preserve, develop and transmit to future generations their ancestral territories and their ethnic identity, as the basis of their continued existence as peoples, in accordance with their own cultural pattern, social institutions and legal systems."*

This definition, written by an indigenous intellectual, has been under profound scrutiny and is widely accepted by diverse organizations, taking it as a basic reference to re-affirm the rights to self-determination of indigenous peoples on international fora such as the United Nations (see also other indigenous declarations such as: The Barbados II Declaration, 1978; WCIP-UN, 1993; Mataatua Declaration, 1993; Voices of the Earth Recommendations, 1993). According to Daes (1996), the Cobo study refers to demands forwarded by indigenous peoples concerning territory, cultural patrimony, self-determination and subordination.

### 2.4.1. Territory

Territoriality implies at least three demands: (1) the rights over the land and the usufruct of the natural resources (the agrarian rights); (2) the rights to control the production, consumption, distribution and commercialization of the resources (forest, flora, fauna, genetic, land and mineral resources); and (3) the rights to determine and regulate the appropriate ways of managing, conserving and restoring the natural resources in accordance with the needs, aspirations and beliefs of peoples (Toledo, 2001). The claim on territorial rights means the recognition of a legal delimitation of the ancestral territories continuously occupied through time. A territory represents the geographical space that allowed indigenous peoples to secure their social and cultural reproduction (Stavenhagen, 1998). The expropriation and nationalization of indigenous lands and natural resources have led to a drastic expoliation of the local economies, as the majority of indigenous peoples organizes rural production in a communal way (Davis, 1993). Despite this, most indigenous peoples still maintain a strong sense of territorial ethnicity, looking at themselves as rooted to their territories, as *"sons of the land"* (UNESCO, 1996). The restitution of their economies, based on reciprocity and subsistence as principal goals, and the request of fair exchange with commercial marketing constitute some of their most important demands (Durning, 1992; Ghai and Vivian, 1992; Davis, 1993; Escobar, 1995; Varese, 1996; Peet and Watts, 1996; Shiva, 1997). These vindications are directly linked to the aspiration of self-determination and endogenous development, or ethno-development (Stavenhagen, 1990). According to Escobar (1995), the peasants' every-day resistance and demands reflect more than a battle for the land and living conditions, they reflect a vindication for cultural symbols and meanings.

### 2.4.2. Cultural patrimony

*"The voluntary perpetuation of the cultural distinctiveness or the legacy rights to preserve and use what is considered the cultural patrimony".*

This includes several features such as the use of native languages and own organizational institutions, the maintenance of local knowledge systems, spiritual and religious values, and the control of the production systems, laws and customs. These features organize the livelihoods and cultural systems of local peoples. Livelihoods and cultural systems shape the ways of perceiving, knowing, signifying and managing the natural contexts, and the symbolic and material constructions of the territories.

As subordinated subjects, indigenous peoples experience the negation, exploitation and extinction of their cultural patrimony. The indigenous cultural patrimony should be understood as an integrated and interdependent whole. Its diverse cognitive, aesthetic, religious and practical components cannot be isolated, as all of them maintain an equivalent value according to a holistic worldview and constitute a collective right. This patrimony is not conceived as a property or commodity, and its use and management are grounded in long-standing rules and customs. In a period where global, market-oriented interests exert a growing pressure to exploit indigenous peoples' cultural heritages, the latter deserves special attention (Mooney, 1983 and 1998; Shiva, 1991, 1993 and 1997; Martínez-Alier, 1991; RAFI, 1994; Pretty, 1995; Brush, 1992a and b; Brush and Stabinsky, 1996; Posey and Dutfield, 1996; Yapa, 1996). In response, indigenous social subjects demand legal guarantee and rights to protect, possess and control their cultural and intellectual heritage. These demands refer especially to knowledge systems, technologies, genetic resources –human and non-human-, oral traditions, literature, designs, crafts, and visual and performance art (for a comprehensive review, see articles 8, 12, 25 y 26 of the Draft Declaration of the UN-WGIP, 1993).

### 2.4.3. Self-determination

*"Self-determination rights and the recognition of collective identities from other social groups".*

Self-determination has been central to the indigenous peoples' demands over the last 50 years. This implies the formalization of indigenous peoples' political status and their cultural, social and economic autonomous development (Stavenhagen, 1990). Self-determination covers all above-mentioned demands and constitutes the identity project of indigenous peoples. The legal recognition of these social subjects as peoples at international level equates the juridical affirmation of the self-determination of peoples as signed in the Magnus Chart of the United Nations. The right to be recognized as peoples constitutes a fundamental human right (Simpson, 1997). The search for alternative governments that respect the rights to difference, the rights to the co-existence of multiple collective identities and sovereignty, and the establishment of multicultural states as essential norm of governing, are the implications of these demands (Tully, 1995).

### 2.4.4. Subordination

*"The international community should recognize that indigenous peoples are exposed to subjugation, marginalization, dispossession, exclusion and discrimination as a consequence of colonialism, thus conferring a status of non-dominant sector within the society at large".*

The international recognition that indigenous peoples are deprived of equal conditions and rights implies the acceptance of the colonial heritage promoted during the last 500 years. It also implies the establishment of legal, political, cultural, social and economic bases to abolish their subordinated condition and the full acceptance of their self-determination as peoples, with equal and similar rights to the rest of the international community. This is the background to the emergence of indigenous peoples' identity projects and the grass roots of multicultural movements on the international political arena.

## 2.5. Conclusion

The complexity of indigenous peoples' condition can be recognized through their diverse social realities, cultural polymorphism and contrasted livelihoods. Self-determination is a fundamental criterion to evaluate the indigenous condition (consciousness of inequality) and to recognize indigenous peoples as depositaries of their own and distinctive cultures (consciousness of difference). These two interwoven and collective forms of consciousness allow indigenous peoples to carry out a reflexive and negotiated deconstruction of their social imaginary when answering questions such as: Who are we? Why are we like we are? Which are the differences between 'us' and the 'others'? In addition, what would we like to be and do in the future? Those are fundamental questions that became important during the last 50 years among these emergent social subjects and provided the avenue to their political projects.

Today, global interaction shapes the indigenous self-identitarian ascription, tensing the relations between cultural homogenization and cultural heterogenization. This is the central issue of cultural globalization (Appadurai, 1996). Current globalization is intensifying geographical mobility (rural-urban, regional and international migrations), economic mobility (massive impoverishment in contrast to the elites' economic bonanza), and cultural mobility even in the most isolated areas of the world.

Changes at local and global levels are framing these tensions in a moment of great complexity and overlapping. These changes are also revitalizing resistance identities, especially among social minorities and marginalized social sectors of the Third World and the ex-socialist European countries (youngsters, unemployed individuals, small-farmers, indigenous peoples, cultural minorities, migrants, women, homosexuals, retired and elderly people). That is why the indigenous condition and the status of indigenous peoples are drastically changing. On the one side, assimilation and integration are carried out as part of standardization but, on the other, resistance movements reappear searching for a renewed existence and defending diversity, as a contested collective response. A complex and hybrid socio-cultural mosaic stands between these two extremes, organizing the ways to escape from the homogenizing and exclusive cultural dynamism in creative but unpredictable manners at local, regional and global levels.

It is important to evaluate the current momentum of indigenous peoples, when analysing their environmental knowledge systems in a contextual way. It is also important to explain how they identify and differentiate themselves with respect to the global society, rather than analyzing the size of the indigenous population when measuring its importance at global scale. The recognition of the historical contexts of indigenous peoples and the analysis of their roles in the complex and unpredictable present time are other major features to be fully understood.

A set of features explains the indigenous condition and characterizes the ecological, economic, political and cultural realities of indigenous peoples at the end of 20$^{th}$ century:

(1) the condition of historical peoples with a territorialized culture developed long before the colonial period;
(2) the condition of subordinated peoples as a result of diverse forms of colonialism;
(3) the condition of ethnic minorities with their own and distinctive cultures;
(4) the condition of emergent social subjects struggling for their survival;
(5) the condition of emergent social subjects searching their self-determination rights and searching to preserve, maintain and develop their cultural patrimonies;
(6) the condition of emergent social subjects trying to control their own decisions and governance;
(7) the condition of emergent social subjects searching for the reorganization of their relations with the dominant sectors of the global society and defending their cultural diversity.

The recognition of this cultural phenomenon is relevant when exploring the geographical links between cultural, biological and agricultural diversity throughout the world. These inextricable links constitute major legacies of indigenous peoples. The historic construction of local (indigenous) ecological knowledge systems and the symbolic and material practices related to them allowed the development of sound strategies adapted to local environments, which led not only to conserve material richness, but also to widen the basic goods (food, health, energy and shelter). This indigenous legacy is of strategic importance, as demonstrated in Chapter Three. Some of the links between cultural, biological and agricultural diversity are:

(1) important forest extents with high biological diversity and preserved ecological conditions are located in a vast number of current indigenous territories;
(2) some current diversity 'hot spots' of domesticated plants and animals overlap with a vast number of indigenous territories;

(3) intense and rapid transformation of some of the highly diverse ecological and cultural areas is leading to severe environmental, agro-productive and cultural degradation throughout the world;

(4) mobilization of sources, services and resources to preserve and promote sustainable livelihoods in the diversity 'hot spots' constitutes a major political, social and scientific challenge for the near future. Ecological and cultural diversity extinction could be reversed when including the full recognition of indigenous peoples' rights as unique owners, keepers and managers of their patrimony.

# CHAPTER THREE

## LINGUISTIC, BIOLOGICAL AND AGRICULTURAL DIVERSITY

### 3.1. INTRODUCTION

Studies from different disciplinary backgrounds, including anthropology, geography, sociology and linguistics from the social sciences, ecology and biology from the natural sciences, as well as agronomy and veterinary sciences, are revealing the intimate links between cultural, biological and agricultural diversity at global and local scales (Klee, 1980; Mooney, 1983 and 1997; Altieri, 1993 a and b; Oldfield and Alcorn, 1991; Berlin, 1992; Durning, 1992; Redford and Padoch, 1992; Brush, 1993; Shiva, 1993 and 1997; Toledo, 1994; Mühlhäusler, 1995; Ellen and Fukui, 1996; Harmon, 1996a, 2001; Nakashima, 1998; RAFI-IPBN, 1999; Posey, 1999a; Maffi, 2001a). These multidimensional and complex relations are named 'bio-cultural diversity' (Maffi, 1998; Zent, 1999; Posey, 1999b), which constitutes one of the most important historical legacies of indigenous peoples (Nakashima, 1998). According to Appadurai (1996), a new anthropological approach recognizes "... the relationships between word and world". The same author argues that "... the word can encompass all forms of textualized expression and world can mean anything from the means of production and the organization of life-world to the globalized relations of cultural reproduction" (Appadurai, 1996: 50-51). The intimate relations between word and world allow mapping the bio-cultural diversity in three global dimensions, which are (1) the linguistic diversity, (2) the biological diversity, and (3) the agricultural diversity.

This chapter discusses the inextricable relations between these types of diversity. It also analyzes the historical role played by indigenous and local peoples in the construction, maintenance and enhancement of the world's bio-cultural diversity. Furthermore, the chapter reveals the environmental consequences of the world's bio-cultural diversity loss, due to the standardization of the globalized relations of cultural and economic reproduction. It also demonstrates that the rapid loss of the ethnoecological experience could be reverted, or at least halted, by means of its full understanding and re-integration in the rural livelihoods and activities where it evolved. Its understanding, preservation and enrichment could potentially promote local and regional sustainable food security and orient development-with-conservation as a major policy in three of the most fragile agroecological zones of the world: (1) the humid tropics, (2) the semiarid and arid tropics, and (3) the cold and dry highlands.

### 3.2. THE MEANING OF DIVERSITY

According to Remmers (1998), diversity is recognized as a social construction. Diversity of life is reproduction, and heterogeneity is its logical consequence (Wilson, 1992). Diversity and heterogeneity are used here as synonymous, as both derive from a social transformation. Even if heterogeneity does not necessarily result from an intentional purpose, as for biodiversity for example, heterogeneity can be consciously created as in the case of indigenous peoples' natural resource management or the managed bio-agrodiversity (Richards, 1985; Chambers, 1990; Steenhuijsen, 1995; Almekinders et al., 1995).

Production of diversity is mediated through a creative and imaginative action (Shiva, 1997). Creativity is a social process when something new is created. Something which changes or transforms becomes a new object, or resource. In a certain way, creativity means producing something original (new, unusual, unexpected) and valuable (useful, good, adapted, appropriate) (Ochse, 1990; Remmers, 1998).

Valuation of creative production is assigned in relation to multiple cognitive and cultural realities in diverse and contradictory ways. Not all that we think is original has the same connotation for other people. Schaffer (1994) suggests that a discovery implies a long process of hard work and negotiation within a complex social network, where power plays a central role. The confirmation of a discovery is not exclusively derived from the individual innovative act, but is necessarily valued, authorized or not by the social context, that makes it evident. Discovery signifies an author act and an authorization act, both embedded in an interactive process (Remmers, 1998).

Change is an implicit feature of diversity, and diversity generation produces more or less stable, changeable and unpredictable configurations (Remmers, 1998). As a social production and a transformative and reproductive action (always dynamic and replaceable), diversity is mediated through imagination (as a game plan and contextual action) and through the actors' creativity (as labor). The production and reproduction of diversity are also the production of experience. As a consequence, the loss of diversity means the extinction of biological and cultural experience, and implies the erosion of the discovery act and the reduction of creativity, as an impulse for the continuation of identities.

### 3.3. Linguistic diversity

Each spoken language represents a unique mode to conceive human experience and the world. Languages resume all the plurality of humankind. As a code of social action, language is used by humans to establish a negotiated dialogue with the social world and within the social and natural worlds (UNESCO, 1996). Language is a socio-cultural construction giving meaning to representations, discourses and negotiations. Moreover, as a dialogical instrument, language constitutes a fundamental bridge between cognition, recognition and recognizing us, and a bridge to differentiate and differentiate us, that is a bridge to negotiate legitimacy (Bordieu and Wacquant, 1995).

The recognition of differences is a condition for the dialogue and a condition for the negotiated construction of a wider union among different peoples. Languages constitute the building of cultural diversity and the staple good of human creativity and knowledgeability. The dramatic reduction of languages erodes the bases of this creativity and knowledgeability. It eventually produces uniformity of the world's cultures and severely reduces cultural diversity (Harmon, 1996a and 1996b).

Linguistic diversity refers to the number of spoken languages throughout the world (Maffi, 1998). The geographical distribution of current linguistic diversity follows a heterogeneous pattern (Krauss, 1992; Harmon, 1996b; Maffi, 1998). Linguistic heterogeneity is the result of diverse cultural constructions and reflects domination/subordination and resistance/hybridization relations among different peoples and between civilizations. Three main historical phenomena contributed to creating linguistic geographical diversity: (1) the origin of linguistic diversity as a response to long-standing geographic and communication isolation of human populations, deriving in an important number of 'endemic' languages (Harmon, 1995); (2) the enrichment of linguistic diversity as a product of interactions among diverse social groups (Mühlhäusler, 1996; Maffi, 1999); and (3) the tendency towards an increasing linguistic uniformity as a result of the colonial domination and the internationalization of the communication systems dominated by few languages, originating the extinction of endemic languages through cultural assimilation and 'language shift' (Harmon, 1996b; Maffi, 1998). This section discusses some of the implicit meanings of the contrasting linguistic diversity and the consequences derived from the loss of linguistic diversity, especially in the case of 'endemic' indigenous languages in severe extinction process (Wurm, 1991; Krauss, 1992; Ladefoged, 1992; Harmon, 1996b).

There is no agreement on the total number of spoken languages in the world. Grimes (1996) recognizes a total of 6,700 spoken languages, while Harmon (1995) reports 6,207 spoken languages. In any case, the number of languages that are in use today by different social groups is impressive. Both sources group countries into five categories according to their linguistic diversity (Figure 3.1). However, using 'country' as a unit to enumerate

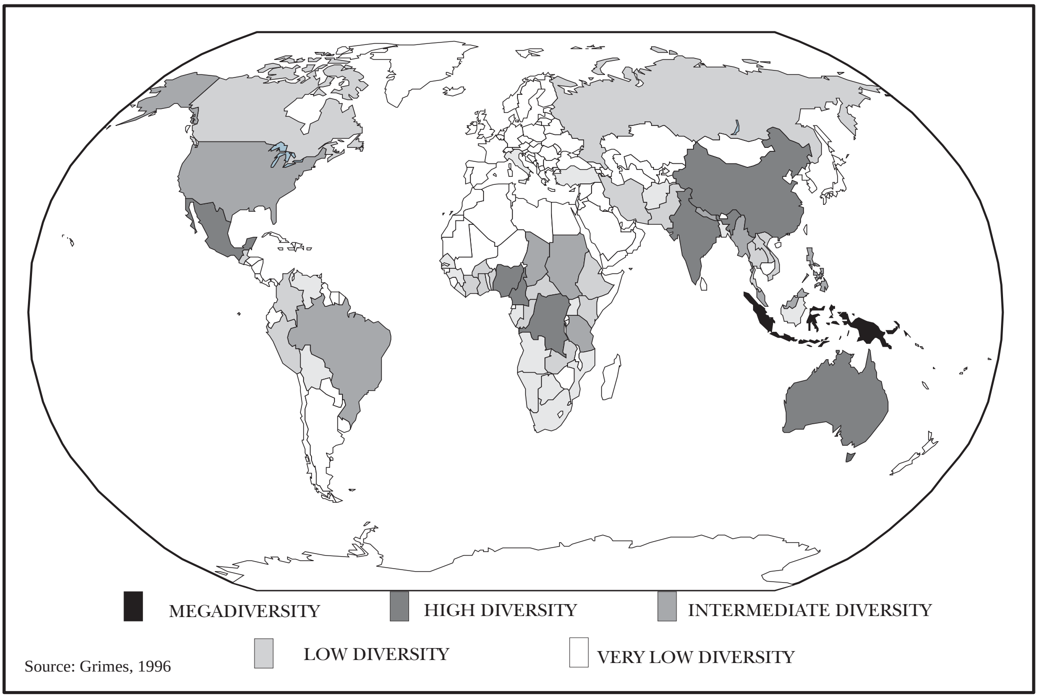



**Figure 3.1.** Linguistic diversity per country

linguistic diversity is problematic as languages' distribution are not necessarily restricted to political boundaries. Nevertheless, here 'country' as a unit serves to compare, despite obvious problems.

Indonesia and Papua New Guinea are linguistically megadiverse. Both countries account for approximately 1,530 spoken languages, representing 23% of all languages of the world, and register the greatest number of languages in a single country. A second set of seven countries (Nigeria, India, Mexico, Cameroon, Australia, Zaire, and China) has high linguistic diversity, with 350 to 470 spoken languages per country, representing 37% (Grimes, 1996) or 49% (Harmon, 1995) of the worldwide languages. Both the linguistically megadiverse and highly diverse countries register 3,634 spoken languages, thus 54 to 57% of the worldwide living languages. However, the nine countries included in these two categories represent only 4% of the 225 countries having linguistic information. A third set of 10 countries (Brazil, USA, the Philippines, Malaysia, Tanzania, Chad, Nepal, Sudan, Myanmar and Vanuatu) has an intermediate linguistic diversity, grouping 21% to 22% of the worldwide spoken languages. Together, the 19 countries with intermediate to very high linguistic diversity correspond to only 8.5% of the countries having linguistic information, but cover some 4,000 spoken languages, representing 75% to 77% of the worldwide languages.

In contrast, a set of 40 countries has low linguistic diversity, including 12 to 14% of the worldwide languages and representing 18% of the countries. Finally, a group of 168 countries has very low linguistic diversity with 1 to 25 spoken languages per country. They represent 73% of the countries having linguistic information and constitute 7 to 8% of all languages spoken in the world.

The global linguistic diversity per continent is as follows: 32% in Asia, 30% in Africa, 19% in the Pacific area, 15% in America and 3% in Europe (Maffi, 1998). However, only 300 of all spoken languages are important when taking into account the number of speakers per language. These languages (Chinese, English, Spanish, Arabic, Hindi, among the most important) are spoken by communities greater than 1 million people, corresponding to 95% of the worldwide population (Harmon, 1995). In contrast, 3,406 languages, 51 to 53% of all languages, are spoken by communities of less than 10,000 inhabitants, totaling no more than 10 million people or 0.2% of the global population. Thus, social minorities including indigenous peoples use most of the spoken languages which are under severe extinction risk. 'Shift language', or the enforcement for native language speakers to use national or international dominant languages, constitutes the major process of linguistic diversity extinction (Harmon, 1995; Maffi, 1998 and 1999). Linguistic standardization caused the loss of 15% of the spoken languages during the 16th century (Bernard, 1992). Its acceleration could result in the loss of 90% of the spoken languages during the course of the next century. Specialists estimate that between 6 and 11% of all spoken languages should be considered to be nearly extinct (Krauss, 1992).

Linguistic standardization by enforcing the use of official languages is better understood when considering language more as an instrument of power relations than just a simple communication source (Bordieu, 1982; Bordieu and Wacquant, 1995). Linguistic assimilation is associated with conquest, colonialism and religion diffusion. Today, citizen interactions are increasingly based on a few languages or, as in the majority of the cases, on only one language, although most of the sovereign states are multilingual. This confers an additional power, status and influence to the official and standardized languages and to the social institutions that enforce them. Nowadays, more than half of the countries of the world use English, French or Spanish as official languages. The current trend of the worldwide linguistic diversity is towards more inequality, unevenness and instability (Williams, 1994). This has some fundamental implications in relation to indigenous environmental knowledge:

(1) a few countries (9 in total), considered linguistically megadiverse and highly diverse, concentrate almost half of the languages spoken in the world;
(2) these countries are located within the intertropical belt, in three of the most fragile agro-ecological zones of the world exposed to severe environmental degradation: the humid lowland tropics, the warm semi-deserts, and the cold and dry highlands;
(3) linguistically megadiverse 'hot spots' are located within these countries;
(4) more than 50% of the world's linguistic diversity concentrates in 0.2% of the total population, corresponding to communities of less than 10,000 inhabitants and totaling less than 10 million people, and
(5) many 'endemic' languages, threatened with extinction, are found in these linguistic 'hot spots' and in rural areas inhabited by the vast majority of indigenous peoples.

Linguistic diversity is intimately related to biological diversity, and both are basic factors of the indigenous ecological knowledge systems (Maffi, 2001a and b). The majority of languages of the world concentrates in tropical rural areas where people lived since centuries ago, evolving local environmental knowledge systems that could be considered endemic. If languages constitute the building of cultural diversity and the staple good for human creativity and knowledgeability, and land is the essential resource for human survival, both resources play a fundamental role in the world's bio-cultural diversity. The next section of this chapter presents evidence of these inextricable relations, both at global and local levels.

### 3.4. Biological diversity

In general terms, biological diversity or biodiversity means the diversity of all life forms on earth (Wilson, 1992). According to Article 2 of the Convention of Biological Diversity (CBD), biological diversity "... means the variability among living organisms from all sources, including inter alia, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems". Biodiversity can also be defined as the quality range or extent of differences between the biological entities in a given set. Biological diversity implies the total diversity and variability of living things and the systems of which they are part (Heywood and Watson, 1995).

Scientists, politicians, institutions and public opinion recently recognized biological diversity and the extent to which biodiversity is being depleted as a consequence of the intensified human intervention on earth and the exploitation of natural resources over the last 300 years (Reid and Miller, 1989; Turner, 1990; McNeely et al., 1995a and b). The risk of massive biological extinction is leading to a growing recognition of the vital importance of biodiversity in political, cultural, economic, social, aesthetic and moral terms (Merchant, 1990; Sack, 1990; Escobar, 1996; Peet and Watts, 1996; Kondratyev, 1998; among others). Noss and Copperrider (1994: p.3-4) point out that in no more than a decade biodiversity developed from a "... short-hand expression for species diversity into a powerful symbol for full richness of life on earth. Biodiversity is now a major driving force behind efforts to reform land management and development practices worldwide and to establish a more harmonious relationship between people and nature".

Some people consider that cultural diversity should be included as part of biodiversity (Posey, 1999b). The Global Biodiversity Strategy (WRI/IUCN/UNEP, 1992) emphasizes that "Human *cultural diversity* could also be considered part of biodiversity. Like genetic or species diversity, some attributes of human cultures (say, nomadism or shifting cultivation) represent 'solutions' to the problems of survival in particular environments. In addition, like other aspects of biodiversity, cultural diversity helps people adapt to changing conditions. Cultural diversity is manifested by diversity in language, religious beliefs, land-management practices, art, music, social structure, crop selection, diet, and many other attributes of human society".

Despite the growing extent of the body of knowledge acquired by specialists, biological diversity is still not well understood as a highly complex system. As many other concepts, biodiversity is perceived differently by different groups, including scientists, farmers, international institutions, transnational enterprises, politicians, social movements, indigenous peoples, urban populations, advocates, developed nations, underdeveloped countries. Both facts, the diversity of perceptions and the imprecision of the definition of biodiversity, could be seen as a weakness of the concept. But, as Heywood (1993) points out, both facts could also be considered as a strength in making an unifying concept and bringing together people from different disciplines and interests with a common goal, i.e. the understanding, conservation and wise use of biological diversity.

This section of the thesis focuses on recognizing the importance of integrating the cultural dimension into the analysis and discussion of biological diversity. Biodiversity is conceived here as both a natural product and a social construct (Nakashima, 1998; Posey, 1999a). Integrating both levels of this multi-layered phenomenon allows to understand in a more comprehensive way the bio-cultural diversities and links. Complex relations appear when overlaying the geographical distribution pattern of linguistically megadiverse and highly diverse countries with that of the countries of the world showing high terrestrial biological diversity.

Four main geographical relations are analyzed here between linguistic mega and high diversities and (1) total biological megadiversity, (2) higher plant megadiversity, (3) mammal megadiversity, and (4) bird megadiversity. The analysis of these bio-cultural links reveals three fundamental issues. The first one is the importance of the historical role played by indigenous and other rural peoples in the preservation of biological diversity. The second relates to the importance of recognizing these bio-cultural links when implementing strategies, management programmes and policies for biodiversity conservation. The last refers to the need for a full recognition of 'territorialized biodiversity' as part of the cultural patrimony of indigenous and other rural peoples.

### 3.4.1. Biodiversity at global scale

There are three fundamental approaches to assess biodiversity, that is (1) the study of the intraspecific genetic variation; (2) the study of species variety within ecosystems; and (3) the study of ecosystems variety within the biosphere. Thus diversity takes place at several levels of the biological organization, which can be further divided into compositional, structural and functional elements of a nested hierarchy (Noss and Cooperrider, 1994). Because nature is infinitely complex, a comprehensive conservation strategy must integrate concerns from all levels of the biological hierarchy. Within this context, the study of species diversity, referring to the variety of living organisms on earth, constitutes a main approach to measure species richness, distribution and endemism (Hengeveld et al., 1995).

The core measure of ecological diversity is species richness or α diversity. This refers to the number of species present in a given area (Hengeveld et al., 1995), adjusting for both sampling effects and species abundance. Diversity and its distribution are the product of a long history of evolution, diversification and extinction in a complex and changing geographical/ecological setting. Endemism applies to taxa that are restricted to a particular geographical area or ecological unit, and means unique biodiversity. Endemics play a major role in reserve selection, based primarily on the complementarity of endemic taxa (Haksworth and Kalin-Arroyo, 1995).

Megadiversity is a concept proposed at the Smithsonian's 1988 Biodiversity Conference (CIF, 1998). Megadiversity helps assess biodiversity at the level of political units, such as nations, rather than by ecosystems. Accordingly, a very small number of countries has an inordinately large share of the world's biodiversity. CIF (1998) estimates that 17 countries out of a total of 228 account for some 60-70% of the 250,000 higher plants, which constitute the global biodiversity, including terrestrial, freshwater and marine species (Figure 3.2). These 17 countries are also homeland to some 60-70% of all higher endemic plants (Figure 3.3).

### 3.4.2. Biological diversity and linguistic diversity

A close correlation between biological diversity and linguistic diversity is recognized when overlaying both global factor-maps (Durning, 1992) (Figure 3.3). Seven countries ranked as linguistically megadiverse and highly diverse are also biologically megadiverse, covering some 40% of the biological megadiverse countries (Figure 3.3). Indonesia, Papua New Guinea, China, Mexico, India, Australia and Zaire (D. R. Congo) concentrate the highest number of languages in the world (43 to 47%), mainly those considered as endemic languages. These countries are also homeland to 56-65% of the total higher plant diversity and the reserves of 30-37% of the endemic higher plant diversity at global scale. They include three islands (Indonesia, Papua New Guinea and Australia) and four continental, eco-geographically complex countries (China, Mexico, India and Zaire) These countries also account for some 13% of the forest coverage of the world and have an important percentage of rural population, using estimates from the beginning of the 1990s (Table 3.1).

Another group includes countries with intermediate linguistic diversity and biological megadiversity. Brazil ranks first in terms of total biological diversity and higher plant diversity. The USA belong to the same group, but have a smaller number of endemic languages. Malaysia and the Philippines have a large number of indigenous peoples. Brazil, Malaysia and the Philippines have a close correlation between biologic and linguistic diversities. In total, 58% of countries with many endemic languages and ranking as biologically megadiverse concentrate some 50-55% of all languages of the world. Some 40-50% of all endemic higher plants are also found in these countries, together with 21% of the forests of the world (Table 3.2). CIF (1998) considers the Amazon Basin, the Congo Basin, Papua New Guinea and the Melanesian Islands as the major tropical 'wilderness' areas of the world.

There is also a close correlation between large diversity of mammals and large diversity of languages (Figure 3.4 and table 3.3). According to Harmon (1996a), the 25 countries with the highest number of endemic languages correspond to the top 25 countries with endemic higher vertebrates (mammals, reptiles and amphibians). Harmon considers endemic the languages restricted to a single country. Based on this criterion, 83% of world's languages are endemic. On the other hand, endemic species are those found in restricted localities and nowhere else (WRI, 1988). Of the 25 countries with the greatest number of endemic higher vertebrate species, 16 are also among the top 25 in endemic languages (64%) (Harmon, 1996a).

Harmon also recognizes three main geographical and environmental factors that explain the above correlation. (1) Large countries with a complex eco-geographical pattern tend to have many endemic species because of their size and ecological complexity. The same factor fosters the isolation of small population groups, which prevailed before the European expansion, thus allowing many autonomous languages to evolve. (2) Island countries also tend to have high numbers of endemics, because their physical isolation from the continental areas has allowed locally adapted species and languages to develop. (3) Tropical countries tend to have more species than boreal, temperate, Mediterranean or austral countries (WCMC, 1992). They have also many endemic languages because of their natural richness and the local setting of hunter-gatherer societies. Harmon (1996a: 98) states that "Where all the three conditions coincide within a country, there comes the possibility of extremely high endemic richness in both species and languages".

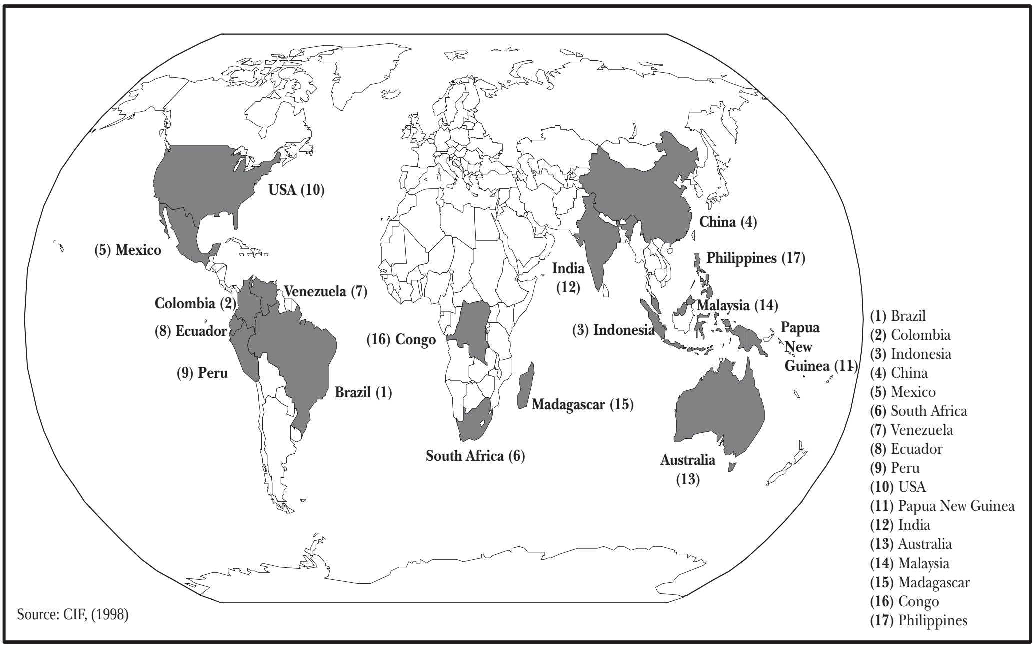



**FIGURE 3.2** Biological megadiverse countries

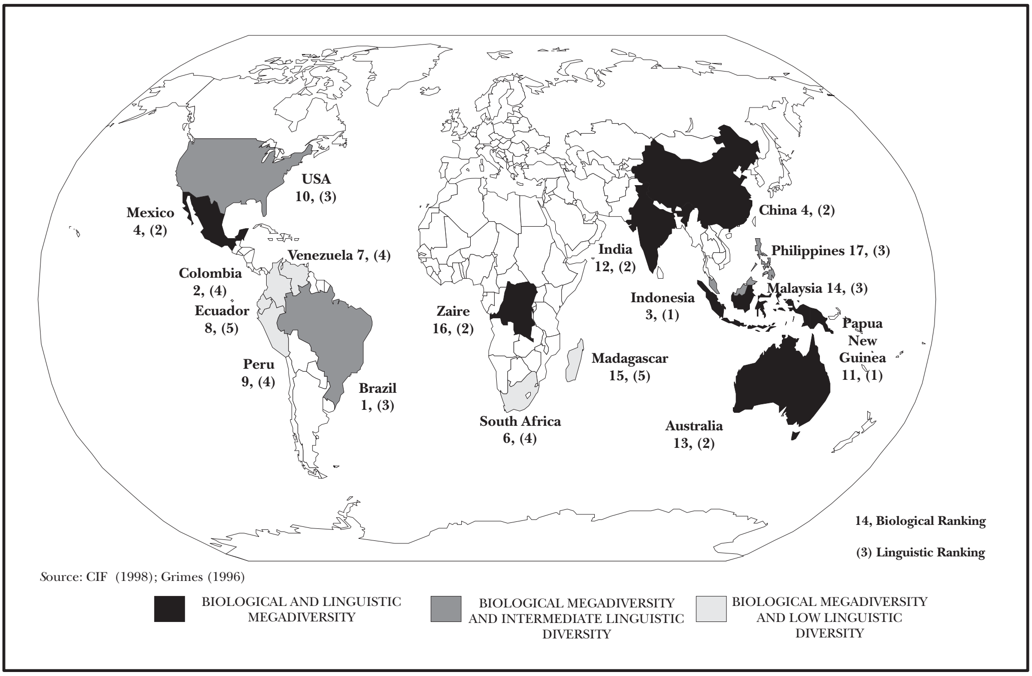



**FIGURE 3.3** Higher plants megadiversity and linguistic megadiverse countries

In addition, there is a close correlation between bird megadiversity and linguistic diversity per country (Figure 3.5 and table 3.4). Seven of the countries having the highest number of languages, as well as endemic languages, are among the 14 top countries with very high bird diversity. This correlation accounts for some 40% of the bird megadiverse countries and for some 43-47% of all languages of the world. Similar to the case of plant and mammal diversity, the countries concerned include three islands (Indonesia, Papua New Guinea and Australia) and four continental ecogeographically complex countries (India, China, Zaire

**Table 3.1.** Total, urban and rural population of selected countries

| COUNTRY According to language diversity ranking | TOT. POP. 1997[1] Millions | TOT, URBAN POP.[1] Millions | % URBAN POP.[1] | TOT. RURAL POP.[1] Millions | % RURAL POP.[1] | AGRIC. Labor Force[2] Millions 1990 | |
|---|---|---|---|---|---|---|---|
| **Indonesia** | 203 | 76 | 37 | 127 | 63 | 48% | 36 |
| **Papua New Guinea** | 5 | 1 | 17 | 4 | 83 | 84% | — |
| **China** | 1,2 | 600 | 46 | 600 | 54 | 67% | 391 |
| **Mexico** | 94 | 74 | 78 | 20 | 19 | 30% | 3 |
| **India** | 966 | 265 | 27 | 700 | 73 | 66% | 17 |
| **Australia** | 18 | 16 | 85 | 2 | 15 | 5% | 0.5 |
| **Congo** | 48 | 14 | 29 | 34 | 71 | 66% | — |
| **World's population** | **4,1** | **1,9** | **46** | **2,2** | **54** | | |
| **Selected countries pop.** | **3,0** | **1,0** | **40** | **2** | **60** | | **447** |
| **% of world's population** | **64.2** | **55.7** | | **71.4** | | | **11** |

**Sources:** (1) UNDP (1997), (2) WRI (1996).

**Table 3.2.** Biological megadiversity and high biological endemism correlated with linguistic diversity

| HIGHER PLANT DIVERSITY | | | | LINGUISTIC DIVERSITY | | |
|---|---|---|---|---|---|---|
| Country[1] | Total diversity rank[1] | Endemism rank[1] | Forest %[3] | Diversity rank class[2] | Number of languages[2] | Diversity rank[2] |
| **Brazil** | 1 | 1 | 52 | 3 | 195 | 10 |
| **Colombia** | 2 | 4 | 52 | 4 | 79 | 25 |
| **Indonesia** | 3 | 2 | 50 | 1 | 712 | 2 |
| **China** | 4 | 8 | 12 | 2 | 205 | 9 |
| **México** | 5 | 7 | 35 | 2 | 289 | 5 |
| **South Africa** | 6 | 3 | 9 | 4 | 27 | 58 |
| **Venezuela** | 7 | 12 | 69 | 4 | 40 | 44 |
| **Ecuador** | 8 | 15 | 52 | 5 | 22 | 66 |
| **Peru** | 9 | 13 | 69 | 4 | 96 | 20 |
| **USA** | 10 | 16 | 33 | 3 | 176 | 11 |
| **Papua New Guinea** | 11 | 6 | 80 | 1 | 817 | 1 |
| **India** | 12 | 10 | 19 | 2 | 407 | 4 |
| **Australia** | 13 | 5 | 19 | 2 | 234 | 7 |
| **Malaysia** | 14 | 11 | 45 | 3 | 137 | 13 |
| **Madagascar** | 15 | 9 | 13 | 5 | 6 | 130 |
| **Congo** | 16 | 17 | 10 | 2 | 221 | 8 |
| **Philippines** | 17 | 14 | 21 | 3 | 168 | 12 |
| **TOTAL** | **17** | **62 – 73%** | **38** | **7** | **3,831** | **11** |

**Sources:** (1) CIF (1998); (2) Grimes (1996); (3) World Bank (1999)
Linguistic diversity rank classes: 1, megadiverse; 2, highly diverse; 3, intermediate diverse; 4, low diverse; 5, very low diverse.

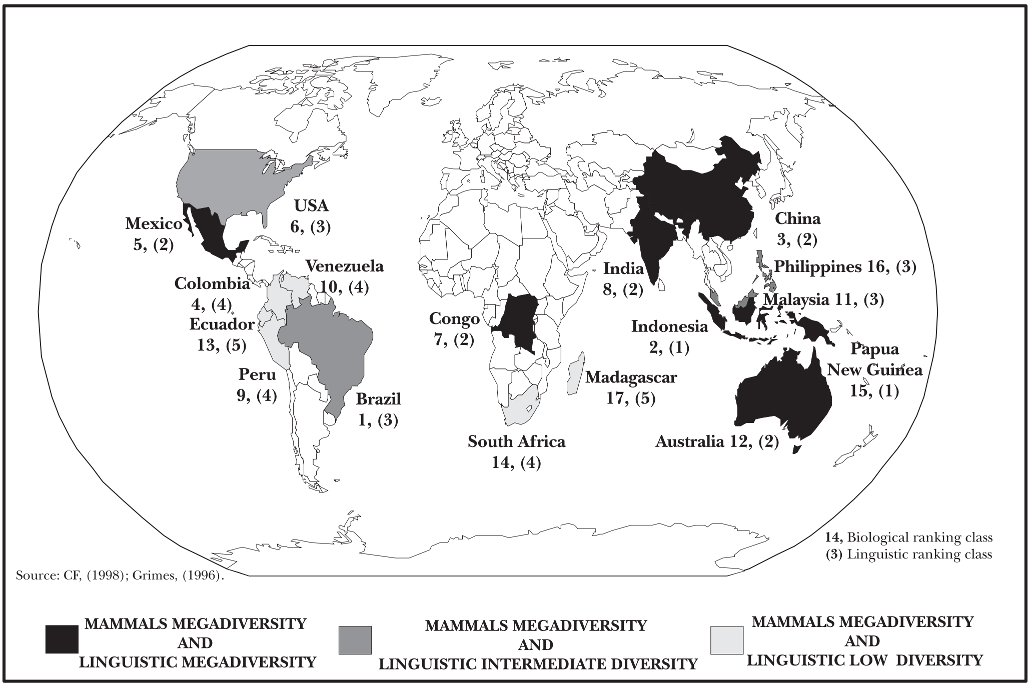



**FIGURE 3.4.** Mammal megadiversity and linguistic megadiverse countries

**Table 3.3.** Mammal megadiversity and high mammal endemism correlated with linguistic diversity

| MAMMAL DIVERSITY | | | LINGUISTIC DIVERSITY | | |
|---|---|---|---|---|---|
| Country[1] | Diversity rank[1] | Endemism rank[1] | Diversity rank class[1] | Number of languages[2] | Diversity rank[1] |
| **Brazil** | 1 | 4 | 3 | 195 | 10 |
| **Indonesia** | 2 | 2 | 1 | 712 | 2 |
| **China** | 3 | 7 | 2 | 205 | 9 |
| **Colombia** | 4 | 12 | 4 | 79 | 25 |
| **Mexico** | 5 | 3 | 2 | 289 | 5 |
| **USA** | 6 | 6 | 3 | 176 | 11 |
| **Congo** | 7 | 12 | 2 | 221 | 8 |
| **India** | 8 | 11 | 2 | 407 | 4 |
| **Peru** | 9 | 10 | 4 | 96 | 20 |
| **Venezuela** | 10 | 17 | 4 | 40 | 44 |
| **Malaysia** | 11 | 14 | 3 | 137 | 13 |
| **Australia** | 12 | 1 | 2 | 234 | 7 |
| **Ecuador** | 13 | 16 | 5 | 22 | 66 |
| **South Africa** | 14 | 14 | 4 | 27 | 58 |
| **Papua New Guinea** | 15 | 9 | 1 | 817 | 1 |
| **Philippines** | 16 | 5 | 3 | 168 | 12 |
| **Madagascar** | 17 | 7 | 5 | 6 | 130 |
| **TOTAL** | **17** | * | **7** | **3,831** | **11** |

**Sources:** (1) CIF (1998); (2) Grimes (1996) Linguistic diversity rank classes: 1, megadiverse; 2, highly diverse; 3, intermediate diverse; 4, low diverse; 5, very low diverse and Mexico). In a second group of countries, including Brazil, USA, Malaysia and the Philippines, an intermediate linguistic diversity correlates with megadiversity of birds, higher plants and mammals.

The close and multi-layered correlation between biologic and linguistic diversities does not imply that the engagement of indigenous and rural peoples with their environment is fortuitous. The myth of nature as a 'natural wilderness' to be preserved, isolating it from the local farmer who has been historically considered as a 'noble savage', is rapidly vanishing (Horigan, 1988; Denevan, 1992b; Durning, 1992; Gómez-Pompa and Krauss, 1992; Posey, 1999b). Today, many of the so-called 'pristine landscapes' of the planet are considered 'anthropogenic landscapes'. Concealed within these landscapes lies a cognitive system spanning generations of people who created or modified the land by direct or indirect human-environment interaction (Hirsch and O'Hanlon 1995; Posey, 1999b). This is particularly the case of the tropical forests, which can no longer be perceived as 'virgin forests' and considered as an exclusive product of nature, despite being inhabited and managed since thousands of years (Colchester, 1993; Fairhead and Leach, 1996). The history of a forest reassembles the history of humans, and the history of humans reflects their engagement with that forest. Both form part of the same world.

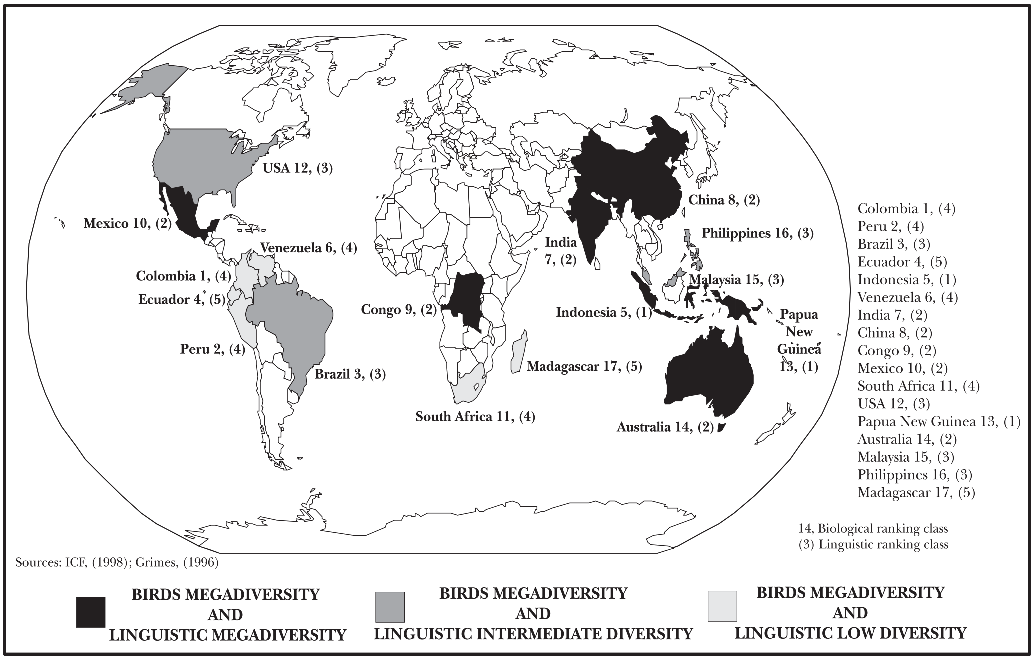



**FIGURE 3.5.** Bird megadiversity and linguistic diverse countries

The view of 'natural wilderness' as *Terra Nulis* -empty or unowned land and resources- implies the negation of the historical existence of their inhabitants and managers, mainly indigenous peoples considered 'backward peoples' or romanticized as 'noble savages'. Many scientists and environmentalists may perceive that nothing is more valuable than a 'natural wilderness area', that has 'not suffered' significant anthropogenic disturbances or transformations (McClosekey and Spalding, 1989; Crumley, 1994; Hanna et al., 1994), but in reality it is improbable that many, if any, pristine forests exist (Denevan, 1992; Gómez-Pompa and Krauss, 1992; Balée, 1994). As Sponsel and collaborators state: "In any event the concept of a wilderness area in which no person (other than a few biologists) may ever tread is increasingly an impractical Western luxury, given the practical needs of many societies… specially with their rapid population growth and expansion into the forest zones. Thus managing forests wisely, rather than simply demarcating and guarding supposed wilderness areas, is the real challenge for future forest conservation" (Sponsel et al., 1996: 25).

Because nature and humans have profoundly influenced each other for millennia, neither can be fully understood in isolation. In fact, an increasing amount of evidence shows this inextricable link, specially in those areas considered as biologically and culturally megadiverse (Klee, 1980 and 1996; McNeely and Pitt, 1985; Marten, 1986; Clay, 1988; Denevan and Padoch, 1988; Posey and Balée, 1989; Altieri, et al., 1987; Altieri and Hecht, 1990; Gadgil and Berkes, 1999; Berlin, 1992; Croll and Parkin, 1992b; Colchester and Lohmann, 1993; Gadgil et al., 1993; Williams and Baines, 1993; Barton, 1994; McNeely, 1994; Brookfield and Padoch, 1994; McNeely et al., 1995b; Toledo, 1995a; Descola and Pálsson, 1996; Ellen and Fukui, 1996; Sponsel et al., 1996; IUCN, 1997; Nazarea, 1999a, b and c; Posey, 1999a; among others). Case studies carried out at local level in the 17 biologically megadiverse countries reveal strong evidence of complex systems of understanding and managing natural resources and biodiversity among indigenous and small-farmer communities (Table 3.5). Showing sound ways of biological and cultural resources conservation and management, these examples should be taken into account when considering the implementation of rural planning and conservation programmes and policies. Local experiences should be analyzed in diachronic and synchronic terms to frame a comprehensive understanding of the diverse interpretations of 'nature', besides the conventional and scientific-oriented systems. Both should be contrasted, integrated and implemented with the local participation. Nevertheless, the analysis of case studies needs to reach beyond the local scale or the single biogeographical landscape to that of the regional, national and global levels, avoiding to be poorly grasped, misinterpreted or over-generalized, specially for the implementation of development with conservation strategies. Furthermore, the case studies carried out at local level must be analyzed as products of ever changing biophysical and cultural processes, never isolated from the regional, national and global levels, and always evolving according to multiple and complex circumstances.

**Table 3.4.** Bird megadiversity and high bird endemism correlated with linguistic diversity

| BIRD DIVERSITY | | | LINGUISTIC DIVERSITY | | |
|---|---|---|---|---|---|
| Country[1] | Diversity rank[1] | Endemism rank[1] | Diversity rank class[2] | Number of languages [2] | Diversity rank[2] |
| **Colombia** | 1 | 5 | 4 | 79 | 25 |
| **Peru** | 2 | 7 | 4 | 96 | 20 |
| **Brazil** | 3 | 3 | 3 | 195 | 10 |
| **Ecuador** | 4 | 14 | 5 | 22 | 58 |
| **Indonesia** | 5 | 1 | 1 | 712 | 2 |
| **Venezuela** | 6 | 13 | 4 | 40 | 44 |
| **India** | 7 | 12 | 2 | 407 | 4 |
| **China** | 8 | 9 | 2 | 205 | 9 |
| **Congo** | 9 | 15 | 2 | 221 | 8 |
| **Mexico** | 10 | 6 | 2 | 289 | 5 |
| **South Africa** | 11 | 17 | 4 | 27 | 58 |
| **USA** | 12 | 11 | 3 | 176 | 11 |
| **Papua New Guinea** | 13 | 10 | 1 | 817 | 1 |
| **Australia** | 14 | 2 | 2 | 234 | 7 |
| **Malaysia** | 15 | 16 | 3 | 137 | 13 |
| **Philippines** | 16 | 4 | 3 | 168 | 12 |
| **Madagascar** | 17 | 8 | 5 | 6 | 130 |
| **TOTAL** | **17** | *** | **7** | **3,831** | **11** |

**Sources:** (1) CIF (1998); (2) Grimes (1996). Linguistic diversity rank classes: 1, megadiverse; 2, highly diverse; 3, intermediate diverse; 4, low diverse; 5, very low diverse.

### 3.4.3. Loss of species, languages and experience

Extinction has played an important role in the maintenance, renewal and enrichment of biodiversity at both geological and evolutive time-scales (Ricklefs, 1995). Mass extinction of biological species has occurred either by systematic pressures on species and/or due to stochastic perturbations or natural fluctuations (Shaffer, 1981). Extinction occurs when the remaining individuals of a species are incapable of producing offspring (O'Connor et al., 1990). For every species that goes extinct, many populations have become extinct, and small populations (as the case of endemic species) have high risk of extinction. Mechanisms of extinction include negative population growth-rate, birth and death randomness, climatic and other external variability, and genetic factors (Barbault and Hindar, 1995).

**Table 3.5.** Biologically megadiverse countries and indigenous systems of biodiversity management and conservation (selected studies)

| COUNTRY | INDIGENOUS PEOPLE | AUTHORS |
|---|---|---|
| **Brazil** | Kayapó<br>Ka'apor | Anderson and Posey (1985); Hecht and Posey (1989); Posey and Balée (1989); Moran (1996) |
| **Indonesia** | Nuaulu (Seram, Eastern Indonesia)<br>Bunaq (Timor)<br>Javanese<br>Dayak Pasir (East Kalimantan) | Ellen (1993a); Ellen (1993b);<br>Friedberg (1990);<br>Soemarwoto and Conway (1992);<br>Enris et al. (2000) |
| **Colombia** | Yukuna<br>Yukuna and Matapi<br>Tukano | Van der Hammen (1992);<br>Van der Hammen (1996);<br>Reichel-Dolmatoff (1968) |
| **Australia** | Gagadju (Northern Territory) | Lewis (1989) |
| **Papua New Guinea** | Wola | Sillitoe (1996);<br>Eaton (1997) |
| **Mexico** | Mayan<br>Huastec<br>Totonac | Gómez-Pompa et al. (1987);<br>Alcorn (1984);<br>Medellín (1988); Barrera-Bassols et al. (1994); Toledo et al. (1994) |
| **China** | Small farmers (Yunuen Province)<br>Small farmers (Northern Fujian Province) | Pei Sheng (1999);<br>Chandler (1991);Chandler (1994) |
| **Madagascar** | Small farmers (Imerina) | Ramiarantsoa (1995) |
| **India** | Tirumal Nandiwalla, Vaidu, Phasepardhis (Maharashtra)<br>Chakhesang, Angami, Chang, Yimchunger and Konyok (Nagaland)<br>Different tribal communities (Orissa, West Bengal, Bihar) | Gadgil and Guha (1992);<br>Sharma (1998);<br>Poffenberger and McGean (1996) |
| **Malaysia** | Penan Sarawak (Borneo) | Brosius (1991) |
| **Venezuela** | Piaroa<br>Warao<br>Orinoco river floodplains<br>Yekuana | Zent (1999);<br>Wilbert (1995);<br>Barrios and Herrera (1994);<br>Barrios (1996);<br>Arvelo-Jimenez (1993) |
| **Peru** | Bora (Peruvian Amazon) | Denevan and Padoch (1988);<br>Alcorn (1989a); Barton (1994) |
| **Philippines** | Hanunoo<br>Talaandigs and Dagamats | Conklin (1957);<br>Nazarea (1999a) |
| **Ecuador** | Achuar | Descola (1994) |
| **USA** | Zuni<br>Chicano<br>Mid-Columbian | Nahban (1985); Ford (1999);<br>Peña (1999);<br>Hunn (1990) |
| **Congo** | Efe, Ese Mbuti Pygmies | Burguer (1990) |

Causes of extinction include habitat degradation (loss, change in quality and fragmentation), overexploitation and persecution, and introduction of alien species (Hanski et al., 1995). The 'basic rate' of global biological extinction is presumably very low, between $10^{-6}$ and $10^{-7}$ percent of species per year, although measuring the speed of species loss during the earth's geological and evolutive history is quite difficult (Raup, 1986). Nevertheless, with the exception of a few mass extinction events in ancient geological history, the rate at which new species are created has exceeded the rate of extinction. Therefore, the number of species on earth seems to have slowly but steadily increased over time (Noss and Copperrider, 1994). Besides, the number of plant species lost in any of the past massive extinction periods was not of a great amount, and plant species diversity maintained steadily high when compared to the acute reduction of animal species (Challenger, 1998). However, this trend is being reversed today (Wilson, 1985).

The impact of human intervention on species extinction began not earlier than 30,000 years ago, but showed an alarming acceleration during the last 500 years (Reid and Miller, 1989). The speed of bird and mammal extinction rose 400% from 1600 to 1950, reaching 0.5 to 1% of all species per century. Human-induced extinction takes place at a speed 100 times higher than that occurring under natural conditions. Losses by extinction are not compensated by new speciations. Current and future extinction rates have been estimated indirectly from the relationship between the size of an area and the number of species it holds, but outcomes differ widely according to the different predictive models used (Hanski et al., 1995). A rate of deforestation of 1% per year translates into a rate of extinction of about 0.25% per year according to the species-area relationship (Barbault and Sastropradja, 1995). Wilson states that the rate of extinction is now about 400 times that recorded through recent geological time and is accelerating rapidly. Under the best conditions, the reduction of diversity seems destined to approach that of the great natural catastrophes at the end of the Paleozoic and Mesozoic eras, with the most extreme 65 million years ago (Wilson, 1985).

Today, human-induced biodiversity losses affect species from all environments. Furthermore, estimates show that the tropics are more affected than other climatic zones (Turner II et al., 1990; Heywood and Watson 1995; Kondratyev, 1998). Extinction rates in the tropics are estimated at somewhere between 10,000 and 150,000 species lost per year over the next decades (Wilson, 1988). These losses are of particular importance because species diversity in tropical forests accounts for some 50% of the world's species diversity (Myers, 1980; Reid and Miller, 1989). About 1-10% of the species in tropical forests is estimated to become extinct or threatened over the next 25 years. This would be approximately 1,000 to 10,000 times the average expected 'background' extinction rate (Hanski et al. 1995).

To revert or, at least, to halt these trends in the tropical areas, constitutes one of the most important challenges for the near future (McNeely et al., 1995a,b; Myers, 1996). Two contrasting phenomena are threatening these important strategic areas. On the one side, the tropics contain the majority of the biologically megadiverse countries, but face severe environmental degradation and socio-economic pressures (Goodland, 1992; Peet and Watts, 1996; Sponsel et al., 1996; Byron and Arnold, 1999). On the other side, the tropics represent the highest linguistically diverse agroecological zone of the world (Oldfield and Alcorn, 1991; Durning, 1992; Colchester and Lohmann, 1993), but cultural standardization is severely threatening its most important richness, its historical bio-cultural links (Gadgil et al., 1993).

Paralleling the species extinction and biodiversity loss, languages vanish and cultural diversity decreases. Uniformization results from the loss of human experience and bio-cultural diversity (Durning, 1992; Maffi, 1998; Posey, 1999a). Recently, linguists have highlighted the meaning of the ecological and cultural consequences of the linguistic diversity extinction (Mühlhäusler, 1995 and 1996; Harmon, 1996a and 1996b; Maffi, 1999). They also revealed the present trends of language disappearance, specially of those considered as endemic languages (Harmon, 1996b; Maffi, 1999), and the loss of their 'linguistic ecologies' (Mühlhäusler, 1995 and 1996), defined as "the functional relationships that develop in space and time among linguistic communities that communicate across language barriers, encompassing not only the linguistic and social environment, but also the physical environment, within a worldview in which physical reality and the description of that reality are not seen as separate phenomena, but instead as interrelated parts of a whole" (Maffi, 1998: p.15).

Some authors suggest that the peak of linguistic diversity at global scale was reached at the beginning of the Neolithic (10,000 BP) because of the isolation of an extended number of hunter-gatherer groups. An estimated number of 12,000 to 14,000 thousand oral languages may have been spoken during this period (Robb, 1993; Hill, 2001). From then on, linguistic diversity decreased following the integration among social groups and the merging of new communication and exchange systems (Maffi, 1999). However, many small languages survived, even in densely populated areas with high cultural diversity and complex exchange systems, despite the acceleration of the integration process during the last 500 years. This is important to the understanding of the actual linguistic diversity and linguistic ecologies.

Currently, language extinction proceeds at an unprecedented magnitude and pace. Populations of less than 100,000 inhabitants, who lived until recently in geographic isolation, speak some 5,000 languages out of the 6,000 to 7,000 living languages of the world. These endemic languages are considered as threatened or at risk of disappearing (Krauss, 1992). If the present trends are not reversed, as many as 90% of the world's languages may become extinct or moribund in the course of the 21st century (Krauss, 1992; Maffi, 1999). The rate of language loss is estimated to be 500 times higher than the biological species extinction (Maffi, 1999). The close correlation between linguistic diversity and biological diversity at global scale can be summarized as follows:

(1) in total, 58% of the countries with a majority of the endemic languages and ranking as biologically megadiverse concentrate 50 -–55% of all languages of the world;
(2) some 40–50% of all endemic higher plants are also found in these countries, together with some 20% of the forests of the world;
(3) of the 25 countries with the greatest number of endemic high vertebrates, 16 are also among the top 25 in the endemic language ranking;
(4) seven of the countries having the highest number of languages, as well as endemic languages, are among the 14 top countries with very high bird diversity. This correlation accounts for some 40% of the bird megadiverse countries and for some 43–47% of all languages of the world;
(5) case studies carried out at local and regional levels in 16 biologically megadiverse countries reveal strong evidence of endemic environmental knowledge systems;
(6) the vast majority of the countries, that show close correlation between linguistic and biological diversities, is located in the tropical areas of the world and faces severe environmental degradation and cultural standardization;
(7) the reduction of biological diversity through extinction shows an alarming acceleration during the last 500 years. Although current and future extinction rates have been estimated by indirect procedures, some estimations state that the rate of extinction is now about 400 times greater than the estimations recorded in recent geological time. Current estimated rates approach those of the great natural catastrophes at the end of the Paleozoic and Mesozoic eras, and
(8) extinction rates in the tropical forests are estimated at about 1–10% of their species over the next 25 years. These losses are of particular importance because species diversity in tropical forests accounts for some 50% of the world's species diversity.

### 3.5. Agricultural Diversity

Agricultural biodiversity cannot be fully understood without comprehending all the human ecological complexity of the societies, that have been able to create and preserve the richness of their genetic resources. This is however difficult to value in economic terms (Martínez-Alier, 1994). What does agricultural biodiversity or domesticated species diversity mean? What has been the role of indigenous peoples and small farmers in creating agricultural richness? Where are the agricultural genetic 'hot spots' of the world located? What are the agrarian processes contributing to genetic diversity erosion? Which is the role of the traditional rural productive systems in maintaining and expanding genetic diversity? The following section explores some of the factors and features, which play a role when addressing these questions. To explore the role of indigenous peoples and small farmers in developing and conserving genetic richness, and to assess the strategic value of the latter for maintaining and increasing the food production in the near future, are the main objectives of this section.

### 3.5.1 Defining genetic diversity

Genetic diversity is defined as the internal genetic variation of a plant or an animal, among plants or animals of the same species or between different plant and animal species (Almekinders et al., 1995). Genes are the basic unit of inheritance. They are discrete hereditary traits that replicate at each cell division. Genetic diversity is the basis of ecological diversity and species richness (O'Connor et al., 1990). It is a product of complex interactions over time between biophysical factors and human intervention (Harlan, 1971, 1992). Genetic diversity occurs in different forms, at different scales of time and space, and necessarily implies human intervention in the selection and management of genetic material. A plant can be genetically homogeneous or heterogeneous at a particular locus; a crop can consist of different genotypes of one or more cultivars, and even of one or more sub-species (Brush et al., 1981). A field can be a monocropping or multi-cropping system (Swift and Anderson, 1992) (Table 3.6). At higher levels, genetic diversity is present in farming systems or at regional, national and global scales (Conway and Barbier, 1990; Conway, 1993, 1994). At a temporal scale, cultivar or crop rotations and land-use sequences cause genetic variation (Almekinders et al., 1995).

Erosion of genetic diversity is caused by the replacement of old, native germoplasm by new high-yielding varieties. Genetic erosion can be also defined as an accelerated loss of germoplasm from the extant crop gene pool. Genetic erosion is thought to be primarily caused by social factors including technology diffusion, changing preferences and commercialization (Zimmerer, 1991). Gene replacement occurs when an indigenous variety is replaced by an introduced one, resulting in the substitution of alternative alleles within the same species. Gene displacement refers to the loss of whole genomes by the substitution of one crop species for another or by elimination of the crop entirely (Qualset et al., 1997).

Genetic erosion can be seen also as genic or allelic erosion and as genomic erosion. Genic or allelic erosion occurs when the replacement of old, native crop varieties by new ones changes totally or partially the allelic frequencies. The replaced alleles can be lost or eroded if not preserved elsewhere. Also lost are the specific combinations of genes that occur in the replaced varieties. Genomic erosion is potentially more devastating, because all the genes of a crop would be lost when another crop is introduced or when the agricultural habitat is lost due to urban and industrial development (Qualset et al., 1997). The fundamental unit of conservation is the gene and its allelic forms. Genetic erosion must be evaluated based on the degree of replacement and conservation status.

Biophysical factors and human interactions involve diverse issues concerning the preservation, maintenance and expansion of genetic variation, such as (1) the introgression from wild and weedy relatives, (2) the hybridization with other cultivars, (3) mutations, and (4) natural and human selection pressure. Resulting from an evolutionary process, crop genetic resources are materials called 'landraces' or 'folkraces' according to Mooney (1992), which are well adapted to local biophysical conditions (Richards, 1995). Landraces are local crop varieties (Bellón and Brush, 1994), adapted by farmers' plant genome management. The evolutionary process involves the acquisition of new genotypes and the maintenance of the existing ones (Rindos, 1989). The strategic value of maintaining and expanding the genetic diversity of the major food crops is that this underpins long-term world food security by providing the raw material needed for future crop adaptations to changing pests and pathogens, as well as to changing environmental, socio-economic and cultural conditions (Cooper et al., 1992; Prance, 1997; Maxted et al., 1997). Almekinders and collaborators (1995) have summarized relevant agro-diversity features from previous studies:

(1) crop genetic resources are principally the product of complex interactions over time between the abiotic and biotic environments, and of farmers' handling and selection of the material (Harlan, 1992);

(2) the results of this evolutionary process are materials or 'landraces', which are well adapted to the local abiotic and biotic environmental variation (Collins, 1914; Curtis, 1968; Richards, 1985; Benzing, 1989; Weltzien and Fischbeck, 1990);

(3) landraces are often genetically heterogeneous populations as a consequence of the variation in the environmental conditions under which the material evolved (Harlan, 1992; Hardon and Boef, 1993);

(4) genetic variation within and between crops often favors stability in space and time through the suppression of pests, diseases and weeds (Altieri and Liebman, 1986; Barret et al., 1990);

(5) stabilization of yield levels over seasons and over fields through genetic variation is probably associated with large variation between genotypes in contribution to the total yields (Almekinders et al., 1995);

**Table 3.6.** Diversity of agricultural systems

| DIVERSITY OF SPECIES | **Multi-field type** ← | | | → **Single-field type** |
|---|---|---|---|---|
| High | Shifting cultivation | Traditional compound farm | | Home garden |
| | Nomadic pastoralism | Rotational fallow | | |
| | | Savanna mixed farming | | |
| | | | Horticulture | Multi-cropping |
| | | Compound agribussines | Pasture mixed farming | |
| | | | Alley farming | |
| | | | Crop rotation | Alley cropping |
| | | | | Intercropping |
| | | | | Plantation and orchard |
| Low | | | | Intensive cereal production |

**Source:** Swift and Anderson, (1992)

(6) crop diversity at the field level can also increase production (expressed as land equivalent ratio or farm income) and use efficiency of other resources such as solar energy, water and labor (Trenbath, 1986; Lynman et al., 1986; Stinner and Blair, 1990);
(7) at the level of the farming system, crop diversity can increase and stabilize the total output (Lynman et al., 1986; Barret et al., 1990);
(8) at the farm and regional levels, diversity in agricultural commodities is likely to affect prices and income, resulting in a damping of the market fluctuations (Anderson et al., 1987), and
(9) at the regional level, the effect of crop diversity on stability is reflected by the variety of land-use types and land cover patterns (Almekinders et al., 1995).

The important role played by indigenous production systems in the conservation of soil and water resources and in the biological management of pests and diseases, is receiving more attention. Using mixed cropping and intercropping, the traditional production systems play a conservationist role based on the permanent experimentation and innovation by local producers (Table 3.7). The conservationist role of these systems is able to produce an extensive number of goods, often in marginal conditions, by adapting and expanding genetic diversity patterns in micro-local conditions (Conklin, 1954; Mooney, 1983 and 1997; Halffter, 1984; Richards, 1985; Wilken, 1974, 1987; Nabhan, 1985, 1989; Posey and Balee, 1989; Warren and Cashman, 1988; Altieri, 1990 and 1993a; Oldfield and Alcorn, 1991; Croll and Parkin, 1992a, b, and c; Cooper et al., 1992; Millar, 1992; Pretty, 1992; Gadgil et al., 1993; Inglis, 1993; Alcorn, 1984, 1989a, 1989b1994; de Boef et al., 1993; Haverkort and Millar, 1994; Nazarea, 1999a; Prain et al., 1999).

Genetic management evolved through hundreds or thousands of years constitutes a primordial reserve of agricultural and husbandry resources. Genetic management is a principal provider of genetic resources adapted to resist environmental adversities, possessing high food quality, and adjusted to ecological and economic highly predictable or unpredictable conditions. The maintenance and enrichment of genetic diversity allow local farmers:

(1) to maximize production through the management of heterogeneous environmental conditions;
(2) to reduce pests, diseases, risks, and uncertain climatic variations;
(3) to increase yields when producing mixed crops and varieties well adapted to micro-environmental conditions;
(4) to introduce high-yielding varieties in the environments provided with better land qualities, uniform biophysical conditions, and higher soil fertility, and
(5) to assure a wide range of multi-purpose goods (food, medicines, energetic resources, ceremonial resources, etc.) all along the year.

The conservation of the traditional production systems covers a strategic value for maintaining and enriching the genetic diversity, as part of the cultural patrimony of the local producers. The preservation and control of the local genetic diversity constitute fundamental social and individual rights, which do not compare to the Western rules that regulate formal property of commodities. Montecinos and Altieri (1991) list some of these fundamental rights:

(1) the right to freely choose the production systems and technological options to employ;
(2) the right to fully control the genetic resources that fit the needs and uses, including the control of the production process and the selection and amelioration of seeds without any legal limitation;
(3) the right to freely decide over the germoplasm information and exchanges;
(4) the right to repatriate the germoplasm collected by national and international seed banks in an unconditional way and without intermediates;
(5) the right to request support to conserve the genetic and productive sources;
(6) the right to be compensated for the conservation and amelioration work done through long periods;

**Table 3.7.** Selected countries with highly diverse agricultural systems

| COUNTRY | PROVINCE | VILLAGE | ETHNIC GROUP | CROPS | SOURCE |
|---|---|---|---|---|---|
| **SIERRA LEONE** | National | | Diverse | 180-200 rice varieties (named and distinguished by farmers) | Longley and Richards (1993) |
| **ZIMBABWE** | | Gokwe | | 13 native varieties of sorghum | van Oosterhout (1993) |
| **ETHIOPIA** | Bako-Gazer Awaraja, South Omo Province | Metsar | Ari | 78 varieties (landraces) of ensete *(Ensete ventricosum)* | Shigeta (1996) |
| **MEXICO** | Veracruz | Plan de Hidalgo | Totonac | 254 species cultivated in milpa and homegarden systems | Barrera-Bassols et al., (1992) |
| **MEXICO** | San Luis Potosi | | Huastec | 300 species cultivated in the village | Alcorn (1984) |
| **ECUADOR** | Amazon region | | Jivaro Achuar | 62 cultigens and over 150 crop varieties in a single garden | Descola (1994) |
| **PERU** | Amazon region | Iquitos | | 168 different crops; | Brush (1992a) |
| | Cajamarca | La Encantada | Quechua | 48 varieties of potato; 12 varieties of bean; 8 varieties of maize | Tapia and Rosa (1993); Zimmerer (1998) |
| **NEPAL** | | | | 1 Nepalese farmer growing 20 different varieties of rice | McNeely (1989) |
| **MYANMAR** | Rainfed uplands and lowlands | | | 52 varieties of rice; rainfed uplands: 18 varieties; deepwater: 18 varieties; rainfed lowlands: 16 varieties | Fujisaka et al. (1992) |
| **LAOS** | Upland Laos | Regional | Lao | 29 varieties of rice | Fujisaka et al. (1992) |
| **THAILAND** | Northern Thailand | | Lua | 120 cultivated crops; 75 for alimentation; 21 medicinal; 20 ceremonial; 7 for weaving and/or dyeing | Kunstadter (1970) |
| **INDONESIA** | West Nusa Tenggara | Islands of Lombok and Sumbawa 20 villages | | 59 varieties of soybean; 34 varieties of maize; 7 varieties of cassava; and 27 varieties of sweet potato | Van Dorp and Rulkens (1993) |
| **PHILIPPINES** | Northern Luzon | | Hanunoo | 150 species of plants at one time in the same swidden | Conklin (1954) |

(7) the right to maintain and recuperate their cultures, including knowledge systems, history and beliefs; and
(8) the right to the respect of their cultures and traditions and their own ways of creation, cognition and innovation.

To fulfill the above-mentioned rights, *in-situ* conservation of genetic diversity becomes a crucial task, implying a drastic re-orientation of genetic resources conservation. In contrast, the conservation of genetic resources is now mainly done outside the production systems where they evolved, thus in *ex-situ* conditions. The evolution of crop germoplasm and particularly of landraces, used in breeding and genetic conservation programs, relies on extensive collections and seed banks in botanical gardens and zoos. These gene banks store an enormous amount of goods gathered from farmers' fields and markets and kept in a worldwide network of national and international agricultural research centers (IARCs). An international board (IBPGR) coordinates the IARCs for plant genetic resources. This *ex-situ* conservation of genetic diversity has been the basis for breeding improved high-yield genetic varieties (HYV) for high-technology agriculture. In spite of the scientific and technological advances obtained from the *ex-situ* conservation strategy, criticisms have been conveyed by scientists, farmers, indigenous and other social organizations, NGOs, advocates and technicians (Oldfield and Alcorn, 1987; Kloppenburg and Kleinman, 1986 and 1987; Kloppenburg, 1988; Zimmerer, 1991; Cooper et al., 1992; Brush, 1995; Posey and Dutfield, 1996; Mooney, 1997; Prance, 1997; Shiva, 1997; Simpson, 1997; Christie and Mooney, 2000; Thrupp, 1989, 2000). Criticisms focus mainly on the following points:

(1) the limitation of the gene banks to store no more than 30 of the world's most important crops, leaving aside their wild relatives and other crops, vegetables and trees;
(2) the dramatic displacement of landraces by new HYV, causing a rapid genetic erosion within areas of ancient agriculture;
(3) the highly vulnerable *ex-situ* conservation approach to human error;
(4) its static and freezing way of preserving germoplasm by divorcing genetic resources from their agro-ecological and cultural origins;
(5) the privatization of genetic resources through patenting, without compensating the original breeders;
(6) the farmers' limited access to the *ex-situ* gene banks;
(7) the lack of international laws to protect farmers' rights and intelectual property of genetic resources, as part of their cultural legacy.

In contrast, Brush (1995) and Zimmerer (1998, 1999) stress the strategic importance of *in-situ* conservation, as (1) it preserves evolutionary processes that generate new germoplasm under conditions of natural selection; (2) it maintains important field laboratories for crop biology and biogeography; (3) it provides continuing sources for *ex-situ* collections; and (4) it provides a means for wider participation in conservation, allowing for a more equitable role for nations with abundant crop germoplasm resources. Bellón and collaborators (1997: pp.265-266) also define on-farm conservation of crop genetic resources "as the continued cultivation and management of a diverse set of crop populations by farmers in the agrosystems where a crop is evolved. This set may include the weedy and wild relatives of the crop that may be present together with it, and in many instances tolerated. It is based on the recognition that, historically, farmers have developed and nurtured crop genetic diversity, and that this process continues in spite of socio-economic and technological changes."

Evaluation of *ex-situ* and *in-situ* genetic resources conservation as mutually exclusive strategies is doubtful and partial. Both are needed and constitute complementary approaches to preserve, maintain and improve genetic diversity (Prescott-Allen and Prescott-Allen, 1982, 1983 and 1990; Boyce, 1996; Brookfield and Stocking, 1999). Bellón and collaborators (1997: 288) argue that "the complementarity of on-farm *in-situ* conservation and *ex-situ* conservation clearly exists at the level of objectives. *Ex-situ* conservation aims to capture and maintain the genetic diversity at a given instant, whereas on-farm conservation aims to promote the adaptation of this diversity by using an evolutionary process. This complementarity does not mean that these genetic conservation strategies should remain isolated from each other. On the contrary, it should be enhanced through reciprocal flows of genetic material". Mooney (1992) recognizes five laws of genetic conservation:

(1) agricultural diversity can only be safeguarded using diverse strategies. Different conservation systems can complement each other and provide insurance against the inadequacies or shortcomings of any other method;
(2) saving agricultural diversity depends on who is consulted, and a stronger involvement of all interested social agents enhances the potential to conserve;

(3) agricultural diversity will not be saved unless it is used; its value is in its use;
(4) agricultural diversity cannot be saved without saving the farm community; conversely, the farm community cannot be saved without saving diversity; and
(5) the need for diversity is never ending; as extinction is forever, conservation must be also forever.

### 3.5.2. Centers of origin of domesticated plants and animals

Vavilov, a Russian geneticist-biologist, identified the geographical areas where cultivated plants originated, from the analysis of the major plant collections of his time, a wide literature review, and fieldwork throughout the world. In his book about the *Origins of Cultivated Plants* (1926), he confers the status of plant domestication centers to the following areas (Figure 3.6):

(1) **China: The north central and western mountainous regions and their adjacent lowlands.**
First evidence of agricultural foxtail millet and pig raising is recognized in the north of China at 7,000-8,000 BP (Gadgil, 1995). Other crops, such as soybean, are considered to originate from this area (Boyden, 1992).

(2) **India: The Himalayan region (Nepal and Burma) and the Indo-Malayan region, including Indochina, Malaysia and Indonesia.**
Rice, tea, banana, yam, as well as cebu, pig, chicken and water buffalo, are considered original from this wide and complex eco-geographical area (Boyden, 1992).

(3) **Central Asia: northwestern India, Pakistan, Afghanistan, Tajikistan, Uzbekistan and the Tanshan mountains.**
Alfalfa, millet, hemp, as well as the Bactrian camel and yak, are considered original from this area (Boyden, 1992).

(4) **Near-East: Iraq, Iran, Turkey, Syria and Jordan.**
The earliest evidence of agriculture based on the cultivation of seeds, notably wheat and barley, and the domestication of goats, sheep and cattle, is found in a broad area known as the Fertile Crescent, extending from Greece to a region about 2,400 km to the east and south of the Caspian Sea, as well as in the uplands flanking the valleys of the Tigris and Euphrates rivers (Baker, 1970; Heiser, 1973; Reed, 1977). The origin of agriculture in this area is estimated at 9,000 BP (Harlan, 1995).

(5) **Mediterranean region: coastal ring and adjacent areas.**
Barley, rye, grapes and olive, as well as goose, cattle and pig raising, are considered original of this area (Boyden, 1992). Ploughing came into use in Europe between 5,000 and 4,000 BP. Some regions practiced alternated fields between spring- or winter-grown grains and fallow (the two-field system), by the time of the Roman Empire (Gadgil, 1995).

(6) **Ethiopia: including Eritrea and Somalia.**
Boyden (1992) recognizes coffee, finger millet, sorghum and sesame as original from this area. Harlan (1995) identified other cereals that did not expand outside this area, but still constitute staple crops for the current population. Chat, tef and noog are the most important ones.

(7) **Mexico and Central America: center and southern Mexico, Guatemala, Honduras and Costa Rica.**
Maize, cabbage, beans, tomato, cotton and chili peppers were domesticated in Middle America from 7,000-8,000 BP (Gadgil, 1995; Harlan, 1995). Other crops, such as avocado, cocoa and sweet potato, are also considered original from this area (Boyden, 1992).

(8) **Andean region: Peru, Ecuador, Bolivia, the Chiloe archipelago in Chile, and the subtropical region of Brazil and Paraguay.**
Archaeological evidence shows the cultivation of potato, tomato, beans, chili pepper, cotton, manioc and other tubers in the Andean region from 9,000 BP (Salaman, 1949; Harlan, 1995). Llama, alpaca, guinea pig, peanuts and pineapple are also considered original from this area (Boyden, 1992). Horkheimer (1973) recognized 44 original Andean crops in Peru. At the time of the Spanish conquest, Inca farmers were cultivating more than 70 separate crop species (Cook, 1937).

Vavilov's centers of agriculture of the world still maintain their original status (Grigg, 1974) and continue having high diversity of crop varieties (Hawkes, 1983; Reid and Miller, 1989; Cooper et al., 1992; Harlan, 1995), despite some disagreements about considering all of them as centers of original plant domestication (Harlan, 1971, 1992 and 1995). In his proposal, Vavilov assumed that the areas with a large number of varieties belonging to the same domesticated species should be counted as centers of origin, as they group more dominant genes than their peripheries do. The presence of wild relatives on the margins of a cultivar area allows the permanence and amelioration of cultivars, according to Prance (1997). Cultivated crops often intercross with their wild or weedy relatives growing in the field or close to, resulting in new plant characteristics (McNeely, 1995b).

After Vavilov and others (Source: Darlington, 1963)

| | |
|---|---|
| 1 SOUTH MEXICO AND CENTRAL AMERICA | 7 NEAR EAST |
| 2 SOUTH AMERICA (PERU, ECUADOR, BOLIVIA) | 8 CENTRAL ASIA |
| 3 BRAZIL AND PARAGUAY | 9 INDIA AND BURMA |
| 4 CHILOE ARCHIPELAGO | 10 CHINA |
| 5 WEST AFRICA | 11 INDO-MALAYA |
| 6 ETHIOPIA | 12 MEDITERRANEAN AREA |

**Figure 3.6.** Centers of plant domestication

The areas identified by Vavilov correlate with important centers of civilization development, such as Middle America, the Andean region, the Mediterranean region, Ethiopia, the Middle East, India and China. In most of them provided with bio-climatic and eco-geographic diversity, agricultural histories developed since 10,000 years ago. Many of these historical centers, as depositaries of high genetic diversity, overlap with current important food producing areas at global scale (Figure 3.7). Some of them are located in the tropical belt where many of the world's farmers live today, depending on multi-species agriculture for their food and income (Vandermeer et al., 1998). Furthermore, these areas also correlate with some of the areas having high linguistic diversity (Table 3.8). Extreme poverty, environmental degradation, demographic pressure, and cultural disintegration are major issues.

### 3.5.3. Role of major agricultural systems in the maintenance of genetic diversity

What is the role of agricultural modernization in the conservation and enrichment of genetic diversity? According to Pretty (1995), rural modernization during the last 50 years contributed to the development of three major types of agriculture:

(1) industrial agriculture in developed countries is based on market-oriented enterprises. The use of large external inputs allows high productivity, with the implementation of technological packages, mechanization, the introduction of genetically ameliorated crop varieties, and massive input of non-renewable energetic resources, all of them oriented to monocropping commercial production;
(2) applied to the Third World irrigated lowlands, the green revolution agriculture maintains the same logic as the industrial agriculture. Both agricultural systems share similar characteristics, in particular simplification and standardization through high technology and *ex-situ* originated genetic resources, and
(3) traditional agricultural systems, indigenous agriculture or complex, diverse and risk-prone (CDR) agricultural systems are mainly based on low external inputs, manual labor, and *in-situ* adapted technologies oriented to local resources conservation. Outputs are low, if compared to the industrial and green revolution agricultural systems.

The main characteristics, status, conditions and location of these three agricultural types are summarized in table 3.9. The extent of the world population benefiting from these three agricultural types during the 1990s, ranged as follows: (1) the industrial agriculture satisfies 20-22% of the world population (1.2 billion people); (2) green revolution agriculture satisfies 43% of the world population (2.6 billion people); (3) the complex, diverse and risk-prone (CDR) agricultural systems satisfied 30-35% of the world population (1.9 to 2.2 billion people) (Pretty, 1995). At the same time, the distribution of the world population living from the direct appropriation of natural resources was as follows: (1) some 50 million people living in the industrialized countries, and (2) 1.05 billion people living in the Third World countries (Salas, 1996).

Toledo (1994) shows the importance of agrarian activities in the world at the end of the 20th century, using (1990) statistical indicators. Nearly 50% of the world population (2.4 billion people) is engaged in direct exploitation of goods and services offered by nature. Despite intensive urbanization, industrialization and the shifting of national economies to the service sector, rural population duplicated during the last 40 years. Increasing from 1.42 billion people during the 1950s to 2.4 billion people at the beginning of the 1990s, it shows a reduction of some 12% during the same period, if compared with urban population.

About 95% of the economically active population of the world are involved in primary activities, with 80% concentrating in China, India, Africa and Latin America. The other 5% is located in industrial countries, possesses 45% of the total agricultural land and contributes to 45% of the cereal production of the world. Moreover, 80% of all tractors of the world are used by farmers working with industrial and green revolution mechanized agricultural systems (Toledo, 1994). All that is evidence of the unequal distribution of sources and production between the three major types of agricultural systems.

Two thirds of the farmers of the Third World maintain their agricultural production with their own local genetic resources and the use of renewable energy inputs. Most of these are small-scale farmers (1.27 billion people), managing CDR agricultural systems (Chambers, 1997). The overall estimates show that 50 to 60% of the Third World farmers based their production on local inputs during the 1990s (Toledo, 1994).

Traditional agricultures are complex and highly diversified through the management and conservation of *in-situ* crop genetic resources, as compared to the industrial and green revolution agricultures (Table 3.9). CDR agricultures are also based on local or traditional knowledge systems, that underlie their ecological and economic rationales for risk minimization and control (Chambers, 1997). Poor soils, irregular topography and erratic rainfalls contribute to creating a scattered and fuzzy pattern of agricultural fields. CDR agricultural systems are distributed over diverse landscapes, including warm semi-arid areas, humid tropical areas and hilly to mountainous areas (Chambers, 1990; Toledo, 1990).

Most of these areas are inhabited by self-subsistence small farmers, some of them being indigenous peoples, whose households constitute the basic production units. Small farmers are members of communities having land, forest and water resources managed and controlled by communal rights, or having private ownership, or having defined rights to possess and manage a piece of land (Netting, 1993). Netting (1993: 3-4) defines these production units as entities "…that are alike in that for all of them land is objectively a scarce good, agrarian production per unit area is relatively high and sustainable, fields are permanent, work

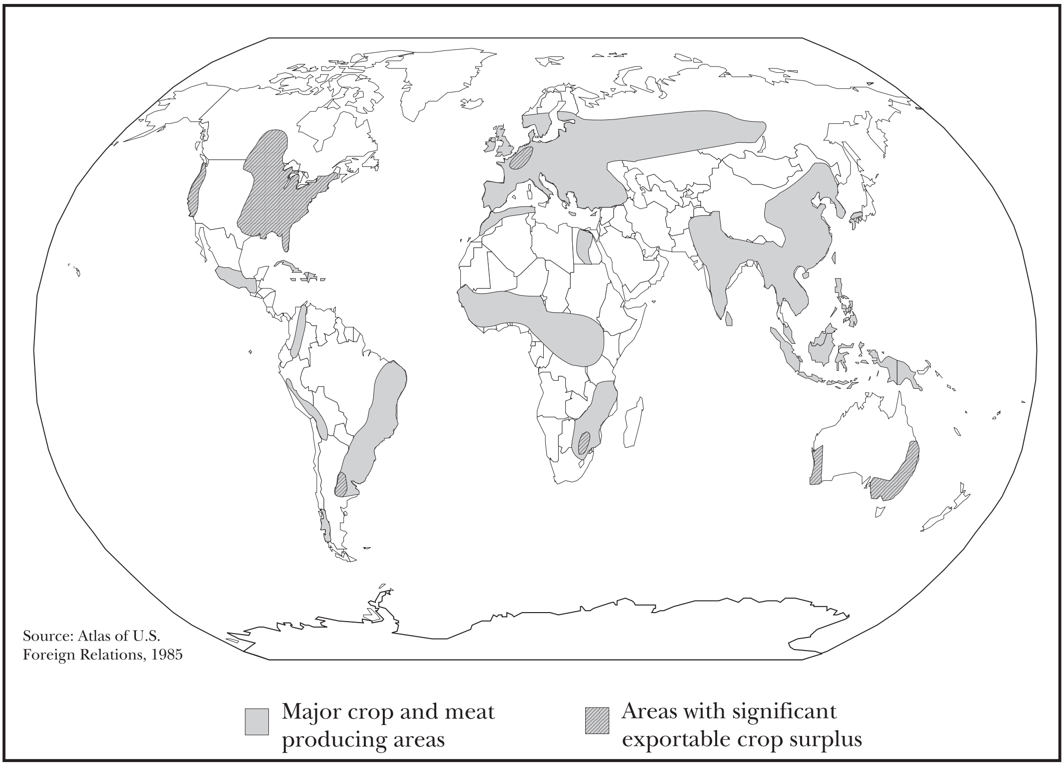



**Figure 3.7.** Major food producing areas of the world

**Table 3.8.** Linguistically megadiverse countries located in areas of origin of plant domestication, and major food production areas of the world

| THE MOST LINGUISTICALLY DIVERSE COUNTRIES | NUMBER OF LANGUAGES | AREAS OF ORIGIN OF PLANT DOMESTICATION | MAJOR FOOD-PRODUCTION AREAS |
|---|---|---|---|
| **Papua New Guinea** | 817 | X | * |
| **Indonesia** | 712 | X | * |
| **Nigeria** | 470 | X | * |
| **India** | 407 | X | * |
| **Mexico** | 289 | X | * |
| **Cameroon** | 279 | X | * |
| **Australia** | 234 | | * |
| **Congo** | 221 | | * |
| **China** | 205 | X | * |
| **Brazil** | 195 | X | * |
| **USA** | 176 | | * |
| **Philippines** | 168 | | * |
| **Malaysia** | 137 | X | * |
| **Tanzania** | 131 | | |
| **Chad** | 127 | | |
| **Nepal** | 124 | X | * |
| **Sudan** | 123 | | * |
| **Myanmar** | 110 | X | * |
| **Vanuatu** | 109 | | |
| **Peru** | 96 | X | * |
| **TOTAL: 20** | **5,130** | **12** | **17** |

**Sources:** Grigg (1974), Atlas of U.S. Foreign Relations (1985), and Grimes (1996)

**Table 3.9.** Characteristics of the three main agricultural systems

| | TYPE OF AGRICULTURE | INDUSTRIAL | GREEN REVOLUTION | TRADITIONAL or 'CDR' (Complex, diverse and risk-prone) AGRICULTURES |
|---|---|---|---|---|
| LOCATION | **Main locations** | • Industrialized countries | • Irrigated and high rainfall areas<br>• High potential areas in the South | • Rainfed tropics<br>• Cold and dry highlands<br>• Wetlands<br>• Hilly tropic lands<br>• Semi-deserts<br>• Deserts |
| | **Climatic zone** | • Temperate | • Mainly tropical | • Mainly tropical |
| STATUS | **Condition** | • Overdeveloped | • Developed | • Underdeveloped |
| | **Current production as % of sustainable production** | • Far too high | • Often near the limit | • Low |
| | **Priority for production** | • Reduce production | • Maintain production | • Raise production |
| CHARACTERISTICS | **Soils** | • Deep fertile, few constraints<br>• Low soil diversity | • Few effective constraints<br>• Medium soil diversity | • Shallow, infertile, often severe constraints<br>• High soil diversity |
| | **Macro- and micro-nutrient deficiency** | • Rare, remediable | • Occasional | • Quite common |
| | **Usual topography** | • Flat or undulating | • Flat | • Undulating |
| | **Plot size** | • Large, square | • Large | • Small, irregular |
| | **Hazards** | • Nil or few | • Few, usually controllable | • Frequent |
| | **Irrigation** | • Usually available | • Usually available | • Often non-existent |
| | **Size of management unit** | • Large, contiguous | • Large or medium, contiguous | • Small, scattered and fragmented |
| | **Natural vegetation** | • Eliminated | • Eliminated or highly controlled | • Used, managed and protected at micro-level |
| | **Farming system** | • Simple | • Simple | • Complex and dynamic |
| | **Environmental diversity** | • Uniform | • Uniform | • Diverse and dynamic |
| | **Relative stability** | • Low risk | • Low risk | • High risk |
| | **Use of external inputs** | • High, reliable | • High, reliable | • Low, unreliable |
| | **Source of seeds** | • Purchased, seed of high quality | • Purchased, seed of high quality | • Own seed, locally high quality |
| CONDITIONS | **Access to credit when needed** | • Very good access | • Good access | • Poor access and seasonal shortages of cash when most needed |
| | **Labor** | • Hired, no constraints | • Hired, few constraints | • Family, constraining at seasonal peak |
| | **Prices** | • Relatively low | • High for inputs, low for outputs | • Higher for inputs; lower for outputs |
| | **Priority for food production** | • Low | • Low | • High |
| | **Access to extension services** | • Very high | • High | • Nil to low |

**Modified from:** Chambers and Toulmin (1991)

takes skill and relatively long periods of time, decisions must be made frequently, and the farm family has some continuing rights to the land and its fruits. In these type of traits, the smallholder differs in kind or in degree, both from other food producers and from those who pursue other occupations".

### 3.5.4. Modernization of agriculture and genetic diversity: a paradox

Technification, modernization and concentration of agricultural activities during the last 50 years caused substantial changes in land-use and soil productivity and an extraordinary increase of yields per capita, but also a negative impact on the environment (Kondratyev, 1998) (Table 3.10). Over the same period, 1.2 billion hectares, nearly 11% of the global soil resources, corresponding to an area larger than India and China together, have been significantly degraded, and their fertility depleted (Gardner, 1996; Hammond, 1998).

Some of the factors impacting negatively the environment and especially bio-agrodiversity are the high levels of mechanization, application of chemicals, and excessive production specialization. More than 75% of the crop genetic diversity got lost over this century (Pretty, 1995). Only three out of 150 crops commercially cultivated (rice, maize and wheat) provide 60% of the calories derived from plants (FAO, 1993). Crop genetic diversity erodes at annual rates of up to 2%, while cattle races genetic diversity erodes at rates of up to 5% annually (Mooney, 1997). The knowledge of small farmers about genetic diversity could be lost during the next two generations, if the current genetic erosion trend maintains (Mooney, 1997).

India lost 30,000 rice varieties and today produces only 10 varieties in 75% of its rice land (Fowler and Mooney, 1990; Shiva, 1998a). Seven highly resistant maize varieties, coming from the USA and promoted by the green revolution since the 1970s (Hewitt de Alcántara, 1976; Marglin, 1991, 1996; Pretty; 1995), have substituted 5,000 maize varieties cropped by Mexican farmers until a few years ago. NAFTA agreements will accentuate the crop genetic erosion (Boyce, 1996). Small farmers in the Philippines cultivated about 3,500 rice varieties before the green revolution. Today, three to five rice varieties are cropped in modern irrigation systems in the same country (Pretty, 1995). China is estimated to have gone from growing 10,000 wheat varieties in 1949 to only 1,000 in the 1970s (Tuxill, 1999).

Industrial countries are also facing acute crop genetic erosion. In the USA, six maize varieties, cropped over 71% of the maize agricultural land, replaced 90% of the former maize varieties. One single potato variety covers 80% of the potato land in the Netherlands. In Europe, half of all the breeds of domesticated animals (horses, cattle, sheep, goats, pigs and poultry) became extinct since the early 20$^{th}$ century. A third of the remaining 700 breeds is in danger of disappearing by 2010 (Pimbert, 1993; Pretty, 1995; Fowler and Mooney, 1990).

In synthesis, agricultural modernization produced a great impact on genetic diversity. Initially, crop productivity increased, especially in the case of the cereals submitted to technological uniformity, such as maize and rice. E*x-situ* technological packages caused yields to increase by reducing the crop height and directing energy to grain production. Massive use of chemical fertilizers, chemical inhibitors, insecticides, fungicides and pesticides was promoted together with the use of high yielding crop varieties and intensive irrigation. Agricultural uniformization caused a set of ecological consequences in CDR agricultural systems, such as the disruption of biological chains and the reduction of the mixed cropping systems developed by small farmers to

**Table 3.10.** Major environmental problems induced by modern agriculture

- Contamination of water and soil by pesticides, nitrates, crops and livestock wastes, causing harm to wildlife, disruption of ecosystems and human health problems;
- Contamination of food and fodder by residues of pesticides, nitrates and antibiotics;
- Damage to farm and natural resources by pesticides, causing harm to farm workers and the public, disruption of ecosystems and harm to wildlife;
- Contamination of the atmosphere by ammonia, nitrous oxide, methane and the products of burning, which play a role in ozone depletion, global warming and atmospheric pollution;
- Overuse of natural resources, causing depletion of groundwater, loss of wild foods and habitats, loss of their capacity to absorb wastes, water logging and increased salinity;
- Tendency in agriculture to standardize and specialize by focusing on modern varieties, causing the displacement of traditional varieties and breeds;
- New health hazards for workers in the agrochemical and food-processing industries.

**Source:** Pretty (1995)

biologically control pests and diseases. In replacement, new high-yielding crop varieties, chemically resistant to pests and diseases, were introduced, resulting in erosion of the crop genetic diversity.

Agricultural standardization by *ex-situ* innovation produced a technological displacement from parcel to laboratory and from local genetic crop diversity to international seed banks. Genetic resources were isolated from the agricultural production process. This technological conversion reduced small farmers' control over their production sources and production systems. The loss of information about complex crop-biophysical interactions was accentuated by divorcing the genetic resources from their original agro-ecological complex.

The reduction tendency in the world's grain production (Figure 3.8) during the 1980s (Dresrüsse, 1996; Gardner, 1996; Singer, 1996) was reflected in the remnant stocks carry-over, reaching an all-time minimum during the late 1990s, as consumption exceeded production (Brown et al., 1996). FAO estimates that the number of people without adequate diet increased from 540 to 580 million during the last 10 years, despite improved food production (Bailey, 1995). Some 750 million people are chronically under-nurtured (Brown et al., 1996; Pinstrup-Andersen and Pandya-Lorch, 1996; Singer, 1996).

Today, we live in a bipolar nutritional world. While a small percentage of the world's population is over-nurtured, especially people from industrial countries, a growing population of the Third World is under-nurtured (Singer, 1996; von Braun, 1996). The cereal demand for the next 20 years is estimated to be 56% greater than the current one (Alexandratos, 1995), because of global population growth to about 7 to 8 billion people, especially concentrating in Third World countries (Gardner, 1996; Werblow, 1996).

According to scenarios assuming different levels of economic-financial growth, the estimated deficit of global grain production for the coming 20 years will be around 300 million tons, representing 17% of the total grain production in 1990 and 10 to 12% of the grain production projected for 2020 (Werblow, 1996). This does not take into account some 400 million tons of grain expected to be supplied to the net grain-importer countries, suffering extreme poverty (Singer, 1996). Moreover, the increase of the population suffering extreme poverty will affect the future global food consumption capability. This will be specially acute in some urban and rural sectors of Third World countries, with some 1.3 billion people living with less than 1 dollar per day at the end of the 1990s (Alexandratos, 1995; Brown, 1999).

Predictions on future global food security are alarming, especially for Third World countries (Carruthers and Kydd, 1994; Brown, 1995; IFPRI, 1995; Dresrüsse, 1996). All scenarios recognize an acute degradation of food security in areas such as the sub-Sahel Africa and South Asia. The deficit between grain supply and demand will increase in many developing countries, which will shift from being grain-exporters, only a few years ago, to net grain-importers (Dresrüsse, 1996).

The knowledge of small farmers and indigenous peoples on the creation, maintenance and enrichment of bio-agrodiversity could play a relevant role for designing alternative production-consumption systems, protecting the *in-situ* crop genetic diversity and searching new food sources. This implies a profound review of the conventional scientific, ethic and moral understanding and perception of nature, and the maintenance of cultural richness and diversity. This postulate is based on the following statements:

(1) there is a strong geographic correlation between the centers of origin of domesticated plants and animals and the current areas considered as having high genetic diversity;
(2) this correlation is based on the permanence of historical rural populations, which manipulate their genetic resources as a complex adaptation of local livelihoods and ecologies;
(3) the genetic 'hot spots' are located all along the intertropical belt, including the humid tropics, warm drylands, and cold and dry highlands, which face today land-use changes, severe environmental degradation, and extreme poverty of their inhabitants;
(4) the genetic 'hot spots' are highly correlated with major areas of 'endemic' linguistic diversity, constituting *in-situ* agro-cultural depositaries and having the most important genetic resource pools;
(5) these areas have CDR agricultural systems, with complex eco-geographical micro-environments with high climatic variability, but with well-adapted multicropping systems and crop varieties;

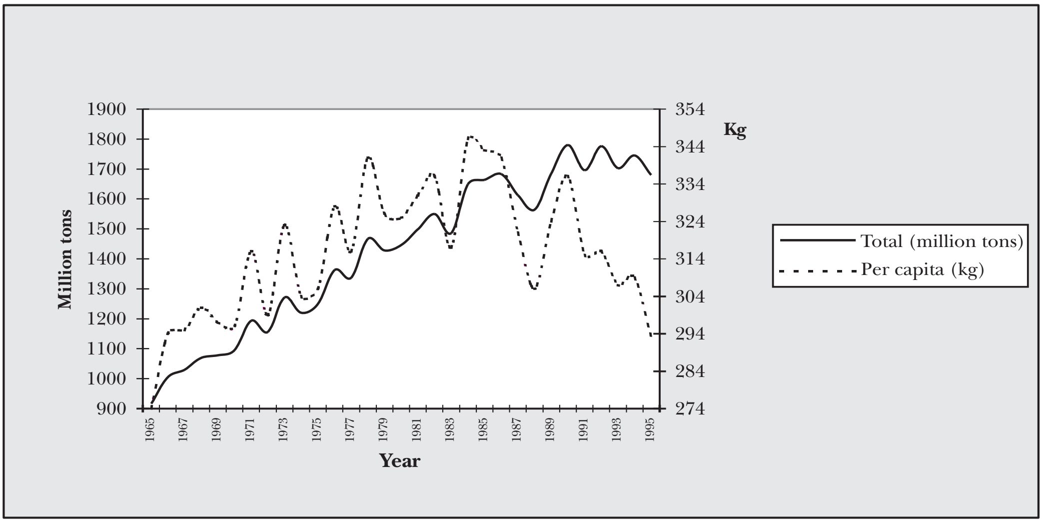



**Figure 3.8.** World grain production: 1950-1995

(6) in these areas, the natural resources management is based on the maintenance and expansion of genetic diversity as part of the local self-subsistence strategies. Local resources and services are used at low and renewable inputs to diminish environmental and economic risks.

### 3.6. CONCLUSION

This chapter provides a conceptual framework and empirical evidence of bio-cultural diversity. Bio-cultural diversity is seen here as the construct of the environmental knowledge and management systems historically displayed mainly by indigenous peoples and small-scale farmers, at global and local scales. To demonstrate the inextricable links between linguistic, biological and agricultural diversities, diversity is defined as a natural and social process, as a resource, and as the staple good for the production and reproduction of human experience. Bio-cultural diversity could be seen also as the ethnoecological experience developed through millennia by rural populations, which are still engaged in food production whilst maintaining extensive biologically preserved areas of the world.

The multifaceted and complex connections between linguistic, biological and agricultural dimensions are revealed when overlapping them at global scale. A close correlation between linguistically, biologically and agricultural megadiversities is shown at country level. This close correlation accounts for a small number of countries located in the tropical belt, possessing the majority of endemic languages and the majority of rural populations, structured as small farmers or peasantry. Also, these countries have an important percentage of the world's forests, and are repositories of the major number of biological species, ecosystems and biogeographical regions. Furthermore, most of these countries are located in the original centers of plant domestication and still maintain an important role in the creation, preservation and enhancement of crop and animal genetic diversity. Besides, most of these countries are located within the major food-producing areas at global level.

The recognition of related high linguistic-biological-agricultural endemisms within some of these countries constitutes another central issue discussed in this chapter. These bio-cultural 'hot spots' demonstrate that the historical nature-social relations among local peoples were not fortuitous, but show the intimate and long-standing engagement between human and non-human beings. The environmental knowledge systems evolved in these bio-cultural 'hot-spots' could be considered as 'endemic knowledge systems', if their specificity were properly recognized and valued in their own context. These intimate relations show sustainable co-evolutionary systems, in contrast to the trends of uniformization, standardization and simplification of languages, cultures, agricultural systems and nature conservation strategies, led by the globalized market forces. This current process leads to monocultures of the mind, production and conservation.

If creativity and knowledgeability are the driving forces of bio-cultural diversity, extinction plays the opposite role. Biological extinction never played a negative effect on nature's construction of diversity; on the contrary, biological diversity was enriched through geological times, even if taking into consideration massive extinction periods. Agro-diversity was originated, enriched and maintained during the last 10,000 years of crop and animal domestication. Furthermore, linguistic and cultural diversification played a major role in human communication and knowledgeability, expanding human plurality and knowledge as a resource and as a process.

Today, extinction is threatening the maintenance and enhancement of bio-cultural diversity. Although this major process involves the entire planet, the tropical countries having high bio-cultural diversity are facing acute environmental, socio-cultural and economic degradation. Threatening is even more acute in the high bio-culturally complex areas populated by indigenous peoples, small farmers and other cultural minorities. Paradoxically, food insecurity, soil fertility depletion, land degradation, deforestation and extreme poverty are among the major problems that these areas are facing.

One of the conventional assumptions guided to preserve linguistic, biologic and agro- diversities was built upon *ex-situ* conservation. This implied the storing and recording of languages and cultures, seeds and botanical and zoological specimens in museums, gene banks, botanical gardens and zoos. In contrast to the enormous efforts to acquire and store these complex information and knowledge systems outside their own contexts, there was no similar effort aimed at *in-situ* preservation, maintenance and enhancement of diverse bio-cultural experiences. Two main assumptions supported *ex-situ* conservation. On the one side, science and technology were assumed to be the only feasible alternatives to modernize the Third World countries, via top-down rural development. The sampling, extracting, recording and storing of biological specimens, crops and languages outside their own contexts were done to document natural objects and cultural remnants of the past; assuming that they would disappear at the cost of modernization. On the other side, tradition was perceived as opposite to modern. In most cases, local and regional experiences were considered primitive and their population as backward peoples who needed to be educated according to modern settings. In other cases, nature was conceived as an empty wild space despite being inhabited and managed through millennia. Biological conservation efforts were guided to preserve 'pristine landscapes' more as a scientific luxury than maintaining bio-cultural territories rich in human ecological experiences.

Led by these assumptions, many traditional agricultural systems were replaced by modern systems and many of them were not studied before substitution. Local environmental experiences disappeared during the last century and the loss of experience was accompanied with that of the biological species and crop genetic diversity. Nevertheless, many rural communities are still engaged in cultivating their land in a traditional way. Most of them are located within the bio-cultural 'hot spots', and their local populations are the only ones maintaining *in-situ* conservation as a survival strategy.

This chapter is based on several results of case studies carried out at local level in 16 biologically megadiverse countries, revealing evidence of complex systems of understanding and managing land resources and biodiversity among indigenous and small-farmer communities. Showing sound ways of biological and cultural conservation and management, these local examples should be taken into account when considering the implementation of rural planning and conservation programmes and policies to maintain bio-cultural diversity. To do so, local experiences should be analyzed in diachronic and synchronic terms to frame a comprehensive understanding of the diverse interpretations of nature, in addition to the conventional and scientific-oriented systems. Both should be contrasted, integrated and implemented with the participation of the local people. The analysis of case studies needs to go beyond the local scale or the single biogeographical landscape to reach the regional, national and global levels, avoiding to be poorly grasped, misinterpreted or over-generalized. Furthermore, the case studies carried out at local level must be analyzed as products of ever-changing biophysical and cultural processes, never isolated from the regional, national and global levels, and always evolving according to multiple and complex circumstances.

According to the findings presented in this chapter, one of the most important challenges in the near future is to revert, or at least to halt, the magnitude and pace of the bio-cultural extinction process. Without idealizing the 'noble savage' or the 'harmonious' local community, scientific efforts should develop integrated methodological approaches to better understand the local bio-cultural experiences and formulate strategies to maintain bio-cultural diversity at local, regional, national and global levels.

# Chapter four

## Indigenous environmental knowledge systems

### 4.1. Introduction

Chapter Three demonstrates the close spatial links between areas having linguistic, biological and agro-ecological diversities at global level. These links are not fortuitous but were historically constructed by different civilization trends, mainly by non-western societies of indigenous peoples and other rural populations living in three main agroecological zones: the warm and dry lowlands, the warm and humid lowlands, and the dry and cold highlands. The construction, maintenance and enhancement of diversity are central to the production and reproduction strategies of cultural minorities and small farmers, despite having been subordinated and controlled by colonial rules during the last 500 years. Today, many of the best preserved and highly biodiverse areas of the world correlate with the multicultural areas inhabited by indigenous peoples. These complex areas are also spatially correlated with some of the most important centers of origin of plant domestication, some of them corresponding to the current major food-producing areas at global level.

How and why was this possible? Chapter Four discusses the ways nature is conceived, represented, known and managed among indigenous peoples and small farmers as part of their cultural and economic rationality. It also analyzes the concept of 'Indigenous Environmental Knowledge Systems' (IEKS), as a complex cultural ensemble of beliefs (Kosmos), cognition systems (Corpus) and management practices (Praxis) of nature, paying attention to how, in these contexts, environment and culture are constituents of the same world view and world-life. The first objective of Chapter Four is to discuss how environment is a local cultural construct and culture is the result of the engagement of local people with nature in non-western societies. The second objective is to show how to study IEKS, taking into account the full repertory of local wisdom and practices, and why this enhances the discussion on the sustainability paradigm.

Four main questions are addressed here. How are nature and culture socially constructed in non-western societies? Why have some indigenous land-use systems succeeded and survived through thousands of years? How can complex ecological and cultural systems be analyzed at local level? Why could indigenous production systems contribute to enhance the discussion on the sustainability paradigm?

This chapter is divided into seven sections. Section 4.2 analyzes the ecological rationale of small farmers, emphasizing the management of diversity as central to their risk-avoidance strategy. Section 4.3 recognizes how nature is culturally constructed and how it is socially shaped among indigenous peoples. Section 4.4 explores IEKS as holistic worldviews composed by three different and inseparable dominions: (1) the belief system (Kosmos); (2) the knowledge system (Corpus); and, (2) the performance system (Praxis). Section 4.5 proposes the ethnoecological approach as an integrated scientific method to study IEKS, seeking to adapt local solutions to local needs in a more sustainable way. It also highlights why the ethnoecological paradigm challenges the conventional scientific paradigm, especially when referring to local natural and cultural resource management and to endogenous development. Finally, section 4.6 discusses the false opposition between IEKS and science according to conventional positivist views and proposes an alternative conceptualization of the relations between IEKS and science. This alternative recognition shows dimensions that have been left out or dismissed, and recognizes that both coexisted and exchanged their ways of knowing until today;

thus they are contemporary. It also recognizes multiple levels of existence and, accordingly, multiple modes of cognition that should coexist rahter than compete.

### 4.2. The ecological rationale of small farmers

It is now largely recognized that many indigenous peoples and traditional rural societies implement ecologically sound systems to manage, protect and restore natural resources, in contrast to most modern systems of rural production (Toledo, 1990). However, the limitations of these systems must be taken into account when considering the adoption of new styles of rural development (Reijntjes et al., 1992; Remmers, 1993). Not all the systems developed by indigenous societies were successful in the past due to economic, social and cultural factors (McNeely, 1994). Today, many indigenous villages and communities are facing severe changes in their livelihoods and land-use systems. Their environmental knowledge systems are losing strength due to political, cultural and economic pressures from inside as well as from outside. At least three conditions should be fulfilled to justify the maintenance of local ecologically sound systems (Östrom, 1990):

(1) the community continues depending substantially on the resources provided by the local environment;
(2) the community has full control over the local resource base; and
(3) the community retains a sufficiently high level of internal cohesion and cultural control.

The historical role played by humans in relation with the environment has been analyzed (Merchant, 1987; Toledo, 1990; Worster, 1988; Noorgard, 1994). These ecological approaches to human history recognize three to four different "modes of natural resource use" (Gadgil and Guha, 1992), "modes of transformation" (Turner et al., 1990) or "modes of appropriation of nature" (Toledo, 1994). The ways of appropriation of nature by humans are determined by three fundamental criteria: (1) the degree of transformation of the appropriated environment; (2) the energy sources used; and (3) the type of management used to manipulate the structure, components and dynamics of the environment (Toledo et al., 1994).

According to Toledo (1990, 1994, and 2001), one of the modes of appropriation of nature is the 'peasant or small-farmer production'. A set of characteristics defines the ecological, economic and cultural rationality of this model of production, but such characteristics may vary according to historical, cultural, economic and ecological factors that permeate, in many different ways, the contemporary rural communities.

(1) small-farmer production is mainly for subsistence. Most of the goods produced by the household are self-consumed. The use values (goods consumed by the production unit) dominate over the exchange values (goods produced as commodities). Production is based on household labor, with minimal external inputs;
(2) small-farmer production of use values and commodities is strategically oriented to fulfill the household consumption-reproduction, and this includes the reproduction of the entire community or village;
(3) most small farmers own relatively small landholds and/or produce in communal landholds, due to cultural and technological reasons and to scarcity of labor, capital and land;
(4) small farmers are engaged in diverse production activities during the year cycle, including agriculture, forestry, fishing, hunting, small-scale cattle ranching and gathering, as well as part-time (seasonal or intermittent) off-farm activities such as handicrafts or other activities inside or outside the village or the community;
(5) small-scale farmers make use of natural resources as the basic and irreplaceable means of production. Therefore, they are economic actors within an ecological and economic context;

(6) small farmers make use of their environmental knowledge systems (Corpus) to appropriate the local natural resources (Praxis). Their cognitive systems evolved locally and form part of a vast cultural system; and
(7) small-farmers perception and behavior are guided through their own systems of beliefs and values, or cosmology (Kosmos).

Small farmers adopt a strategy of maximizing a variety of products to satisfy the basic needs of the households and community throughout the year, considering four aspects: (1) multi-purpose production activities, (2) multi-purpose use and management of the local environment, (3) dual ecological-economic nature of the production, and, (4) application of the cognitive and belief systems for the appropriation of the local and individual natural resources (Chambers, 1990; Pretty et al., 1995). This ecological strategy allows small farmers to manage local natural resources in such a way as to maintain and enhance spatial heterogeneity and biological diversity in meso- and micro-land units, with different biophysical components. The main role played by the non-agricultural activities is not only to obtain additional goods and commodities, but also to buffer the households and the community from unpredictable economic and environmental uncertainties, such as market fluctuations and natural hazards (Mazzucato and Niemeijer, 2000a and 2000b).

The complex landscape pattern constructed during hundreds and even thousands of years contrasts with the uniformity produced by industrial agriculture, as shown in Chapter Three. The long-standing ecological rationality of the small farmers produces a variety of land-use units in a relatively small territory, including agricultural plots, homegardens, agroforestry, fallowland, fragments of primary and secondary forests, ponds, extensive and intensive cattle ranching areas, etc. Small farmers use variable strategies at different scales:

(1) at the level of the cultivar or vegetation association units (intra-agricultural or intra-forestry plots);
(2) at the level of the agricultural plots and fragments of forest types (inter-agricultural or inter-forest plots);
(3) at the level of the landscape or terroir (land-use patterns), and
(4) at the level of the local territory (land-use systems).

In synthesis, the main feature of the small-farmer model is to create and maintain complex geographic, ecological, biological and genetic diversity, because diversity itself is a risk-avoidance mechanism. This multiple purpose strategy constitutes an ecological rationality, that tends to conserve the natural resources, maintaining the environmental and biological diversity for the reproduction of the small-farmer household and the local community (Toledo, 1990, 1994, 2001; Chambers, 1990 and 1997; Altieri, 1990; Sevilla, 1995).

### 4.3 The cultural construct of nature

The ecological cultures of non-western societies are complex and vary in many different ways according to historical, economic and political contexts. Nevertheless, there are common principles built into environmental knowledge systems, that conform a significant part of the total cultural system of a given society or local community. These contextual knowledge systems have been analyzed by different specialists according to their own research perspectives and experiences (Conklin, 1954 and 1961; Fowler, 1977; Hunn, 1990 and 1999b; Toledo, 1992b; Croll and Parklin, 1992a; Ingold, 1996; Descola and Pálsson, 1996; Ellen and Fukui, 1996; Nazarea, 1999a; Posey, 1999a and 1999b). From this research, a new comprehensive ecological and anthropological research domain is emerging (Toledo, 1992a; Rhoades and Harlan, 1999). Political, social and economic interests underlie the debate and individual positions are influenced by moral and ethical values (Martínez-Alier, 1992; Warren, 1991; Tully, 1995; Warren et al., 1995: Peet and Watts, 1996; Posey and Dutfield, 1996; Escobar, 1996 and 1997; Shiva, 1997; Leff, 1998; Smith, 1999).

Traditional ecological knowledge (TEK) (Johnson, 1992; Berkes, 1993; Williams and Baines, 1993), indigenous knowledge systems (IKS) (Brokensha et al., 1980; Warren et al. 1995), local environmental knowledge (LEK), traditional ecological knowledge and management systems (TEKM) (Johannes, 1989, 1992), indigenous technical knowledge (ITK) (Warren, 1991), peasant ecological cognitive systems (PECS) (Toledo, 1990) and ethnoecology (Toledo, 1992a) are the most common terms used to characterize and compare local ecological cultures with modern sciences. An integrating concept is that of Indigenous Environmental Knowledge Systems (IEKS) defined as:

> *"The ecological dimension of the intellectual and practical activities that non-western societies execute during their appropriation of natural resources" (*modified from Toledo, 1992a*).*

IEKS are holistic constructs that allow practitioners to integrate facts, meanings and values in a comprehensive way. IEKS are accumulative (diachronic), dynamic (process-oriented) and open (innovative) systems, building upon the local experience of earlier generations and adapting to technological and socio-economic changes (Johnson, 1992). IEKS roots are grounded in a monistic view of the surrounding world (Descola, 1996; Hornborg, 1996; Descola and Pálsson, 1996). According to these views, humans are seen as part of nature and act as one more agent in it. Man and nature are ontologically part of the same world; both are mutually entangled agents (Croll and Parkin, 1992a).

A precarious equilibrium between the material and symbolic worlds precludes a good performance of man with nature (and nature with man), seeking for renewable cycles of non-human beings and the humans themselves (Eliade, 1972). The renewability of natural and mythical cycles –the visible and the invisible- stands at the center of these monistic views of the world (Croll and Parkin, 1992a). Nature is considered as essentially sacred and the natural elements are considered as non-human beings that have a life force. All life forms have kinship and are interdependent (Boege, 1996). In these world views, humans are not given the inherent right to control and exploit nature for their own and exclusive interests at the expenses of nature and non-human beings (Johnson, 1992).

IEKS are contextual, contingent, environmental and social systems. Context means all human and non-human beings that surround an individual in a specific situation, allowing her or him to interact (1) according to previous experience and goals, (2) according to her or his present scenario, and (3) according to her or his future plan. The context is also conceived as a set of meanings, that a given individual perceives according to her or his previous experience and allows to perform (Remmers, 1998). IEKS are contingent in the sense that there are no fixed programmes of performance, and contexts vary according to unpredictable and uncertain phenomena. IEKS are also environmentally and socially embedded in such a way that an individual's performance is directly related with her or his local biophysical management units (diverse agricultural plots, agroforestry systems, and fragments of forest), and within a given social system, local institutions, rules and cultural values, that sanction people's engagement with nature and with their social group.

The learning processes, acquisition of knowledge and communication mechanisms form part of a complex cultural and social educational setting. IEKS and their transmission shape society, culture and nature; at the same time, culture, society and nature shape IEKS (Ruddle, 1993). Although the learning process is mainly individual and informal, the acquisition of knowledge is displayed by reciprocity and obligation. The basic learning institution is the household unit. The knowledge acquired by the members of the family is recorded and transmitted mainly through oral tradition and rituals. It is obtained from observation, trial and error experimentation, and innovation.

The information acquired by the members of the household unit are basically of qualitative nature, although complex interactive natural processes, dynamics and trends are in some cases recognized in a very detailed way. That is the case of forest regeneration processes (Gómez-Pompa, 1987; Anderson and Posey, 1989; Moran, 1996), agroecological processes (Conklin, 1954; Bellón, 1990; Brush, 1992b), entomology (Posey, 1983; Fairhead and Leach, 1999), fish population trends (Akimichi, 1996), and mammal population trends (Nakasima and Roué, 1995; Ellen, 1996; Fukui, 1996).

IEKS are mainly intuitive and emphasize emotional involvement and subjective certainty of understanding. Specialization of the learning process is based on age and gender, and tasks are thought in a sequence ranging from simple to complex. Tasks are taught mainly at specific sites during fixed periods of the year, according to natural cycles and production processes. In the process of transmitting knowledge to a new generation, the transmitter's sense of reality is strengthened. The social and cultural world, which is based on tradition, becomes enlarged during the transmission, giving meaning to the context (Ruddle, 1993).

Knowledgeability is highly respected. A knowledgeable person has a prestigious status among community members. Knowledgeable members constitute one of the most important local institutions. They represent the local experience and link between the past and future. IEKS are established by reciprocity and obligations to ground collective consciousness of a logical framework for linked resource systems and their accompanying institutions. In addition, knowledge is power, but local normative institutions prevent individuals to take advantage of their intellectual and practical resources through the implementation of a set of rules and sanctions.

IEKS are not uniformly spread. Individuals vary in their aptitude for learning, storing and generating knowledge. According to age and experience, each individual possesses part of the total local knowledge, but there is a common cultural background that allows agreement and shared meaning. Individual knowledgeability is socially confronted, negotiated, accepted and codified to establish a set of common cognitive references, that constitute the local epistemologies or social theories of knowledge.

### 4.4. Kosmos, corpus and praxis

According to Toledo (2000, 2001, 2002), IEKS are organized in an holistic perspective. The way to understand their complexity and operation should center on the analysis of the concrete processes carried out by household members of a given community to satisfy their ecological and economic needs. It is possible to explore the connections between three different cultural domains as a set of intellectual and practical systems, when analyzing the concrete processes of production-consumption-reproduction. That is the belief domain (Kosmos), the cognitive domain (Corpus), and the practical performances carried out during the nature-human engagement (Praxis). The complex and diverse interactions between the elements of these domains are organized as structures giving cohesion and meaning to the decisions and practices an individual should carry out during the production process.

#### 4.4.1. The belief system

Belief systems (Kosmos) play a central role in the production and reproduction of means and meanings. Belief systems operate as complex perceptual and symbolic representations of the context through the interconnection between memory and concrete realities, giving sense to practical activities and expected goals at individual and social levels. In a synthetic view, belief systems produce mindscapes and landscapes; they connect the invisible with the visible contexts. These eco-cosmologies do not constitute isolated theoretical schemes of the natural world, but are structured abstractions that give meaning to language and practice. These codified systems allow people to 'stay in place', interconnecting intellectual 'tools' with peoples' everyday life tasks and embodying their past with their ever constructing projects. In this perspective, they become the principles for the construction of realities.

As Descola (1992) points out, if "... such principles of order are rooted in overarching schemes through which each culture organizes its practices in patterns…, (*then the*) schemes of praxis are not intuitively given, they can only be deduced from the results of their operation". In this sense, the act of interpreting nature should not be visualized as an isolated mental construction, but as an interpreting action directed to reach a concrete engagement with nature (Boege, 1996). Lévi-Strauss (1962) denominated this as 'the science of the concrete world'.

Each particular indigenous worldview is mainly organized by myths, which are cyclically renewed by ritual activities (Lévi-Strauss, 1962; Reichel-Dolmatoff, 1971; Descola, 1992 and 1996; Reichel, 1989; Jara, 1990; Bloch, 1992; Denos, 1992; van der Hammen, 1992; van den Breemer, 1992; van Beek and Banga, 1992; Schlee, 1992;

Boege, 1996; Dove, 1996; Hviding, 1996). Nature is perceived as a sacred space with an invisible force that humans cannot control. Nature is viewed as a life force of which human and non-human beings are unequal parts. To establish a 'sacred balance', humans need to engage carefully with this unequal and complex world. To negotiate the 'damage' done to nature from where goods (non-human beings) are 'borrowed', all activities on the landscape imply a symbolic exchange. Ritual activities are performed as symbolic exchanges between the living and the sacred spaces to re-establish the reciprocal balance among the unequal parts. The origin of the sacred space is represented by the mythical time as the primordial one, when a new order governing human and non-human beings was established by mutual engagement.

The myth's structure allows recognizing the codes giving meaning to this engagement. The ritual functions allow evoking the world's origin, reinforcing the efficiency of the engagement, re-organizing the imbalances created by the damage, and guarantee human's survival. Rituals are performed as a search for the restoration of disruptions and imbalances created by man to nature; otherwise, man could be punished by the invisible and uncontrollable force of nature. Adversity, damage and imbalance are confronted to reconcile the concrete relations among unequal parts and to guarantee sustainability by mobilizing the symbolic system. Therefore, producing is not only an economic, social and ecological process, but also a spiritual (or symbolic) one (Boege, 1988; Posey, 1999b).

### 4.4.2. The knowledge system

In general terms, cognitive systems (Corpus) are the substratum of natural discontinuities and modes of relations, that combine elementary biophysical units such as life-forms (including land, minerals, water, and meteorological and astronomical phenomena), classes of life-forms, categories of tools and operations, physiological processes, forms of exchange, and systems of energy flow (Descola, 1992). Cognitive systems are constituted by the interactions between mind and matter. They organize a variety of forms, functions, uses and meanings.

The reading of the landscape is a cultural practice motivated not only by social entailments and by political or economic agendas, but also by the experience gained from a meaningful engagement with the past of one's place. The codification of this experience is perceptual and practical. Perception of the environment is individual and given through the visual sense as much as through smell, test, touch and hearing, but incorporated in the cultural matrix of the perceiver. Perception and codification are derived from practice, trial and error experimentation, and innovation. Both are constantly evolving and enriching through experience.

Indigenous cognitive systems have received much attention from ethnobiologists and ethnolinguists (Hunn, 1977 and 1990; Ellen, 1982, 1993b and 1996; Ellen and Harris, 1999; Berlin, 1992). During the last 40 years, a large number of cognitive studies demonstrated the diversity and complexity of the ways indigenous peoples recognize and classify natural entities, processes and phenomena. These studies focused mainly on the plant and animal classification systems (Berlin, 1992). From their point of view, 'folk' cognitive systems conform the intellectual devices applied by non-literate peoples to describe nature, mainly for utilitarian purposes (Hunn, 1977).

Important attempts were made to demonstrate the existence of universal principles that guide all classification systems, including those constructed by local non-western societies. Berlin (1992) considers that ethnotaxonomies are based on human perceptual and largely unconscious appreciation of the natural affinities among groupings of plants and animals in their environment. Comparative analysis and a generalization approach permit to clarify the regularities concerning the categorization and nomenclature of plants and animals, where patterns emerge from the regularity of diversity. In this perspective, "people must be able to recognize, categorize and identify examples of one species, group similar species together, differentiate them from others, and be capable of communicating this knowledge to others" (Berlin, 1992). In all cases, classification was the basic research objective. The intra- and trans-cultural effort has been and still is a promising research trend (Descola, 1992).

Nevertheless, the ways some 'folk' classification systems were elaborated are currently debated from opposite positions among ecological anthropologists. One the one hand, the constructivist and relativist position argues that it is not possible to make trans-cultural comparisons because cultural and environmental experiences are constructed at specific locations and according to unrepeatable local performances (Ingold, 1992; Ellen, 1996; Ellen and Fukui, 1996; Hornborg, 1996). On the other hand, the universalists intend to demonstrate the validity of the trans-cultural classification principles.

One of the most debatable issues concerns the techniques applied by the outside observer (the ethnobiologist) and the conclusions made from the information gathered from selected local informants. 'Folk' taxonomies seem to be artifacts created by the outside observer when organizing the objects under scrutiny according to western science rationality, rather than the expression of the perception and recognition by local people. For the universalists, 'folk' taxonomies are presented as closed, fixed and hierarchical trees; for the relativists, they are polysemic, polythetic and polyvalent constructions. Another debatable issue concerns the exclusion of the symbolic valorization of non-human beings by the universalists, giving more emphasis to the linguistic and biological domains than to the cultural meanings. They deny that different ideas about nature are associated with different contexts or linked to different philosophical traditions (Grillo, 1991; Bloch, 1992; Descola, 1992; van der Breemer, 1992; van Beek and Banga, 1992; Bruun, 1995; Kalland 1995).

The contrasting positions of relativists and universalists call for a comprehensive effort of integration. Even if there is no predictable correspondence between specific ecosystems and specific schemes of praxis, an epistemologically coherent anthropology can develop from the cognitive devices shared by all to elaborate a grammar of the variety of ways in which nature is socialized. This hypothesis gains strength from the observation that a relatively homogeneous class of societies deals with nature according to entirely different patterns in globally similar ecosystems or, conversely, imposes globally similar modalities on entirely different ecosystems, which at the end would suggest that ecological differences were irrelevant (Descola, 1992).

Toledo (1992a) also argues that "by exploring only knowledge (Corpus), ethnobiology is becoming a closed discipline, where research has turned to itself without any connection with the practical problems of the farmers (Praxis), or with the set of natural resources that the producer knows, uses and manages". He points out that if ethnoecology is going to evaluate, from an ecological perspective, the efficiency of rural productive systems, then comparative analysis will be more and more required from this new discipline. From different perspectives, relativists and universalists consider the need to integrate the contextual and the universal approaches, to understand the multi-layered links between Kosmos, Corpus and Praxis.

When analyzing indigenous cognitive systems, we should consider that knowledge systems organize the order of the world, taking into account the sacred as well as the living world. Therefore, indigenous cognitive systems integrate both fundamental aspects to give meaning to life and preserve a 'place in life'. They 'objectify' nature according to utilitarian needs and symbolic representations. They are highly contextual and ruled to cope with spiritual uncertainties and concrete contingencies. From the former, we should expect a dynamic and open but coherent knowledge substratum in order to cope with everyday realities at site-specific locations. The nature of indigenous cognitive systems implies the acceptance of a polysemic, polyvalent and polythetic order of nature and context, instead of fixed, hierarchical and closed mental organizations of natural beings and the environment.

### 4.4.3. The performance system

The concrete forms of nature's appropriation throughout the production process constitute the individual and social performance of certain ecological rationality. These forms are organized by diverse activities shaping the particular engagements of nature and humans as mutual constituents of the same world. Concrete activities form a sort of synthesis of the particular relations between nature, culture and production. To perform these activities, technical devices are used according to each individual's expertise and according to time availability. Activities are multiple and variable to cope with scarcity and contingency.

Each performance requires the implementation of a cognitive device, according to symbolic representations and spiritual values. A performance is never isolated from the other two constituent domains of the cultural local systems, that is the Kosmos and the Corpus. All are intimately entangled, giving coherence to the ecological and economic rationale of the household units and community plans and projects. Thus, culture should not be separated from practice when studying the ecological and economic rationale of a given indigenous context. The latter is often advocated by external technicians when implementing sustainable indigenous technical knowledge in other ecological and cultural contexts for utilitarian purposes (Agrawal, 1995). The implications of integrating Kosmos, Corpus and Praxis as major domains of IEKS are (Figure 4.1):

(1) the acceptance of IEKS as complex and multi-layered cultural devices that integrate facts, meanings and values;
(2) the recognition of IEKS as ecological cultures that give sense to environmental and economic rationale as the basis of small-farmer subsistence strategies;
(3) the recognition that the elements within the three cultural domains (Kosmos, Corpus and Praxis) are linked to each particular conception of the sacred and living worlds in a highly contextual, spatial and temporal engagement, both at individual and social levels. The linkages cannot be disentangled, as they constitute parts of a dynamic and open whole, and
(4) the recognition that the ecological context is highly diverse and socially constructed, but also highly risk-prone and uncertain. Diversity is maintained and enhanced as a risk-avoidance strategy, not as a fixed program but as an open plan organized to buffer sacred and concrete disturbances.

### 4.5. The ethnoecological approach

Toledo (1990,1992a,1994, 1995a and b) elaborated a comprehensive methodological approach aiming at the analysis of IEKS. Toledo argues that ethnoecology could be the new scientific discipline required for evaluating and validating, from an ecological perspective, the efficiency of all rural productive systems, including the IEKS. The aim of ethnoecology, as a new and hybrid discipline, should be "the ecological evaluation of the intellectual and practical activities that a certain human group executes during its appropriation of natural resources" (Toledo, 1992a: 10).

The emergence of ethnoecology as a discipline originated some 50 years ago from work done by different specialists, mainly from ecological anthropology (Conklin, 1954; Frake, 1962; Lévi-Strauss, 1962; Harris, 1968; Vayda and Rappaport, 1968), ethnobiology (Berlin, 1973; Berlin et al., 1973; Hunn, 1982; Posey, 1983; Alcorn, 1984; Gragson and Blount, 1999), agro-ecology (Brosius et al., 1986; Altieri et al., 1987; Brush, 1991), and cultural and environmental geography (Sauer, 1952; Johnson, 1977; Donkin, 1979; Denevan, 1980c; Klee, 1980; Wilken, 1987; Zimmerer, 1998).

Ethnoecology, as part of ecological anthropology, is based on an interdisciplinary integration approach. Its theoretical and practical framework is influenced by the natural and social sciences. Its holistic approach is fulfilled from two different epistemologies, the local and the scientific knowledge theories and practices. Ethnoecology can be seen as a dialogical discipline founded on the 'long conversation' that constitutes the ethnographic fieldwork, as considered by Malinowsky (1965). The research process can be divided in two main tasks (Toledo, 1994): (1) the dialogue between the local actor and the researcher, guided to explore local world-lives (Corpus and Praxis) and worldviews (Kosmos), and (2) the scientific ecological assessment and land-use evaluation, and their comparison with the local epistemologies and practices (IEKS). This research process allows the comparison of two models of the same local context: the outsider's model and the farmer's model.

Modified from Toledo's initial proposal, it is argued that ethnoecologists should carry out a set of methodological steps to assess, validate and integrate the data obtained from the two main tasks discussed above:

(1) the exploration of the local codification and performances with the world-life;
(2) the exploration of the local representations and engagements with the worldview;
(3) the interpretation of the local epistemologies and practices;

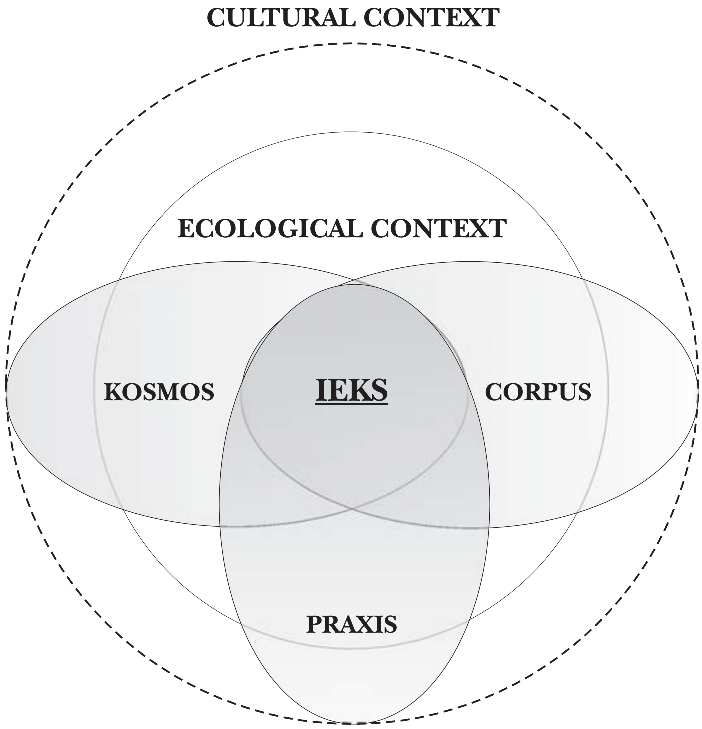



**Figure 4.1.** Indigenous environmental systems and their three domains

(4) the researcher's environmental impact assessment and land-use evaluation;
(5) the comparison and validation of both models, and
(6) the integration of both models in a participatory approach.

These methodological steps should be applied to the analysis of the production process within the various activities carried out by representative household units and actors of different age, gender, specialization and social status. The holistic integration of Corpus, Praxis and Kosmos throughout the production process covers the three domains of nature, production and culture. Additionally, the local context must be analyzed according to: (1) a short-term scale to cover the whole production-consumption-reproduction household strategy over a year cycle, and (2) a long-term scale to assess land-use and vegetation cover changes over a selected number of years.

One of the main tasks of ethnoecological studies is to explore, interpret and assess the implementation of local belief representations and cognitive systems during the production process in different land management units. From an ecological perspective, the rural production process should be understood as a set of skills, strategies and practices for the appropriation of the local environment and its natural resources. Therefore, a detailed analysis of the local cognition and beliefs about (1) spatial heterogeneity and temporal variability of biophysical factors and phenomena, (2) natural dynamics and processes, and (3) biophysical interrelations, should be carried out to interpret local environmental epistemologies and practices (IEKS). The local producers regularly assess these criteria when concrete and practical problems need to be resolved during the production process.

Four factors should be analyzed to comprehend the multi-layered and complex relations between spatial heterogeneity, time variability, and biological and genetic diversity, considered as the most important environmental factors of the multi-purpose use of a natural resource strategy (Figure 4.2 and table 4.1).

These factors are climatic, eco-geographic, agro-ecological and biophysical:

(1) **Climate factor.** Here are considered the main climatic factors and meteorological phenomena that regulate local production activities throughout the year. Climatic zoning, climatic seasonality, meteorological events and moon cycles organize labor in space and time. This factor also controls the religious activities at local and regional levels. Production, consumption, and economic and symbolic exchanges are strongly regulated by water availability and the temperature regime in space and time, which are locally assessed to determine productive and non-productive activities within household units.
(2) **Eco-geographic factor.** This refers to the geographic distribution of the biophysical landscape, including bioclimatic patterns, soil-relief patterns and forest types. The landscapes are shaped through multi-purpose production practices throughout the year according to their own characteristics. They form the local agricultural and forestry systems. Soil erosion and sedimentation processes, as well as forest succession, are assessed to predict yields, to fallow the land, or to obtain timber and non-timber forest products. Different religious activities take place according to each production practice throughout the year, but mostly at the beginning or at the end of each production process.
(3) **Agro-ecological factor.** This covers the agro-habitats and forestry units managed by household members at parcel level, according to specific biophysical settings. This is the level of biological and genetic diversity manipulation and enhancement. Ecological cycles and soil nutrient cycles are assessed for the implementation of soil and forest conservation practices. Agricultural rituals take place at the household parcels.
(4) **Biophysical factor.** This is the scale of the cultivars inside the parcel, or the specific biological species in the homegarden or at the forest plot, according to micro-biophysical variations. At this level, the farmer experiments and innovates. The distribution of different crop varieties also corresponds to symbolic meaning and beliefs. Sacred species and specific varieties are grown or tolerated to provide ritual food, or fulfill medicinal and magical purposes.

To validate and integrate an improved sustainable land management model, the ethnoecological research must analyze the combined implementation of different intellectual and practical tools in all dimensions described above, that constitute the small-farmer's complex ecological rationality. As Toledo argues (1992a: 17) "…if sustainability refers to the ability of a rural culture to maintain primary production through time, then (*ethnoecological findings*) should emphasize a shift from the primary goal of maximizing rural production and profit for the short term to a new perspective that also considers the ability to maintain production in the long run" (see also, Redclift, 1987 and 1992; Egger and Majeres, 1992; Farshad and Zinck, 1993; Murdock and Clark, 1994). Finally, Toledo considers that the development of ethnoecology as a robust discipline could challenge conventional scientific paradigms in three main ways:

(1) by comparing ecological knowledge systems different from those derived by scientific inquiry and imposed to rural cultures;
(2) by disclosing an apparent ecological advantage of traditional producers over modern producers, and
(3) by making an unorthodox confluence between facts and values during the process of research.

The former would lead to the breakdown of several conventional assumptions. Two of them refer to the false belief that traditional rural cultures are inferior to scientific researchers and technicians, and that science is the only valid knowledge system for solving human-induced environmental problems (Apffel-Marglin and Marglin, 1990; Marglin, 1990). The first is based on the false opposition between tradition and modernity (Banuri, 1993) and between universalism and particularism (Wallerstein, 1996), and the second on the mythification and ideologization of science (Feyerbend, 1987; Latour, 1993).

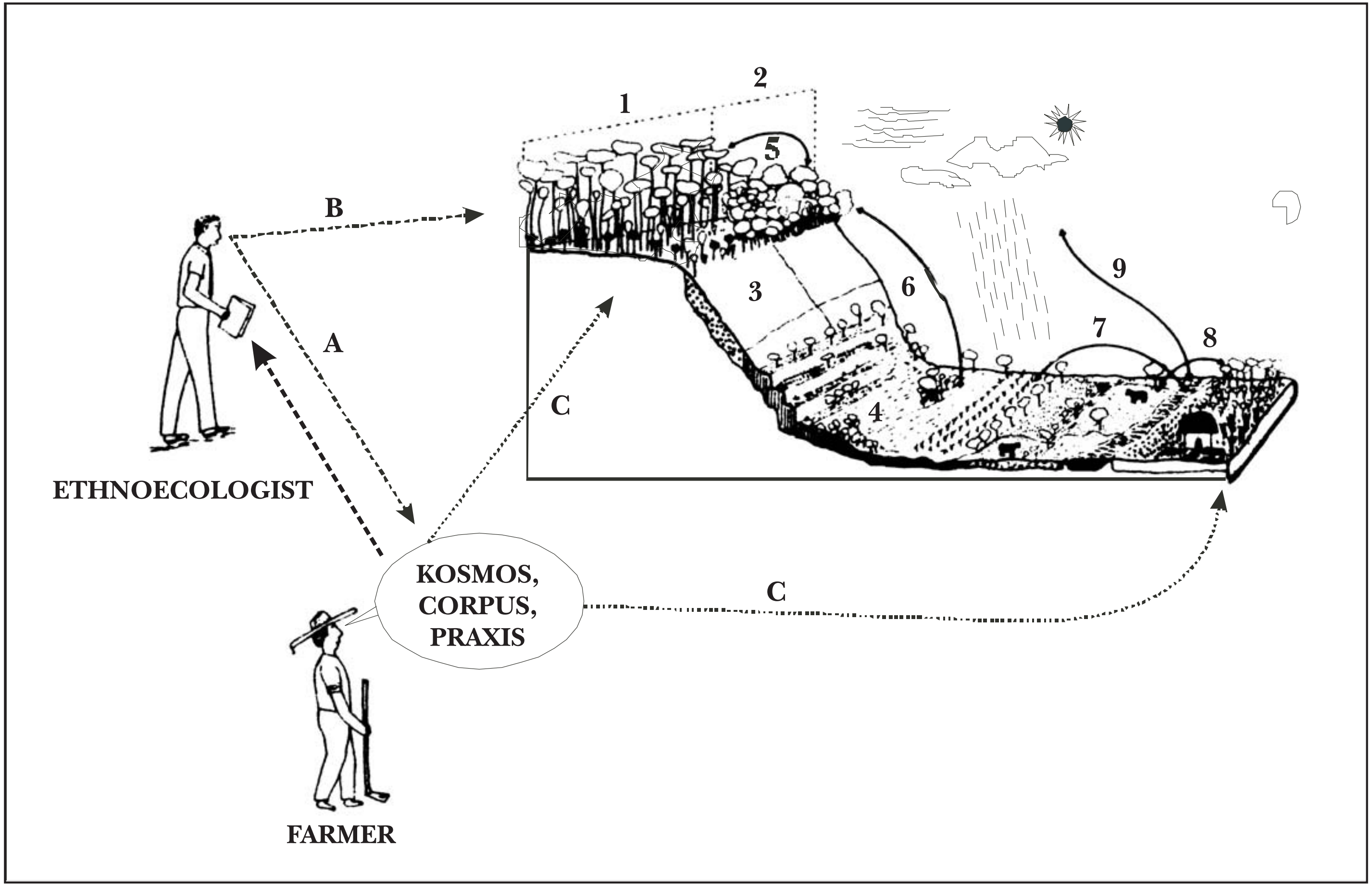



**Figure 4.2.** The ethnoecological approach analyzes two models of the same local context, the outsider's model and the farmer's model by means of (A) the dialogue between the local actor and the researcher, guided to explore local world-lives (Corpus and Praxis) and world-views (Kosmos), and (B) the scientific ecological assessment and land-use evaluation, and their comparison with the local epistemologies and practices (IEKS). The (C) farmer's model consists on the recognition of (1 and 2) vegetation structure and patterns; (3 and 4) soil classes and soil – relief relationships; (5) plant and animal species and relations, and micro-environments; (6) microclimates; (7) soil – water relationships; (8) cropping systems, and (9) life cycles, climatic and meteorological phenomena. **Source:** Toledo (1994)

Ethnoecological studies of alternative and marginal knowledge systems could breakdown the epistemological domination that contemporary science has imposed (Chambers, 1997; Posey, 1999c). If the ethnoecological paradigm is capable to fully demonstrate that there are multiple ways to sustainable engagements between humans and nature, which are not necessarily based on contemporary scientific rationalism and pragmatism, a new comprehensive and horizontal integration of wisdom and knowledge could lead to strengthening the sustainability paradigm (Croll and Parkin, 1992a; Hunn, 1999b). There is an increasing acceptance that traditional production systems perform ecologically sounder than most modern, market-oriented production systems. Increasingly, researchers and extensionists shift from vertical and unidirectional positions to an horizontal engagement with local communities and re-orient the approach to rural development from top-down exogenous to bottom-up endogenous. Communities bear valuable ecological wisdom and are capable to perform their own planning.

This emerging scientific paradigm is challenging the supposed neutrality of the outside observer to guarantee the objectivity of science (Richards, 1985; Pretty, 1995; Chambers, 1997; Posey, 1999b). By re-integrating facts and values, the ethnoecological approach is guided by ethical and moral concerns regarding the sustainable management of natural resources, the self-empowerment of localities, and the increasing production of diversities.

**Table 4.1.** Main criteria and dimensions to be assessed in an ethnoecological survey

| CRITERIA | CLIMATIC | ECO-GEOGRAPHIC | AGRO-ECOLOGICAL | BIO-PHYSICAL |
|---|---|---|---|---|
| **STRUCTURAL** | Climatic zoning<br>Landscape<br><br>Forest cover | Bioclimatic patterns<br>Relief patterns<br>Soil patterns<br>Forest types | Mesoclimatic zoning<br>Relief type<br>Soil associations<br>Forest associations | Microclimatic zoning<br>Landforms<br>Soil types<br>Biological species |
| **DYNAMIC** | Climatic seasonality<br>Moon cycle<br>Meteorological cycle | Erosion/accumulation<br>Forest succession | Soil nutrient cycle<br>Ecological cycles | Crop phenology<br>Biological cycles |
| **RELATIONAL** | Several | Several | Several | Several |
| **UTILITARIAN** | Land use and vegetation cover pattern | Agricultural and forestry systems | Agrohabitats | Agricultural plots<br>Homegardens<br>Forest plots |
| **SYMBOLIC** | Religious calendar | Several | Several | Several |

**Modified from:** Toledo (1992)

## 4.6. THE DIVIDE BETWEEN IEKS AND SCIENCE

### 4.6.1. Two contrasting research approaches

Some questions arise when seeking to understand the differences, similarities and relations between IEKS and western science, after reviewing the main characteristics of IEKS. Is it feasible and worthy to compare IEKS with western science? How should this comparison be carried out? What are the distinct and common features? Are they independent, exclusive and replaceable cognitive systems? Is it possible to recognize complementarities or synergies between them, when considering new approaches to local environmental management systems?

A review of the conventional procedures used for comparing IEKS and western science is done, discussing their limitations and problems when contrasting them as independent knowledge systems according to positivist scientific view. The deconstruction of conventional assumptions to separate both knowledge systems requires a critical theorization of knowledge, power, nature and culture. An alternative conceptualization of the relations between IEKS and western science is given when reviewing their differences and similarities in a synergistic approach. This alternative approach reveals their limitations, specific relationships and complementarities, and proposes an attempt towards integrating different knowledge systems, when seeking sustainable development of peoples and their environment.

Two main research approaches emerged from the offspring of a vast number of studies about indigenous and/or traditional environmental knowledge systems, carried out during the last 20 years. Although, these research approaches apparently differ in their perception of the ways indigenous and/or traditional societies and their IEKS have played or should play a major role when seeking local sustainability of natural resource management, both pursue similar views when applying a dualistic, ethnocentric and reductionist scientific approach. Both assume a divide between nature and culture and assume that humans are master of nature, either for dominating it or protecting it (Pálsson, 1996; Berkes, 1999).

On the one hand, there has being a tendency to reify IEKS as a viable alternative for sustainable development with environmental conservation assuming, in an idealistic way, that indigenous and traditional peoples evolved harmonic or balanced relations with nature. This assumption is based on the long permanence of such peoples in isolated areas with low population densities and on their monistic cultures, which prevented or immunized them against environmental degradation and natural resource depletion in their territories. The above assumption is complemented by the idea that some historical culture/nature harmonies were disrupted or distorted only by modern development based on of western scientific advances. So, to prevent such external imbalances people should be maintained as 'primitive' as possible to avoid that they become a threat to the very ecosystem where they live (Berkes, 1999).

The reification and mythification of indigenous and traditional peoples as 'ecologically noble savages', 'conservationists' or 'noble savages/fallen angels', idealize and or distort their current realities when not fully addressing their histories, livelihoods and adaptive capabilities as subordinated social subjects, and when contrasting tradition and modernity as static and sharply separable realities. Tradition or traditional refers, within this approach, to the $19^{th}$ century western perception of simple, savage and static, denoting a divergence from the western norms of reason and progress, while traditional should mean time-tested and wise (Berkes, 1999; Tucker, 1999). Instead of the eurocentric views of tradition or traditional, alternative meanings relate them as to: (a) a practical common sense; (b) the teaching and experience passed through generations; (c) knowing the country; (d) being rooted in spiritual health; (e) a way of life; (f) an authority system of rules for resource use; (g) respect; (h) obligation to share; (i) wisdom in using knowledge; and (j) using heart and head together (Emery, 1997, 1999). In general terms, this research approach proposes a 'way back to the past', without taking into account the IEKS' limitations and the challenges their producers are facing under current globalized circumstances (Pálsson, 1996).

On the other hand, a more dominant research-development approach (R&D), historically based on a scientist framework and conventionally named as bottom-up approach, gained academic, economic and political momentum during the second half of the $20^{th}$ century (Pretty, 1995; Chambers, 1997). In relation to the IEKS, this approach recognizes the importance of appropriating some useful segments of these knowledge systems by means of a previous and rigorous technical scrutiny, advocating that this procedure should benefit humankind at large (Warren, 1991). This research approach has been influenced by the commoditization of knowledge and labor imposed by current globalization (Tucker, 1999). The universalization of extracted segments of 'technical local knowledge' is perceived by their supporters as partial antidotes or corrective measures to some of the environmental costs produced by modernization via development, or top-down approach, especially in countries of the Third World (Escobar, 1996). The trend is towards the prospection of 'useful' knowledge, without taking into consideration the communities that produced and maintained IEKS. Medicine, agriculture and biodiversity conservation have been privileged fields within this context (Mooney, 1997).

Dividing nature from culture, separating knowledge from practice or mind from matter (Bateson, 1972 and 1979), and colonizing the reality studied by the external scientist in terms of a universalist discourse, constitute some of the underlying assumptions of this research procedure. Moreover, a dualistic, mechanistic, reductionist and ethnocentric scientific endeavor is carried out when asserting the superiority of western science in relation to that of the indigenous and traditional peoples. Again, humans are considered to master nature, but now implying a radical distinction between laypersons and experts, as scientists present themselves as the analysts of the material world, unaffected by any ethical considerations (Pálsson, 1996; Pierotti and Wildcat, 2000). Feyerabend (1987) asserts that the intolerance of many scientists towards knowledge and insights, that originate outside institutionalized western science, dismisses cognitive systems that do not fit their own, including understandings of other scientists using different paradigms. This scientific perception of the 'other' shows its own research limitations to the understanding of other cognitive systems, denying that modern scientific methodology is merely one way, and not the only way to acquire knowledge (Nakashima, 1998).

Both research approaches discussed above are compelled to make comparisons between IEKS and western science to orchestrate and legitimize their objectives, policies and results (Agrawal, 1999). The first one needs to contrast both cognitive systems to reveal what was or could be lost from 'the past' mainly biodiversity, while the second one needs to compare them to operate the appropriation of the technically useful leftover from 'the past'. The comparison intending to separate IEKS from the western science is not independent from political agendas driven by particular relationships between development, science and power (Agrawal, 1995, 1999; Gupta, 1998). Even though some of the constituent elements of IEKS and western science are distinct, due to the diverse rationales historically displayed by their producers, what prevails in this contrastive effort is the opposition particularism/universalism, tradition/modernity, nature/culture, mind/matter, rational/irrational and knowledge/practice, as separated dominions, according to the positivist and dualistic scientific view (Latour, 1993; Croll and Parkin, 1992a; Descola and Pálsson, 1996; Tucker, 1999). This contrastive effort also distorts the domination/subordination power relations and realities between IEKS and western science, and among their producers (Apffel-Marglin and Marglin, 1990 and 1996; Marglin, 1990; Latour, 1992; Banuri and Apffel-Marglin, 1993; Escobar, 1996; Peet and Watts, 1996). Table 4.2 shows the main contrastive elements between IEKS and western science, according to the research approaches discussed above.

The opposition between IEKS and western science is supported by a set of criteria based on: (a) the supposed superiority of western science over the other cognitive systems; (b) the segmented and unilineal evaluation of IEKS using exclusively techno-scientific criteria; (c) the display of power relations and discourses to widen the instrumentalization of scientific and technical advances via development, especially in the Third World; and (d) the incomprehension, via negation or misinterpretation, of non-western social systems and their cognitive systems.

The conventional divide between IEKS and western science intends to show the pre-scientific nature of IEKS, which are supposedly constructed by individuals rather than institutions by means of tacit experience and a intuitive, emotional and imaginative understanding about nature, rather than a cerebral, analytical and intellectual analysis about nature. IEKS are also categorized as highly subjective systems, intimately linked to cosmological worldviews based on the existence of a supra-natural world; they are thus considered as interpreting data in a qualitative way. That is why IEKS are not *capable* to distinguish the differences between nature and culture, or between matter and mind, or between material and non-material facts and phenomena. The non-separation of mind and matter allows the performance of myth, ritual and magic as central to the comprehension and management of nature as the only pre-theoretical tools and epistemologies giving meaning to the world (Tucker, 1999). By contrast, western science is conceived as constructed in an impersonal manner, secularizing knowledge thus giving objectivity to cerebral and intellectual reasoning, which enables postulating universal laws and totalyzing theories about the external world, that is nature. These universal laws and postulates are corroborated via experimentation and systematic and deliberate accumulation of facts by an empirical quantitative assessment. Its abstractive capacity is based on the promulgation of theories about nature, always separated from the social or cultural dominion, while IEKS are seen as structured by concrete local knowledge based on personal observations, trial and error, and synthesis of facts. On the contrary, the instrumentalization of western science is perceived as a societal endeavor, institutionalized, highly specialized and universal.

### 4.6.2. The conventional contrasting procedures: limitations and problems

To overcome the dualistic dichotomies sustained by positivist science, a further step is needed to analyze, in a more comprehensive way, the similarities, differences and relations between IEKS and western science. The following facts challenge some of the conventional assumptions about both ways of knowing when conducting an alternative inquiry:

**Table 4.2.** Contrastive elements between IEKS and Western science

| AREA OF COMPARISON | IEKS | WESTERN SCIENCE |
|---|---|---|
| **Scale** | • Local | • Universal |
| **Boundaries** | • Closed | • Open |
| **Relationship** | • Subordinate | • Dominant |
| **Dominating mode of thinking** | • Concrete<br>• Intuitive<br>• Holistic<br>• Mind and matter considered inseparable<br>• Individual<br>• Personal | • Abstract<br>• Analytical, cerebral<br>• Reductionist<br>• Mind separated from matter<br>• Societal<br>• Impersonal |
| **Communication** | • Oral, storytelling, song, dance, ritual, myth | • Literate |
| **Instruction** | • Learned through observation or hands-on experience<br>• Contextualized | • Got taught and learned in a situation usually separated from the applied context<br>• Decontextualized |
| **Effectiveness** | • Slow<br>• Inconclusive | • Fast<br>• Conclusive |
| **Data creation** | • Based on personal observations, trial and error, and synthesis of facts<br>• Data generation by resource users | • Based on experimentation and systematic, deliberate accumulations of facts<br>• Data generated by a specialized cadre of researchers |
| **Data type** | • Qualitative<br>• Historical (long-term series on a locality) | • Quantitative<br>• Statistical (short-term series over a large area) |
| **Explanation** | • Spiritual<br>• Imaginative<br>• Emotional<br>• Moral<br>• Ethical | • Hypothesis, laws<br>• Empirical<br>• Mechanistic, intellectual<br>• Value free |
| **Classification** | • Ecological | • Generic and hierarchical |

**Sources:** Wolfe, (1992), Berkes (1993), Toledo (1994), and Grenier (1998)

(1) Both, IEKS and western science, are the result of specific historical constructions displayed by distinct societies aiming to explain their own existence and their surroundings, to give meaning to their civilization trends and construct their own survival strategies. From this perspective, neither one of them is superior to the rest but just different. All of them constitute partial and limited ways of understanding the world, including western science, and function in relation to the needs and modes of existence of the societies that create and reshape them.

(2) The supposed sharp distinction between local IEKS and western universal science is biased by the way scientists mirror science and themselves (Latour and Woolgar, 1979; Knorr-Cetina, 1981; Fuller, 1997). This mythification is exercised when contrasting science as a superior stance with other cognitive systems and when contrasting the scientists as experts with the producers of other ways of knowing as merely laypersons. Science is biased by the execution of the scientific practice and the power relations displayed by the scientific institutions, aiming to validate and impose their own truth (Said, 1978, 1983, 1993; Shiva, 1988b; Nandy, 1989). An alternative perception that precludes and challenges the conventional divide between IEKS and western science assumes that the later should be seen also as local because it is contextualized in and for the modern world needs, while IEKS should be seen also as universal expressed in the local (Posey, 1999b).

Both are produced locally and intend to universalize their postulates or worldviews but maintain different positions on the domination/subordination relationship.

(3) It is rather difficult to recognize the precise limits between IEKS and western science when admitting that both ways of knowing are plural and different but both maintain their unity by their remarkable diversity in practice. Each IEKS maintains its singularity as a function of its own worldview, in which it is rooted, and as a function of the context from which it evolved. Nevertheless, it is possible to distinguish a set of common features that characterize IEKS as a structured unity. Similarly, western science as a whole is constituted by different epistemologies, paradigms, disciplines, trends and schools, some of them being in apparent contradiction but all of them founded on the scientific method that unifies them. Despite this, since the 17th century has dominated a positivist, rationalist and mechanistic science, based on the separation between nature and culture or between matter and mind (Bateson, 1972, 1979; Horigan, 1988; Westfall, 1992; Descola, 1996). The domination of this dualistic scientific approach has impeded a full comprehension of other cognitive systems, while the traditional societies that possess monistic cognitive systems are limited, as well, in understanding the secularized scientific postulates and practices (Sardar, 1999).

(4) Some other fundamental aspects are dismissed when IEKS are contrasted with western science. IEKS are conceived as local, closed and ethnocentric cognitive systems, distributed in adisperse pattern throughout the world, while science is conceived as a universal, open and progressive cognitive system. One of the forgotten aspects is the relation established between them, since at least the 16th century, in a rather systematic way (Crosby, 1988 and 1992). Western science has been nurtured by the appropriation of non-western sciences since they were 'discovered' after the conquest and during the colonial period of the 'New' World (Wolf, 1982). Adoption, recreation and adaptation of scientific knowledge from colonized societies allowed western science to widen and endure the scientific revolution initiated during the 'Enlightenment' in the 17th century (Westfall, 1992; Harding, 1994; Apffel-Marglin and Marglin, 1996). Thus western science should be looked more as a multicultural cognitive system (Needham, 1969; Harding, 1994; Sardar, 1999). The objectivation of local knowledge was accelerated, during the second half of the 20th century, via its internalization by western science and by means of the commoditization of knowledge induced by current globalization (Appadurai, 1992, 1995a and b, 1996; Fardon, 1995). Moreover, the apparently closed characteristic of IEKS vanishes once it is recognized that the exchanges between the New and Old Worlds started since the colonial times (Apffel-Marglin and Marglin, 1996). Since then, a vast number of indigenous and traditional societies internalized crops, agricultural techniques, domesticated animals, health practices, educational systems, legal norms, etc., from the Old World, widening their IEKS by integration, but most of the time eroding their own cognitive systems by substitution. Since then, both cognitive systems established unequal exchanges of knowledge and practices.

(5) Possibly, the main divide between IEKS and western science is that of their domination/subordination relations (Agrawal, 1999). This condition is founded on the fact that people who possess IEKS have not possessed much power to influence the course of history. Indigenous peoples and some rural societies have remained for the most part in positions of local resistance to the effects of domination produced by those who possess and apply scientific knowledge. Western, positivist science has imposed its domination in many areas of the Third World by extracting segments of IEKS, based on the identification and separation of those segments which have potential commercial value, by means of their previous scientific validation and through maximum abstraction of 'technical environmental knowledge' (TEK) that can be retained because of its easiest transplantation to other contexts (e.g. crop varieties, land races and wild relatives; inoculated soil micro-biota; genomes; medicinal principle reactives; organic products; endemic useful species; etc.). The scientific instrumentalization decontextualized local knowledge and practice by fragmentation, extraction and replacement. This generalization process has been executed by *ex-situ* cataloging, storing

and circulation of ‘useful knowledge’. In general terms, these methodological steps of extraction and replacement of useful segments of IEKS allowed their scientization based on particularization/generalization-implementation practices via top-down development. Because of this, the apparent neutrality of the positivist, rationalistic and mechanistic scientific practice vanishes. Its main political intentionality is to appropriate objects (useful technical knowledge) by extracting them from the contexts (cultural, political, social, economic and environmental) where they evolved, as if they were free of local value. Within this logic, the unity between knowledge and practice is disembodied and disembedded from the producers and users, and just the scientization process gives them universal value. Moreover, once the knowledge of indigenous and traditional societies is separated from them and *ex-situ* saved, there is little reason to pay much attention to them.

### 4.6.3. An alternative conceptualization of the relations between IEKS and science

The sharp differences between IEKS and western science, according to the positivist scientific scrutiny, are attenuated when using an alternative conceptualization that, instead of separating and fixing them in time and space, reveals their commonalties and distinctions within their historical relations. This alternative recognition shows dimensions that have been left out or dismissed, and recognizes that both coexisted and exchanged their ways of knowing until today; thus they are contemporary. It also recognizes multiple levels of existence and, accordingly, multiple modes of cognition, which should coexist rather than compete.

Still, there is a need to deconstruct the monological view to overcome the doubtful divide that is held by the instrumentalization of dichotomies, such as tradition/modernity, closed/open, irrational/rational and particular/universal. This deconstruction should be done in a multidimensional way, allowing a more comprehensive recognition of the distinctions, similarities and current relations between IEKS and western science. Its main intention is to conflate distinct cognitive systems in a more general and hybrid cognitive framework, which recognizes their differences and respects the plural understanding of the world. This requires the de-mythification of the apparent divorce between both knowledge systems. This synergistic approach is central to the needs for a more critical theorization about nature and culture, especially when seeking sustainable development and social transformation. But, this theorization requires the recognition of the critical constituent elements of IEKS and western science, which could be the bases for a synergistic approach.

IEKS are enriched by cosmological symbolism, that guides practice as a millenary experience through intimate and contextual engagement with the environment. Nature is conceived as an ontological part of the social, and the social is conceived as an ontological part of nature, both being part of the same world. The dimension of IEKS is not local but universal, expressed in local terms. Many indigenous and traditional worldviews are centered more in a spatial way than in a temporal way, requiring one to be native to a place (placeness) and live with nature (conectedness). In this sense, such worldviews can be considered eco-centric, placing humans in nature, so that nature and culture are not separated.

Western science is constructed from the secularization of knowledge. Its formalization and institutionalization lie on the universalization of its postulates and laws, and on the separation between social and natural sciences. Western science is centered on a worldview that gives more emphasis to the temporal scale. Western society looks backward and forward in time to obtain a sense of place in history, assuming that humans live above, separated from or in opposition to nature. Such standpoint can be considered ethno-centric, separating culture from nature. Both worldviews shape contrasting livelihoods, production systems and unequal social relations between indigenous and traditional peoples and the western society.

One of the central issues that distinguishes IEKS and western science is that they constitute distinct cognitive rationales or ‘regimes of truth’ (Foucault, 1968, 1970 and 1980). These rationales are limited by their own social practices; they co-exist in unequal conditions and none of them should be considered superior to the rest. Modern conceptions of truth, based on postulates that all minds are structurally similar, truths are universal and knowledge is potentially the same for everyone, are rejected on the assumption that truths are statements within socially produced discourses rather than objective 'facts' about realities. Truth resides in the exact correspondence between externalized reality and internal mental representations of that reality (Rortry, 1997). Foucault (1980) asserts that each society has its own 'regime of truth' linked to the power that controls for its own political and economical benefits, when recognizing the limits of western science claims' to have universal validity. Moreover, this allowed for a more comprehensive understanding of western rationality, supported by its own scientific arguments, that reason is a regional logic supporting, reflecting and justifying a history of global supremacy rather than a universal path to absolute truth (Peet and Watts, 1996). The importance of this has given credibility to the search for alternative 'regimes of truth', or other ways of knowing that have been marginalized, suppressed and discredited by western science (Santos, 1999). The criticisms of the universal truth gave shape to an alternative approach, that analyzes inter-regional relationships focused on the relations between hegemonic and dominated ways of knowing, social practices and cultural constructions about nature. The search of these 'regimes of truth' permitted to discern two ideal and dominating modes of cognition, each one possessing its own characteristics by reasoning and practicality but both linked and hybridized by experience, as shown below.

### 4.6.4. Knowledge and wisdom

Knowledge and wisdom (cognoscere and scire, in Latin; connaître and savoir, in French; conocimiento y sabiduría, in Spanish, kennen and wissen, in German) are two ideal and dominating models of cognition, although their epistemic concepts are not sharply distinguished by the English language (Villoro, 1982). Russell (1918) distinguished both cognitive systems when referring to Knowledge as 'knowledge by description' and wisdom as 'knowledge by acquaintance'. Both are two ways of believing, recognizing and signifying the world. Both are shaped by social and individual practices, which influence qualitatively their construction, maintenance and legitimization. Knowledge is rooted in scientific bases and shared by certain epistemic community: theories together with observable and relational postulates produce a set of propositions founded on sufficient objective reasoning. Wisdom is rooted in fewer shared epistemic concepts because it rests on direct, complex and repetitive knowledge about things; cosmologies play a substantial role as epistemic communities, but they are restrictedly shared by certain knowledgeable communities.

Abstraction and concretion of reasoning differ substantially in each cognitive system. Knowledge is founded on theories, postulates and laws about the world; it is thus assumed to be universal and endured by authority. Wisdom is founded on the concrete experience and shared beliefs of individuals about the surrounding world and endured by testimonies. Practicality also plays contrastive roles in both cognitive systems. Knowledge as an authority is conducted in an impersonal and indirect manner to give meaning about the world, while wisdom as testimonial is rooted in personal and direct experience with the world. The difference between a scientist and a wise person lies in the fact that there is no need to be wise to conduct scientific work. Knowledge is based on formal training and professionalization; it is a professional work. On the contrary, a wise person does not need to formulate general theories about things but take advantage of his/her own personal experience or tacit knowledge about them. Wisdom is based on a way of living and looking at things, endured by the everyday experience.

If knowledge is, by definition, a founded belief based on sufficient objective reasoning, wisdom is, by definition, a founded reasoning based on personal experience and more or less accepted beliefs. Objectification and subjectification of reality play a distinct role as well. Knowledge objectifies things when intending to separate or take distance from emotions and values about them. Mind and matter, or culture and nature, are separated and nature is conceived as an external world to be objectified by facts. The guarantee of a correct judgment is the objective justification of knowledge. Knowledge is produced by the recognition of regularities. Cognition is produced in a synchronic way. Objectification supposes a possible agreement of an epistemic community and is transmitted in an impersonal way. If discovering is done by a personal action, the justification of this discovering becomes impersonal as the guarantee of its objectification. Wisdom does not separate mind and matter in a sharp manner, as values and facts form part of the unity of the individual experience. Intuition, emotions, moral and ethical values are embedded in the ways of looking at things. Nature and culture form part of the same world; facts and values are connected when looking at things. The guarantee of a correct judgment is the personal experience shared within a certain cultural community. Wisdom, as a shared belief, produces knowledge by the recognition of repetition of irregularities in time. Cognition is endured in a diachronic way. Discovering and its justification are always personal and socialized as founded beliefs.

Discourse and transmission of knowledge and wisdom are also distinct from each other. Knowledge explains complexity in a simple and clear way, while wisdom explains complexity in an obscure and complex way. Textual standardization is crucial for knowledge, while wisdom preserves obscurity and richness of the multiplicity of meanings (verbal repetitions, metaphors, etc.). Knowledge aspires to simplicity and generality, while wisdom aspires to depth and detail. Nevertheless, wisdom is a required way to reach knowledge, as personal expertise is needed to hold knowledgeability by experience and authority. Knowledge becomes more important when it is more applied than theoretical. Applied knowledge can be closer or more related to certain forms of wisdom. Agronomists, soil surveyors, cartographers, etc., become experts in their fields by direct and repeated knowledge with their objects; thus by experience they could become wise persons. A farmer acquires objective knowledge to perform his/her agricultural practices by direct and repeated experience, becoming an expert by knowledgeability in a way similar to the agronomist when he/she becomes a wise person by experience and authority (Villoro, 1982).

Knowledge and wisdom as ideal modes of cognition are rarely represented in a pure way, thus are not easily separable. Even more, knowledge and wisdom cannot replace each other. Both are needed to preserve human existence, as both direct human actions to be correct according to reality and to have sense, according to the value of life. Knowledge cannot replace wisdom, because objective knowledge intends to guarantee the correctness of our actions, independently of the goals we have established or elected, but knowledge does not allow us to know which is the goal that we should elect. The election of adequate goals and values for the perpetuation of the human existence depends on wisdom as the giver of the sense of life, the sense of place and the sense of belonging.

To dismantle the divide between IEKS and western science, theoretical deconstruction is needed, including:

(1) the need to invert the binary and fixed opposition view towards a synergistic and adaptive approach. The principle of **relatedness** should be applied;
(2) the need to revert the superiority/inferiority view of different knowledge systems towards substituting the totalyzing and conclusive monological perception with a dialogical process, always contextual, open and inconclusive. The principles of **inclusiveness**, **context** and **decentralization** should be applied, and
(3) the need to subvert the domination/subordination relations of both knowledge systems and their producers. The principles of **respect** and **reciprocity** should be applied.

The two first deconstructing efforts are directly linked to the scientific work, while the third one surpasses the scientific dominion as it is further related with the complex political, economic and cultural arenas of the current globalization. Nevertheless, as western science and its technical mechanization have played a substantial role in legitimizing and directing globalization, the subversion of domination/subordination could, at least, counteract the current ideas and implementation of modernization as the only approach to development. Moreover, some particular issues have to be addressed in a critical way when deconstructing the divide between IEKS and western science. These issues are:

(1) the plurality and difference between all knowledge systems. This assumption allows recognizing that IEKS and western science are diverse in the sense that they conform multiple ways of

knowing, according to historical, social and cultural contexts; thus their diversity permits an enriching recognition of the ways nature is perceived and socialized.

(2) The monistic views of IEKS. Contrary to the separation between nature and culture and between knowledge and culture held by western science views, many IEKS are sustained by the connectedness between mind and matter and between facts and values, forming part of the ever-changing culture of the IEKS producers.

(3) The limited nature of all cognitive systems. The construction of the knowledge systems is always limited and contextual, according to the ways the world is conceived, perceived, classified and socialized by their producers and users. The full recognition of western science as a limited and contextual knowledge system is basic for the implementation of a synergistic approach, because it would allow the deconstruction of the distinct role played by 'outsider experts' and 'local laypersons' or by knowledge and wisdom.

(4) The unequal relatedness of western and non-western knowledge systems. IEKS and western science cannot be artificially separated or divorced, since they have not been isolated in the real world but mutually hybridized over hundreds of years. Nevertheless, this inter-relatedness has been dominated by western science and, therefore, many IEKS have been maintained in resistance to the former.

If these critical issues are fully recognized, then it becomes possible to adopt an alternative cognitive framework that comprehends the pluralist ways of looking at the world to negotiate inclusive sustainable development at local, regional and global scales, assuming openness and contingency as central to this process.

### 4.7. Conclusion

Small farmers, including indigenous peoples, have developed over thousands of years a risk-avoidance subsistence strategy through creating, maintaining and enhancing complex geographic, ecological, biological and genetic diversity at different spatial levels. Diversity is maintained and enhanced as a risk-avoidance strategy, not as a fixed plan but as an open program locally organized to buffer sacred and concrete disturbances. This rationale was aimed to meet local needs and cope with scarcity of labor, capital, land, and uncertain climatic and economic factors. This dual ecological-economic production rationale is reflected in a multi-purpose use and management of the local environment and is culturally rooted in a social network based on reciprocity, obligations and knowledgeability at household and community levels.

Nature, culture and production are inseparable domains allowing the construct of IEKS, which are based on individual and social experiences developed in ever changing contexts and ruled by local social institutions. IEKS are holistic, accumulative, dynamic and open systems built upon the local experience of earlier generations and always adapting to technological and socio-economic changes. IEKS are embedded in a monistic view of the surrounding world, therefore nature and culture cannot be separated. Although IEKS are acquired individually and specialization of the learning process is based on age and gender, the total collective knowledge should be seen as the social theory or the local epistemology of the surrounding world.

To fully understand IEKS it is necessary to comprehend the nature of local wisdom. IEKS are built upon a complex interrelation between beliefs, knowledge and performance. Nature is conceived and represented as part of the invisible and visible sides of the world. IEKS are built upon the bridging of facts, meanings and values in accordance to a particular cultural matrix and social experiences about the world. Local values are grounded in mythical worldviews, and the ritual reinforces the mythical origins of the world. The world is seen both as sacred and secular. Human beings are part of nature and share their existence with non-human living beings, giving a particular 'sense of place'. They are not separated from nature and non-human beings are not separated from culture. In this view, there is a need to find the balance between the worldview and the world-life. As a consequence, a dimension of the 'traditional' knowledge is not local knowledge, but knowledge of the universal as expressed in the local. In this same view, it is possible to overcome the conventional separation between universalism and particularism, grounded in the positivist scientific paradigm.

In IEKS, facts are constructed upon local material needs and social experiences. IEKS form a complex understanding of natural structures, ecological relations and dynamics, always uncertain. That is why nature is profoundly understood and respected. On the one side, nature is seen as a life force impossible to control, and, on the other, as the staple good of human existence; thus knowledge about its behavior is needed to cope with uncertainty. As facts are always changing according to circumstances, the mental organization of the natural world is not fixed and static, and the world's order is conceived as polysemic, polythetic and polyvalent. The multi-layered mental organization of the local world depends on circumstances, according to specific needs and actions at individual, household and community levels. In this view, IEKS are not static but innovative and built upon the relation between internal and external social networks. Innovation, adaptation and adoption are highly dynamic but framed always by the local cultural matrix, which gives the 'sense of place' of the local actors.

Ethnoecology, as a hybrid discipline seeking to study IEKS, challenges the conventional views about the natural and the social as separated domains of the world. It proposes a new scientific paradigm, seeking to meet local sustainable livelihoods based upon the relation between values, meanings and facts, to develop an alternative globalization process based on the maintenance of multiculturality as the staple good of human relations with nature and within themselves. The ethnoecological survey proposes the study of the production process integrating Kosmos, Corpus and Praxis at various spatial and temporal levels, as well as covering a set of key criteria to fully comprehend the complex local understanding of natural factors, relations, dynamics and phenomena, including their symbolism, rituality and representations.

The study of the complex local relations between perceiving, knowing and performing should be covered by ethnoecologists to interpret the farmer's model of the natural world, but an ethnoecological survey requires also the elaboration of the scientific or 'external' model of the local context. As an integrative approach, ethnoecology intends to compare and validate both models and build up guidelines for an endogenous local development with the full participation of the local actors. By re-integrating facts, meanings and values, the ethnoecological approach is guided by ethical and moral concerns regarding the sustainable management of natural resources, the self-empowerment of localities and the increasing production of diversities, challenging the supposed neutrality of the outside observer to guarantee the objectivity of science.

# CHAPTER FIVE

## ETHNOPEDOLOGY: A HYBRID DISCIPLINE

### 5.1. INTRODUCTION

Despite the importance of soil and land resources to rural production and their symbolic meaning in most agrarian societies, a study of how these resources are perceived, classified, used and managed has not yet been considered as a structured approach. Comparatively, more progress has been achieved in ethnobotanical and ethnozoological research than in ethnopedological research during the last 20 years (Barrera-Bassols and Zinck, 1998, 2000, and 2003a). Despite thousands of years of validation of ethnopedology by indigenous and other rural peoples, this has not been historically reflected in soil science research (Buol et al., 1980; Boulaine, 1989; Krupenikov, 1993).

Often, indigenous soil and land knowledge appears as an exotic corpus of primitive human experience and attitudes related with the soil resource. According to the conventional way of thinking, traditional and 'backward' knowledge systems should be converted into technology-driven land management practices, through modernization via development. However, complex pedological wisdom developed much before the Christian era in China (Needham and Gwein-Djen, 1981; Chingkwei and Shenggen, 1990), India (Abrol, 1990) and Middle America (Williams, 1975, 1982), and was intimately related with the major centers of plant domestication in the world (Vavilov, 1949; Grigg, 1974).

### 5.2. HISTORICAL DEVELOPMENT

Since the 16th century, foreign travelers, missioners and explorers documented vast, complex and sophisticated perceptions of nature, pedological wisdom and land management systems possessed by the colonized 'noble savage" societies of Africa, America, Asia and Australia. This was the case of the Quechua people of the Andean region in South America (Salas, 1996), and the Aztec and Maya peoples in Middle America (Sahagún, 1975; Williams and Ortíz-Solorio, 1981; Landa, 1982; Badiano and de la Cruz, 1995). This was also the case of the West African peoples (Richards, 1985; McCluhan, 1994; Niemeijer, 1995) and the Asian Societies (Bruun, 1995). Other descriptions of the North Amerindian peoples (Hunn, 1990), the Maori people from New Zealand (Smith, 1999), the aboriginal Australians and the ancient Japanese (McCluhan, 1994; Kalland, 1995) are additional examples of the diverse cognitive, symbolic and natural resource management systems developed by peoples from the "New World".

In many tropical and subtropical areas, remarkable examples of soil knowledge from non-western civilizations still maintain contemporary and potential validity (Barrera-Bassols and Zinck, 1998). Anthropologists, cultural and environmental geographers, a few agronomists and some soil scientists have contributed to the rapidly increasing collection of ethnopedological studies in diverse geographic entities, agro-ecological zones and ethnic territories of the world (Sillitoe, 1998; Barrera-Bassols and Zinck, 1998, 2000, 2003a; Talawar and Rhoades, 1998; Niles, 1997; Winklerprins, 1998; Mazzucato and Niemeijer, 2000a; WinklerPrins and Sandor, 2003).

Similar to ethnoecology, ethnopedology was only recently recognized as a comprehensive discipline (Johnson, 1977; Williams and Ortíz-Solorio, 1981; Warkentin, 1999). The first structured attempts to acquire soil and land information from indigenous peoples came from social and cultural anthropologists, including Redfield and Villa Rojas (1934) about the Yucatec Maya in Mexico, Malinowski (1965) about the Trobriand people, Conklin (1957) about the Hanunoo people of the Philippines, Carter (1969) about the Maya-Kekchi of Guatemala, Netting (1968) about the Koyfar of Nigeria, Ollier and collaborators (1971) about the Baruya people from Papua New Guinea, and Hecht and Posey (1989) about the Kayapó of Brazil.

Cultural and environmental geographers also contributed directly or indirectly to construct ethnopedology with early fieldwork studies. West (1947) worked with Purhépecha from Mexico; Sauer (Leighly and Sauer, 1963) acquired information from several indigenous peoples of Middle America; Williams (1975) studied the 16th century Aztec soil science; Johnson (1977) did an extensive work among the Otomi people in Mexico; Denevan (1980c) made a comprehensive review of the American indigenous land management systems; Bradley (1983) studied the Guidimaka's soil knowledge from Mauritania; Jungerius (1986) made a comprehensive review of the local soil and land knowledge systems among several indigenous peoples in Africa; Wilken (1987) did an extensive exploration among the Maya people in Guatemala; Osunade (1988a and 1988b) studied the ethnopedology of the Yoruba people in Nigeria; and Hecht (1990) reviewed the Kayapó soil knowledge in Brazil.

Few agronomists were concerned with ethnopedological findings. Marten and Vityakon (1986) studied ethnopedologies from Indonesia, the Philippines and Thailand in Southeast Asia; Tabor (1988) did extensive fieldwork among the Massade small farmers in Haiti. More recently, Bellón (1990) did a comprehensive ethnopedological survey among small farmers in Chiapas, Mexico; Talawar (1991) and Gupta (1998) explored local soil and land knowledge systems in semi-arid India; and Brouwers (1993) studied the case of Adja people in Benin. Soil scientists, such as Furbee (1989), Sandor (1989), and Pawluk and collaborators (1992) studied the Quechua's ethnopedological systems in the Colca Valley in Peru; Mafalacusser (1995) studied the Tonga-Shangana's land-use evaluation procedure in Mozambique; and Norton and collaborators (1998) explored the Zuni's ethnopedology in New Mexico, USA. During the last two decades, the number of ethnopedological studies considerably increased. According to an extensive literature research, around 400 ethnopedological studies cover about 100 countries in Africa, America and Asia. The information refers to some 120 indigenous people and small farmer locations in three of the major and most fragile ecological zones of the world: (1) warm and moist lowlands, (2) warm and dry lowlands, and (3) cold and dry highlands (Barrera-Bassols and Zinck, 2000, and 2003a).

## 5.3. The research approaches

Preliminary evaluation of ethnopedological information sources shows a lack of method and technique integration, contrasting with the holistic nature of the traditional knowledge. A review of existing studies reveals three main research approaches: ethnographic, analogical and integral (Barrera-Bassols and Zinck, 1998). Winklerprins (1999) finds similar genres of literature on local soil knowledge, naming them: "the ethnographies, the nomenclature studies, and the more utilitarian studies". Talawar and Rhoades (1998) give an extensive review of these ethnopedological studies.

### 5.3.1. Ethnographic approach

In the ethnographic approach, field data analysis and ethnopedological knowledge acquisition are the main objectives to recognize farmers' environmental rationality from a cultural perspective. In this type of study, the ethnopedological information is not validated against scientific information. In most cases, the empirical information is useless for an integrated analysis of the local natural resource management.

These are the classical ethnographies, which contain a few sections devoted to ethnopedology, usually in a descriptive manner, by listing the linguistic criteria referring to soil attributes and land management strategies. Earlier ethnopedological attempts were based on the linguistic analysis of local soil and land classification systems, similar to earlier studies on ethnobiology (Talawar and Rhoades, 1998).

### 5.3.2 Analogical Approach

The analogical approach aims to compare local knowledge with scientific information. This type of study intends to identify possible correlation between different soil and land classifications and management systems. The analysis does not take into consideration the socio-cultural contexts, from which perception, beliefs, cognition and practices are derived.

Two main research trends have influenced these studies. The first one, rooted in modern soil science, focuses mainly on developing 'natural' or 'objective' universal soil taxonomies (Queiroz Neto, 1998). It is also concerned with the spatial and temporal patterns and genetic processes of the soil resource (Buol et al., 1997). The second one, related to the 'cognitive universalistic school' developed by Berlin et al. (1973), has been formalized by Berlin (1992) with his theory of universal principles of 'folk' biological classification systems. According to Winklerprins (1999), much of this kind of research seeks to correlate local soil classification systems with the universal folk biological classification or with scientific soil taxonomies, such as the USDA soil taxonomy (Soil Survey Staff, 1996) or the FAO soil legend (FAO-UNESCO, 1974).

Most of the ethnopedological studies have followed the analogical approach. As in conventional ethnobiology, the analysis and correlation of soil and land classification systems form the main objective of the research, thus excluding other fundamental elements belonging to the local environmental knowledge systems, such as the symbolic meanings and values, as well as farmers' expertise. Although some of the studies demonstrate the scientific validity of local soil and land resources cognition, in most cases it is assumed that soil science is superior to local soil knowledge, so that the latter needs to be proven and formalized to be scientifically tapped (Sillitoe, 1998, 1999). The application of local soil and land resources knowledge during the production process is left out; thus the practical consequences of the cognition systems and the analysis of local ecological and economic rationale are not covered by these studies.

### 5.3.3. Integral Approach

The integral approach identifies and mobilizes the relationships between cultural and scientific information to elaborate natural resource management schemes according to social, cultural, economic and ecological local contexts. Local actors participate in validating and integrating information into the local decision-making and planning procedures. Designing sustainable natural resource management models is promoted.

This ethnopedological approach is still in its early moments (Östberg and Reij, 1998; Winklerprins, 1999; Winkler Prins and Sandor, 2003). Its main goal is to link soil and land wisdom and knowledge to promote feasible and sustained local endogenous development in an interdisciplinary perspective. By analyzing historical, ecological, economic and political factors and changes at local level and with the full participation of the local actors, this contextual approach could gain strength through co-validating and implementing in a creative way both, the scientific and the empirical sources of information.

What constitutes the most important aspect of these ethnopedological studies is the analysis of the management process related with the soil and land resources dynamics. Central to this approach is the understanding of the multi-facetted role of people's knowledge about soil and land in the production process. Taking into account local values and symbolic meanings rather than distorting the indigenous knowledge by imposing a western scientific model on it, the limits of both epistemologies are accepted and their synergies enhanced (Weinstock, 1984). Local people are well qualified to define their own problems and are experts on their soils, lands, plants, and so on. For some problems, modern soil science may not be of particular relevance, or might not be adapted to cope with local pedological and land-use aspects (Bocco, 1991; Pawluk et al., 1992; Niemeijer, 1995). Mutual exchange of information could make soil surveyors and scientists more familiar with local soil and land knowledge systems, if they want their work to be more effective, but also less exposed to political manipulation (Chambers, 1997; Sillitoe, 1998).

Recently, the need to develop a more integrated methodological approach to ethnopedology has been discussed among anthropologists, geographers and agronomists (Weinstock, 1984; Niemeijer, 1995;

Barrera-Bassols and Zinck, 1998 and 2000; Östberg and Reij, 1998; Sillitoe, 1998; Talawar and Rhoades, 1998; Winklerprins, 1999; Mazzucato and Niemeijer, 2000b; Krasilnikov and Tabor, 2003; Neimeijer and Mazzucato, 2003). The traditional controversy between utilitarian and scientific, or between relativist and universalistic, is being overcome to the benefit of incorporating ethnopedological information in local sustainable land management models. Relevant issues still hamper reaching this goal:

(1) there is a need to surpass the classificatory approach as the main and only ethnopedological research aim. More important than that is focusing on the management of the soil and land resources;
(2) there is a need for an interdisciplinary integration of natural and social sciences that surpasses the cognitive studies of soil and land as 'perceived natural objects' and focuses on the different ways social subjects engage symbolically, cognitively and practically with soil and land resources. In this sense, the narrow notion of 'indigenous technical knowledge' cannot be abstracted from its cultural context;
(3) there is a need to fully understand the local context as a complex, dynamic and open system where soil and land knowledge is applied in a heterogeneous way, according to individual and social ever-changing realities, and
(4) there is a need for establishing a participatory appraisal aimed to link local actors and researchers in a mutual exchange, negotiation and continuing learning process.

Anthropologists, such as Sillitoe (1998), argue that it is rather difficult to correlate indigenous or local soil knowledge with soil science, due to their different ways of constructing knowledge; the first one being a highly contextual (specific and limited) knowledge and the second being a generic and universal knowledge. Nevertheless, in an early study carried out by the same author among the Wola people in the Highlands of Papua New Guinea (Sillitoe, 1996), the information was organized following a conventional soil science procedure and according to Jenny's model of soil as a function of soil forming factors (climate, topography, parent material, biota and time) (Jenny, 1941, 1994), but including the human intervention as a sixth forming factor. Additionally, Sillitoe correlates the Wola ethnopedology with the USDA soil taxonomy and the FAO legend, and surprisingly finds a strong correlation between the local ethnopedology and the scientific classifications (Sillitoe, 1996 and 1998).

According to Sillitoe (1998), it is rather useless to construct soil maps using local classification systems because indigenous people have no notion of maps. He argues: "we might use the (*local*) soil classes so identified to name the soils mapped in a land resources survey of their region. But this would be a distortion of indigenous ideas". In contrast, Talawar and Rhoades (1998) think that scientific soil classification and the multi-criteria approach in soil phase mapping are somewhat similar to what farmers employ in a local classification. However, these authors show more interest for the local agricultural practices than for the soil and land knowledge system, excluding the cognitive and symbolic aspects and giving emphasis to tapping the 'technical indigenous knowledge' for its application in conventional development. They do not recognize the need to apply participatory research for local endogenous development.

The narrow supposition that tapping 'technical indigenous knowledge' for conventional development would lead to sustainable land management, outside the cultural context where this knowledge was produced, has been criticized. The descontextualized knowledge that results may even promote negative interventions (Sillitoe, 1998). On the contrary, Östberg and Reij (1998) sustain that even if indigenous soil and water practices are usually site-specific, constructed in particular ecological, cultural and socio-economic contexts, this does not necessarily exclude the possibility of transferring local practices to other areas. The false opposition between relativism and universalism should be challenged by developing alternative perspectives and proposing alternative epistemologies (Wallerstein, 1996).

WinklerPrins (1999) proposes integrating local and scientific soil knowledge for the search of sustainable land management models. As there are no concrete examples on how to integrate both knowledge systems, what is urgently needed are new research methodologies that include both perspectives as suitable and complementary. This implies the acceptance that both information sources are limited and neither is superior to the other. Creative and innovative participatory approaches are needed for understanding the "reconstruction of knowledge by both rural people and the researcher through a dialogical process", as Brouwers (1993) points out.

Winklerprins (1999) suggests three ways by means of which local soil knowledge can contribute to develop sustainable land management models: (1) the development of land management strategies and policies can be refined by including the local context and perspectives; (2) studies of local soil knowledge offer a way of understanding soil diversity as a basis for maintaining soil quality and promoting sustainable land-use; and (3) new ideas on environmental management may well be brought into the scientific community where sustainable agriculture is also a challenging prospect. During the last years, cross-fertilization of ideas between anthropologists, geographers and agronomists is widening the ethnopedological endeavor, but still more interactions between natural and social scientists are needed to fully develop an integrative methodological approach (see Geoderma, Special Issue, 2003 (III): 3-4).

## 5.4. AN INTEGRAL METHODOLOGICAL APPROACH

### 5.4.1. The scope of ethnopedology

Ethnopedology might be considered as a subset of ethnoecology (Toledo, 1992a). In a broader perspective, ethnopedology explores soil and land resources in a cultural and ecological context. Synonymous terms include 'traditional soil knowledge', 'folk soil knowledge', 'local soil knowledge' and 'indigenous soil knowledge systems' (Ettema, 1997; Sillitoe, 1998; Talawar and Rhoades, 1998; Winklerprins, 1999).

Ethnopedology studies all empirical soil and land knowledge systems of rural populations, from the most traditional to the modern ones. It analyzes the role of soil and land in the natural resource management process as part of given ecological and economic rationale. Soil and land are explored (1) as polysemic cognitive domains, (2) as multiple-use natural resources, and (3) as objects of symbolic meaning and values. If ethnopedology is taken as a dialogical discipline, then the exploration of soil and land implies an interpretation and analysis from both local and scientific points of view. Within an ethnoecological perspective, ethnopedology should provide information on the role of soil and land resources in the production process.

When adapting Toledo's ethnoecological approach to ethnopedology, it is possible to elaborate a holistic methodology that integrates Kosmos, Corpus and Praxis, as a dynamic cultural dimension that gives coherence and meaning to local soil and land theories and practices. As any rural production process is also a social process of engagement with nature, ethnopedology covers the three interrelated domains of the environment: soil and land resources, production and culture.

Ethnopedology aims to (1) assess local soil and land theories and practices in an ecological perspective, and (2) confront the latter with soil science at different spatial and temporal scales and operational dimensions of the local context. The comparative approach allows understanding two models of the same production reality, the local model and the researcher's model.

The main research subjects of ethnopedology include:

(1) beliefs, myths, rituals and other symbolic meanings, values and practices related with land management and soil quality evaluation;
(2) local classification nomenclatures, and soil and land taxonomies;
(3) local soil and land resource perception, theories and explanations of structure, distribution, properties, processes and dynamics;
(4) local knowledge on soil and land relationships with other biophysical factors, elements and processes;

(5) local land-uses and soil management practices;
(6) local adaptation, renewal and transformation strategies of soil properties and land qualities, and
(7) co-validation of ethnopedological knowledge, abilities and skills with modern soil science, geopedological survey, agroecological strategies, agricultural and other rural practices, to promote participatory land evaluation and land-use planning procedures for endogenous sustainable development.

At least four spatial and temporal scales (climatic, eco-geographic, agro-ecological and biophysical) and five operational dimensions (structural, dynamic, relational, utilitarian and symbolic) should be explored to understand local soil and land knowledge systems (Table 5.1).

The analysis should cover (1) local cognition, (2) local management and conservation, and (3) local perceptions and beliefs about soil and land spatial heterogeneity, temporal variability, natural dynamics and processes, and interrelationships with other biophysical factors. The interrelations between spatial and temporal scales and operational dimensions would allow a systemic approach to interpreting local soil and land theories and practices.

**Table 5.1.** Operational dimensions and spatial and temporal scales included in the systemic ethnopedological approach

| OPERATIONAL DIMENSIONS | SPATIAL AND TEMPORAL SCALES | | | |
|---|---|---|---|---|
| | CLIMATIC | ECO-GEOGRAPHICAL | AGRO-ECOLOGICAL | BIO-PHYSICAL |
| STRUCTURAL | Bioclimatic zoning<br><br>Landscape<br><br>Soilscape<br><br>Vegetation cover | Agroclimatic zoning<br><br>Relief patterns<br><br>Soil patterns<br><br>Vegetation types | Mesoclimatic zoning<br><br>Relief types<br><br>Soil associations<br><br>Biological associations | Microclimatic zoning<br><br>Landforms<br><br>Soil types<br><br>Biological species |
| DYNAMIC | Climatic seasonality<br><br>Hydrological cycle<br><br>Soil drainage pattern | Soil performance variability<br><br>Soil erosion and deposition<br><br>Land productivity cycle | Soil nutrient variability cycle<br><br>Soil quality variability<br><br>Ecological cycle variability | Soil fertility renewal/resilience<br><br>Crop phenology<br><br>Biological cycles |
| RELATIONAL | Climate-land relationships | Soil-relief relationships<br>Soil-water relationships | Soil-agroecology relationships | Soil-crop relationships |
| UTILITARIAN | Multiple land management strategies | Agricultural and forestry management strategies | Agrohabitats<br>Agroforestry | Agricultural plots<br>Homegarden<br>Forest plots |
| SYMBOLIC | Religious calendar | Agricultural and religious calendars | Agricultural and religious calendars | Agricultural and religious calendars |

**Adapted from:** Toledo (1992)

### 5.4.2. Ethnopedology as an interdisciplinary research field

Ethnopedology is a hybrid discipline, structured from the combination of natural and social sciences. Social anthropology and rural geography as social sciences, soil science and geopedological survey as natural sciences, and agronomy and agroecology as applied sciences, contribute all to structuring ethnopedology (Figure 5.1).

Combined application of procedures and techniques from the above-mentioned disciplines would allow analyzing, interpreting and integrating facts and values from both the local and the researcher's soil and land resources management models. This double assessment and co-validation procedure provides a multi-dimensional, multi-scale and multi-facetted diagnosis of soil and land management constraints and potentials, as well as the actual performance of natural resources according to specific ecological and economic rationale. From this analysis, relevant indicators of sustainable soil and land management can be extracted. Both models need to be discussed among local population and specialists to develop a consensual local land-use planning and endogenous development (Zinck and Farshad, 1995). The conceptual frame showing elements and interrelations to be considered when analyzing ethnopedological theories and practices is represented in Figure 5.2.

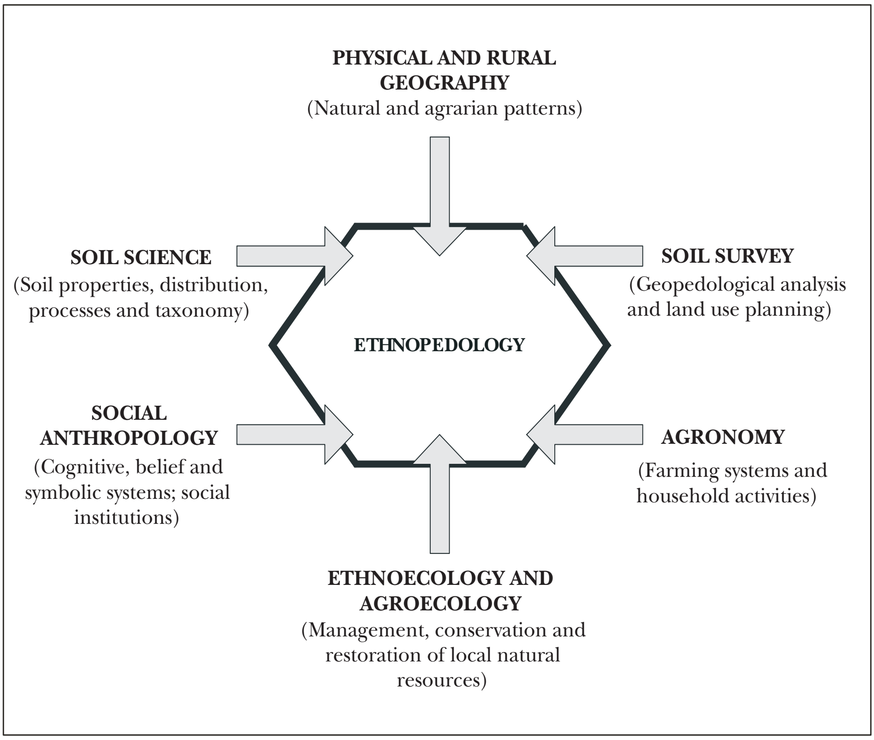



**Figure 5.1.** Ethnopedology as a hybrid discipline

## (1) Social sciences

In addition to the ethnographic procedures and techniques applied during fieldwork to build a comprehensive local soil and land resource theoretical model, anthropologists should explore also the cultural dimension of the political, social and economic realities of the social subject under study. Local contexts must be analyzed as complex, dynamic and open systems, where soil and land epistemologies are applied in diverse ways and according to environmental heterogeneity and variability. Besides, taking into account that local ecological and economic rationales are confronted to global, national and regional labor markets and development policies, the degree of social control of natural resources is highly dynamic.

The degree of coherence of local soil and land theories and practices is a parameter for assessing the cultural control that a given society or community exerts on the use and management of natural resources. Anthropological research permits understanding the degree of cultural control of subordinated or marginal cultures through the assessment of their cultural elements and cultural decision-making where ecological or environmental knowledge is of great importance (Mehaan, 1977; Field, 1991). The degree to which a marginalized social subject has the decision control about its cultural elements and those of other cultures is established by domination/subordination processes (Bonfil, 1987a).

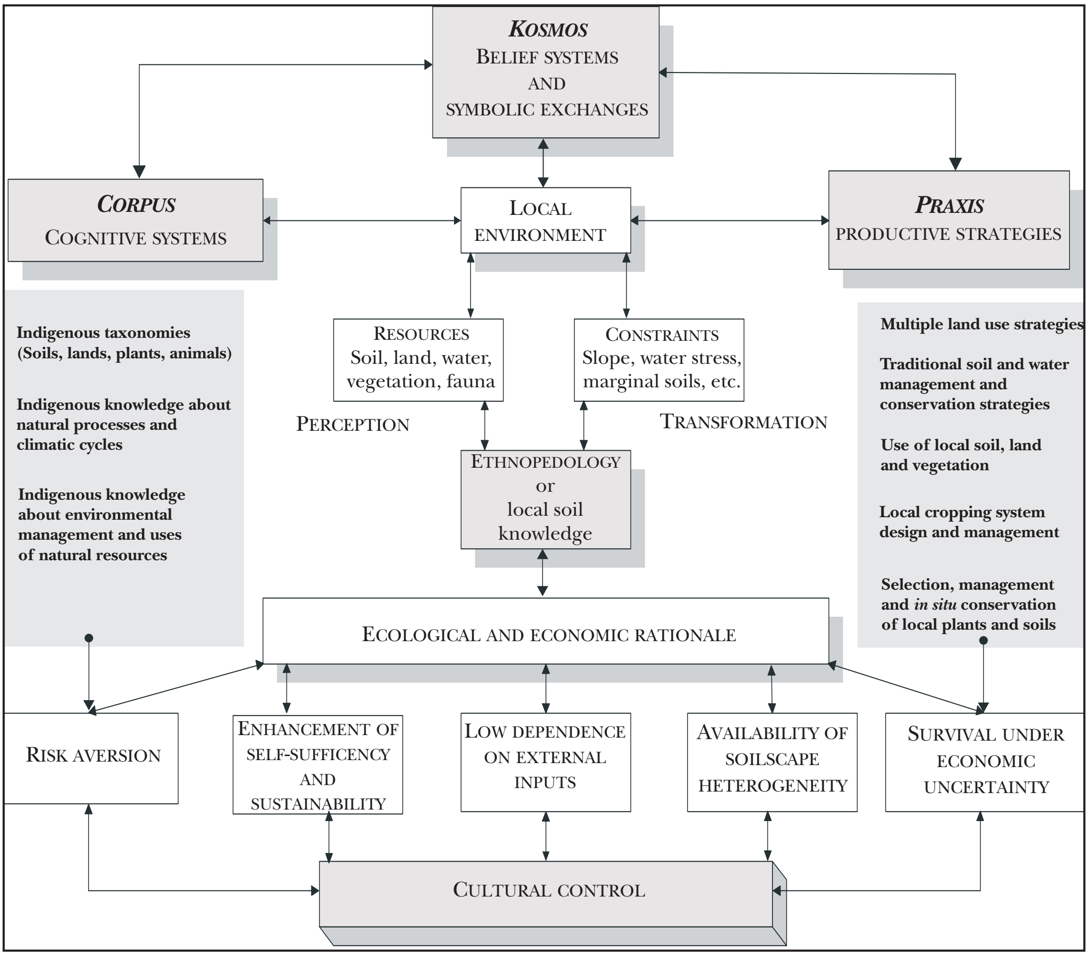



**Figure 5.2.** The scope of ethnopedology. **Adapted from:** Altieri (1993a)

Social relations among different social subjects are estabished by a complex set of decision-making levels, mechanisms and forms. These complex decision-making procedures are, in most of the cases, organized according to the internal cohesion of the community, but are mainly defined by diverse and concrete relations between the subordinated and the hegemonic social subjects. Cultural control operates under a domination/subordination global system constituted of political, cultural and socio-economic discourses and representations.

Cultural control is the decision capacity of a social subject, derived from its historic and current cultural elements. When this social subject is capable of choosing forms of using, producing and reproducing its own cultural elements, a **cultural autonomy** is reached. When a social subject borrows cultural elements from other sources but is capable of using them and deciding about them, a **cultural appropriation** takes place. On the contrary, when a social subject is no longer capable to decide about the uses of exogenous cultural elements, a **cultural imposition** occurs. When the social subject maintains its own cultural elements but is not capable of controlling them, a **cultural alienation** is established, according to Bonfil's Cultural Control Theory (1987a) (Table 5.2).

From an ecological point of view, the above cultural stages can be illustrated as follows. When an indigenous community vigorously maintains its traditional multiple land-uses and is capable of selecting and controling land-uses, seeds, technology, labor organization, cognitive and belief systems, and the practices associated with them, an **autonomic culture** prevails. On the contrary, when the local forest land is exploited by a foreign logging industry in accordance with its market interests, with its own workers and technology, an **alienated culture** is established. When a modern technology-driven agricultural model (e.g. improved seeds, fertilizers and machinery) is adopted by an indigenous community for traditional agricultural implementation, an **appropriated culture** takes place. In this particular case, the social subject does not produce its 'own' cultural elements but is capable to control the elements coming from the 'others'. The extreme case is when a community is despoiled of its land or the land-uses are controlled by external management decisions. The cultural elements of the community are modified by new consumption habits. Here, the indigenous community is totally subordinated to imposed environmental and economic decisions and exogenous cultural elements, both becoming part of an **imposed culture**.

**Table 5.2.** The local control of cultural elements and decisions

| LOCAL CULTURAL ELEMENTS | DECISIONS | |
|---|---|---|
| | Endogenous own | Exogenous others |
| Endogenous own | Autonomic Culture | Alienated Culture |
| Exogenous others | Appropriated Culture | Imposed Culture |

Domination/subordination relations are controlled by different processes:

(1) **Resistance process**: the subordinated social subject defends, in an explicit or implicit complex manner, the preservation of the concrete content of his/her autonomic culture.
(2) **Appropriation process**: the subordinated social subject acquires a decision-making control over exogenous cultural elements and integrates them as part of his/her autonomic culture.
(3) **Innovative process**: the subordinated social subject creates his/her own new cultural elements, integrating them into his/her own autonomic culture.
(4) **Imposed process**: a hegemonic social subject forcibly introduces his/her own cultural elements to the subordinated social subject's cultural dimension.
(5) **Suppression process**: a hegemonic social subject prohibits or eliminates substantial dimensions and elements of the subordinated autonomic culture and imposes his/her own cultural decision-making procedures.
(6) **Alienation process**: a hegemonic social subject takes total cultural control over the subordinated social subject's cultural elements.

Political anthropology can contribute by analyzing the coherence and characteristics of the local soil and land management processes. The same approach is suitable to explain the constraints to and the potential for consensual local endogenous development, according to external scenarios.

### (1) Natural sciences

Climatic, geopedologic and ecological inventories provide scientific information of the natural conditions from which the indigenous environmental knowledge systems arose and from which specific land unit management techniques have evolved. Inventories include information on soil properties, formation processes, geographic distribution and classification.

Ethnopedologists should develop their own local model of soil and land resources management to properly establish a comprehensive dialogue with community soil experts. There is no dialogue if there is no common information to communicate, and there is no learning process if there is no new knowledge to share. Production of diversity is a social construct and dialogue means a social production of discoveries. If local ethnopedological studies are considered as dialogical endeavors, seeking to explore possible synergies among both knowledge sources, then dialogue and synergy are synonymous concepts. Synergy (from Greek, *synergios*, working together) is defined as "…the cooperative action of discrete agencies such that the total effect is greater than the sum of the two or more effects taken independently" (Webster's Dictionary). In ethnopedological research, the concept of synergy is applied in the sense that information (facts and values) of two epistemologies (local soil and land knowledge systems and scientific data) must be obtained from several sources, including ethnographic fieldwork, census, questionnaires, participatory rural appraisal, soil field observations and laboratory determinations, and they must be integrated for further analysis. The integration and co-validation of qualitative and quantitative information constitute the major challenge of ethnopedological studies.

New and old global and local realities and demands are calling in question the role of soil science and soil survey in the coming future (Ruellan, 1998; Cerna, 1998). Despite enormous advances in these disciplines during the last century, a major challenge will be to generate data on environmental quality in ways that benefit both, the land-users and society as a whole (Fujisaka, 1998b). There is a strong need for soil science and soil survey to address this challenge, including the analysis of soil as a part of the ecosystem, as a societal good and the service it provides, and as a holistic object.

(A) Soil scientists and soil surveyors should analyze soil and land resources as part of the ecosystem and integrate people in this system (Swift, 1997). Modern soil science has developed under a reductionist approach led by physics and chemistry, while poorly integrating biology, ecology and geography, and largely uninformed about the social sciences. Additionally, the objectivity of soil science and its applications has been challenged by the general disillusion with the capacity of science to adequately deal with the global and local problems that are arising, including those related to sustainable development.

To overcome this criticism, soil science needs to recognize soil as a functioning part of the ecosystem at different levels of space and time. Also, scientists must take into consideration that people form a relevant factor of the ecosystem and that soil is as much a result of human intervention as a product of biophysical evolution (Swift, 1997). Similarly, Scoones and Toulmin (1998, see also1999) argue that "the interaction of social and economic factors with ecological processes over time is central to understanding the conditions of soils today". Furthermore, people must be seen not just as a constituent part of the ecological system with which they interact, but also as a constituent part of their cultural context where soil and land resources are known, perceived and managed. Soil scientists must make use of information of types and origins different from the conventional soil information (Swift, 1997).

(B) Soil scientists and soil surveyors must fully understand the responsibilities of soil science and soil survey towards society (Queiroz Neto, 1998). Soil, as a polyvalent resource, offers many services to satisfy human needs. Thus, soil scientists must acknowledge the needs to mobilize the right information for providing appropriate services. However, soil science must answer different questions for different societies in different environmental and cultural contexts.

These answers, as Queiroz Neto (1998) notes, "are not universal from social point of view, insofar as they are only applicable to certain social categories". New research approaches, leading to establish different engagements and responsibilities between soil scientists and rural population, could address the issues faced when seeking environmental sustainability of the services provided by soils to the local people.

(C) Soil scientists and soil surveyors need to develop an interdisciplinary and holistic approach (Latham, 1998). Soil science is now under scrutiny by society, as soil and water resources are becoming scarce and valuable (Latham, 1998). Social demand requires soil research to be integrated with other biophysical and socio-cultural investigation, not only with respect to soil productivity and conservation, but also with respect to environmental quality issues, considering the soil as a sustainability indicator and for its symbolic, recreational and aesthetic values. This implies that soil science and soil scientists need to develop an interdisciplinary holistic approach and adapt conventional methodologies to the problems to be solved, and establish new bridges of communication with the different groups of the society.

Soil survey also has been widely criticized in its existence and development (Zinck, 1990). As an applied discipline, soil survey should address some of the main resource issues like scarcity, vulnerability and low resilience, to combat soil and land degradation and inappropriate land-uses. By producing the information required for a sound soilscape management, soil survey can reinforce its vital importance for an endogenous local development. One important contribution of ethnopedology to the revitalization of soil survey is the integration of local expert opinions and farmers' experimentation results at parcel level. As Zinck argues (1990: pp.7) "A domain which has hardly been explored is the elaboration of soil maps through systematization of farmer and peasant expertise. Past civilizations (*and actual indigenous peoples, we argue*), because of their intimate contact with and dependency on the soil resource, developed a rich vocabulary (*and complex land management processes, we insist*) on relevant soil properties and soil types".

Recent innovative experiences, as part of conventional soil surveys, have demonstrated the fertility and validity of ethnopedological studies for participatory soil mapping (Ortíz-Solorio, 1989; Denniston, 1994; Bird, 1995; Poole, 1995; Rocheleau, et al., 1995; Idris, et al., 1998; Payton et al., 2003) and land-use evaluation (Osunade, 1985; Lado, 1986; Mafalacusser, 1995; Siderius and Mafalacusser, 1998; Barrios and Trejo, 2003). There are also promising results from integrating ethnopedological information into knowledge-based systems (Furbee, 1989; Guillet, 1989 and 1992; Balachandran, 1995; Oudwater and Martin, 2003) and geographical information systems (González, 1995 and 2000; Jarvis and MacLean, 1995; Weiner et al., 1995; Lawas, 1997; Harmsworth, 1998), using remote sensing imagery (Cajuste, 1991; Tabor and Hutchinson, 1994; Oudwater and Martin, 2003).

Many ethnopedologists are questioning the validity of comparing and co-validating scientific and local soil resources epistemologies because of their difference in perceiving and understanding soil resources (Niemeijer and Mazzucato, 2003). However, instead of rising the issue of mismatched models (Sikana, 1993), attention should be paid to the synergy of combining local and scientific soil and land knowledge systems and gaining cognition from both perspectives, especially when referring to endogenous local development. We cannot either neglect local soil expertise or reject the usefulness of soil survey information. We should instead build alternative responses by constructing new dialogical bridges among experts (Beek, 1997). Ethnopedology, as a hybrid discipline that studies the relation of soil and land resources with culture at local level, could be one of the many alternatives to help soil science and soil survey confront their challenges in the coming future (Krasilnikov and Tabor, 2003; WinklerPrins and Sandor, 2003).

## (2) Applied sciences: agronomy and agroecology

Decisions adopted by farmers to produce goods do not depend only on the quantity and quality of the local natural resources. Other criteria such as inter-annual climatic variations, regional market variations, socio-cultural compromises and obligations, economic household needs and individual agencies, are taken into account to select proper practices and strategies. Local land-use management processes are highly variable, dynamic and, in many instances, governed by external factors. They depend on dynamic local and individual responses for their maintenance and restoration. These are the socio-economic and technical factors that underlie local ecological and economic rationale. They are key aspects to be taken into account by economic agronomists, agroecologists and ethnopedologists (Mazzucato and Niemeijer, 2000a).

Agronomy has studied farming systems as one of its main research and extension objectives. Nevertheless, agronomic studies have focused mainly on modern technology-driven systems. When studying local traditional farming systems, the main goal was to recognize production constraints and potentials with the purpose of modernization or conversion. Conventional agronomy oriented to rural development has neglected the importance of maintaining and enhancing small-farmers ecological and economic rationale and has imposed external technology-driven solutions to local rural production problems, without taking into consideration the local self-sufficiency production needs (Rosset and Benjamin, 1994).

The introduction of technological packages (e.g. improved seeds, chemical fertilizers, large-scale irrigation, mechanization, and monocropping) aims at increasing crop yields for international and regional market needs, via innovation and substitution (Pretty, 1995). According to this approach, rural peoples are considered as merely producers or stakeholders and not as social subjects embedded in their own historic, environmental and cultural contexts (Kloppenburg, 1991). Thus, rural production is considered more important than rural population, disengaging the production process from the local social realities (Chambers, 1997).

This productivist approach has been challenged by its own development failures and economic, environmental and social consequences (Peet and Watts, 1996), especially in rural areas of the Third World. It has led to the search for a new post-productivist paradigm, centered on the analysis of local sustainable production systems and adopting resource-conserving technologies and processes (Kloppenburg, 1991; Pretty, 1995). The main goal of this sustainable agronomic paradigm is to maintain or even increase yields per hectare without damaging the natural, genetic and cultural bases of the production process. Ethnopedology can contribute to this goal by providing information on (1) spatial and temporal soil and land allocation at local level, and (2) site-specific agroecological management processes.

Local ethnopedological research must analyze the household strategies for soil and land management. Local contexts are highly heterogeneous, and soil and land management knowledge and processes vary from individual to household, according to status, needs, micro-environments, access regulations and land allocation. Representative elements of the local institutions and micro-environments must be analyzed to assess the role of ethnopedology in the local production process (Reenberg and Fog, 1995; Reenberg and Paarup-Lauresen, 1997).

According to Toledo (1990), there are several stages representing the coherence and strength of the local self-subsistence multi-purpose strategy (Table 5.3). This strategy is based on the capacity of a given community to control and manage its micro-environmental heterogeneity, and its biological and genetic diversity, to fulfill its own production-consumption-reproduction needs. The same strategy is pursued by each household to fulfill the same needs, according to specific decision-making processes to manage its different land units. The four self-subsistence multi-purpose stages are:

(1) **local self-sufficiency with surplus:** when the locality is able to produce its own basic needs and exchange a certain surplus outside the local context;
(2) **local self-sufficiency without surplus:** when the locality is able to produce just for its own basic needs;
(3) **local market-oriented production but not self-sufficient:** when the locality produces certain commercial goods without fulfilling its own basic needs, and
(4) **local not self-sufficient production and without market-oriented production surplus:** when the locality is no longer able to produce its own basic needs, neither generate a surplus from commercial-oriented production.

At stages 1 and 2, the local context is able to maintain an unstable equilibrium in its population-resources relationship. These self-sustainable momenta are recognized by the ability of the locality to produce basic goods more than needed or just the quantity needed to fulfill its social reproduction requirements, including those of each household unit. Both stages represent local situations where soil and land knowledge and its technical applications are adequate to take advantage of and control the local production potential. On the contrary, stages 3 and 4 represent different production imbalance momenta due to an inadequate management or control of its productive potential. Both stages also imply the rupture of the cognitive and/or practical soil and land management coherence and reflect the incapacity of the locality to produce the basic goods or to produce a surplus needed to fulfill the local basic inputs. The four production stages are controlled by internal and external exchange relationships, centred on socio-economic and cultural domination/subordination processes.

**Table 5.3.** Stages of the coherence and strenght of the local subsistence, multi-purpose strategy

| | | Self-sufficiency | Surplus | | Self-sufficiency | Surplus |
|---|---|---|---|---|---|---|
| **Local self-sufficiency** | 1 | + | + | 2 | + | - |
| **Local not self-sufficiency** | 3 | - | + | 4 | - | - |

**Source:** Toledo (1990). (+) Positive; (-) Negative

The maintenance of agroecological diversity and functionality is a strategy to produce a wide range of goods, minimizing climatic, biological and economic risks (Almekinders et al., 1995). Low quantities of a vast number of crops and crop varieties are produced in a single environmental unit, adjusting crop requirements to the micro-variability of soil quality and promoting genetic diversity to fulfill food, fiber, medicinal and other household's basic needs (Conway, 1993; Altieri, 1995). These multicropping systems also constitute *in-situ* banks for the conservation of local germoplasm at inter- and intra-specific genetic levels (Brush, 1989, 1991). Soil micro-variability, soil properties performance, soil productivity, soil biology, soil-plant and soil-animal relationships, and soil and water conservation and restoration strategies are well recognized, assessed, manipulated and adapted by farmers to control multicropping performance in diverse agro-habitats and according to different plant phenologies (Altieri, 1993b).

These traditional farming systems show two relevant features: a high degree of bio-agrodiversity and a complex system of indigenous technical knowledge (Brookfield and Stocking, 1999; Brookfield, 2001). The agroecological management at parcel level could be considered as the fundamental experimentation and innovation process, where individual operations are performed according to different perceptions and experiences (Chambers, 1990 and 1997; Pretty et al., 1995). This is the most important level of individual competence, providing an extensive range of strategies and techniques to adapt to micro-environmental conditions and control the maximization of the outputs. Biological control of multicropping also reduces pests and diseases in technological low-level conditions and allows sustainable production (Altieri, 1993a; Guzmán-Casado et. al., 1995).

### 5.5. ASSESSING THE ROLE OF ETHNOPEDOLOGY IN LOCAL ENDOGENOUS DEVELOPMENT: A POLITICAL ECOLOGY APPROACH

The main challenge that many researchers and extensionists are facing today is moving from conventional ethnopedology, seeking to cataloguing and comparing local and technical soil classification systems to each other, which is a self-limiting exercise, towards a more integrative approach that puts local soil knowledge in the development process (Sillitoe, 1998; Talawar and Rhoades, 1998; WinklerPrins, 1999, 2001; Barrera-Bassols and Zinck, 2003a, 2003b; Birmingham, 2003; WinklerPrins and Barrera-Bassols, 2003; WinklerPrins and Sandor, 2003). However, recent studies have demonstrated that introducing local knowledge into the development process requires its previous evaluation using a political ecology research approach (Zimmerer, 1996c; Escobar, 1999; WinklerPrins, 2001). This link allows to answer key questions during the local development design and implementation. How and why local (soil) knowledge is put/ not put into practice? Which are the constraints that hamper the use of local knowledge? Which aspects of the local knowledge are not practiced due to political, cultural, socio-economic or environmental pressure? How local knowledge could guide endogenous development? Who is using local knowledge and why is using it? To which extent local knowledge is hybrid and integrates modern scientific and technological issues and discourses?

Coupling ethnopedology within a broader political ecology research framework involves on several assumptions. According to WinklerPrins (2001: 6) "... local knowledge cannot be decoupled from its socio-economic and political context, and cannot be applied in isolation as a 'bit' of information about land resources". This implies that local knowledge is contextual. Thus, to fully understand how local populations make use of their repertory of cognitive domains, skills and theories about nature, there is a need to carefully consider the broader context of knowledge application, that is the internal-external processes that limit everyday practice. Such processes are diverse and complex, ranging from political, cultural and economic to environmental, and operate as nested hierarchical articulations at different scales, from the local to the global. It is also assumed that all knowledge systems are limited, but play diverse power roles, influencing decision-making. Thus, domination/subordination is central to the understanding of why local knowledge, although adapted, efficient and always changing according to adverse circumstances, has been neglected, undervalued or exploited by dominant scientific- and technological-driven mechanisms through planned intervention. Table 5.4 shows the main characteristics and constraints of local soil knowledge, according to a review of some 250 references covering Africa, America and Asia. Subordination of local knowledge, commonly considered backward and inefficient, contradicts its historical and contemporary roles in meeting great portions of the global food demand (Toledo, 1996a, 2000; Sandor et al., forthcoming). That is why the link between local knowledge and decision-making (K-C-P complex), on the one hand, and the broader context, on the other, makes political ecology a useful framework for field-based research. But, what does political ecology means and how should it be implemented as a research template?

### 5.5.1. The political ecology approach

Political ecology is an interactive way of studying and understanding society-nature relationships, especially when linking investigation on land management (i.e. ethnopedology) with development issues, because it is only through visiting the farmers world-life and worldview that a basis for understanding them as social actors in the development interface can be created. The main objective is to link local issues and land-use changes with processes on-going at regional and global levels. In other terms, political ecology can be defined as the study of the manifold articulations between history and ecology, and the cultural mediations through which such articulations are necessarily established (Escobar, 1999). Each articulation has its history and specificity and is related to modes of perception and experience determined by social, political, economic and knowledge relations, and characterized by modes of use of space, ecological conditions and the like. Therefore, it is the task of political ecology to outline and characterize the processes of articulation, and to suggest potential articulations realizable today and conductive to just and sustainable social and ecological relations (Escobar, 1999: pp. 4).

Political ecology is an interactional, relational or integrative approach, because it attempts to integrate physical and social sciences, using a variety of epistemologies and alternative methodologies, such as grounded theory methodology, ethnographic survey, field-based analysis, environmental impact assessment, geopedological approach, ethnoecology, and the like. Therefore, it is a pluralistic approach and a trans-disciplinary attempt to integrate natural and social domains. The approach combines the concerns of ecology and political economy to comprehend the ever-changing tension between ecological and human changes, and between diverse groups within a society at various scales. That is why it is considered a multi-scale and cross-scale research framework (Peterson, 2000). In political ecology, emphasis has been on nested hierarchies and a chain of explanation, scaling-up from the farmer up to global systems (WinklerPrins, 1999).

The ecological part of political ecology resides in that it analyzes nature as an active agent in a resilience-oriented perspective, assuming that ecological change, whether independent or influenced, or triggered by human action, alters the types of conflict over ecological resources and services that may occur. This is why the study of land-use change, land management, land degradation and environmental history is relevant within this framework. Political ecology also considers political dynamics in its explanation of human behavior, such as the political processes that influence what, why and how people learn and act upon nature and the political dimensions of what events are considered crises. It also explores the environmental, socio-economic and political constraints that limit the use of the full repertory of human agency (knowledgeability/capability), or the individual actor's capacity to process social experience and devise ways of coping with life, even under the most extreme forms of coercion (Giddens, 19910, 1991, 1984; Long, 2001). All above implies that political ecology is an actor-oriented approach. An essential tenet of political ecology is that approaches to land-use and land management should focus on the land manager (an actor perspective), whose relationships with nature should be acknowledged in an historical, political and economic context (Blaikie and Brookfield, 1987; WinklerPrins 2001). This is why political ecology is a situated approach.

**Table 5.4.** Main characteristics and constraints of local soil knowledge, according to analysis of 254 references covering Africa, America and Asia

| | |
|---|---|
| **(a)** | Field-based and individual experience (situated or contextual knowledge) |
| **(b)** | Knowledge grounded on skills as much as empirical cognition and theoretical assumptions (lived experience) |
| **( c)** | Local models about nature, based on symbolism, cognition and practice (holistic perception of world life and worldview) |
| **(d)** | Fine-tuned topsoil knowledge at micro and meso local levels |
| **(e)** | Adaptive, according to ever-changing circumstances and uncertainty |
| **(f)** | Embedded in a risk-avoIdance strategy |
| **(g)** | Knowledge differentiated by gender, age, social status, experience and skills |
| **(h)** | Hybrid trough integrating other exogenous knowledge systems, technology, know-how and discourses (open knowledge acquisition) |
| **(i)** | Shared among individuals in a fuzzy manner, but structured as a social theory through negotiation and consensus (practical and institutionalized knowledge) |
| **(j)** | Subordinated to the dominant socio-economic and political processes on-going at regional, national and global levels |
| **(k)** | Intending to be conservativionist as land resources are scarce, fragile and limited |
| **(l)** | Limited as all knowledge systems, including modern science |
| **(m)** | Grounded on ethical, moral and other cultural values |

A variety of conceptual interpretations and research approaches in political ecology arose since the seminal work by Blaikie and Brookfield (1987), making this research framework robust but still highly debatable (Blaikie, 1995; Zimmerer, 1994a, 1994b; Peet and Watts, 1996; Zimmerer and Young, 1998a and b; Escobar, 1999; Peterson, 2000). However, all the theoretical conceptualizations and applications coincide that political ecology is a comprehensive research template about land management (Black, 1990), although more emphasis has been directed to the explanation of the multiple causes and consequences of land degradation. In fact, some argue that political ecology is perhaps of greater utility when it seeks to examine why land has not been degraded (Whitesell, 1993; WinklerPrins, 2001) It is here where ethnopedological findings, using the K-C-P complex, should play a substantial role in explaining local responses to the regional political ecology. How do local people react upon the 'internalization' of 'external' forces in relation to natural resource management? Which is the repertory of human agency used to buffer the effects of such 'externalities'? How do people react and adapt to ever-changing and unpredictable circumstances? How do they hybridize local knowledge? How do they actively and discursively resist the effects of rural modernization?

Findings from integrating ethnopedological data in a political research framework show a relatively new stream of academic interest (Zimmerer, 1996a, 1996b; WinklerPrins, 2001; this thesis). Linking ethnopedological findings with the explanation of pre-Columbian land management and land degradation in Central Middle America, using a landscape ecology approach within a political ecology framework, resulted promissory, enhancing soil-archaeology relationships as an interdisciplinary research trend (Fisher, 2000; Fisher et al., 2003). However, this kind of academic exercise is still in its early days.

The political ecology approach allows also to overcome positivist science and conventional linear thinking, seeking to re-conceptualize and implement sustainable development at various spatial scales. The actor-perspective development sociology (Long, 2001), the Resilience Alliance Research Group (Holling, 2001; Walker et al., 2002), and sustainability science (Kates et al., 1993, 2001), are among these new 'post-normal' scientific research trends (Maturana and Varela, 1987; Funtowicz and Ravetz, 1993; Escobar, 1999). However, already in 1995, Blaikie defined eight central elements of political ecology as a pluralistic research framework, which are still considered the main research objectives and goals of this relatively new way of explaining nature-culture-society relations (Table 5.5).

**Table 5.5.** The eight central elements of political ecology

| | |
|---|---|
| **(1)** | Use of a variety of epistemologies, specially seeking to renegotiate the role of positivist, reductionist-derived knowledge. In other words, political ecology attempts to Integrate physical and social sciences |
| **(2)** | Emphasis is on local history to understand environment and society |
| **(3)** | Multi-scale perspective |
| **(4)** | Includes a critical analysis of international policy regarding global environment |
| **(5)** | Focuses on the local level because the immediate users of land are the approximate causal agents of environmental change and how decisions are made at local level is key to Understanding environmental change |
| **(6)** | The role of the state and its numerous versions is a central issue |
| **(7)** | Conflict and contestation over the environment (i.e. the struggle over resources as well as struggles over the ideas regarding resource-use) |
| **(8)** | The inclusion of indigenous (i.e. non-western) knowledge systems |

**Source:** Blaikie (1995)

### 5.5.2. Grounded theory

Political ecology and ethnopedological research may be based on grounded theory methodology (Corbin and Strauss, 1990). Mazzucato and Niemeijer (2000a) applied grounded theory methodology to understand the chain of explanations related to land management in indigenous localities of Burkina Faso. Importance was given to understanding farmers' and scientists' explanations about land management and land degradation, contrasting local soil knowledge, management and perception with conventional scientific findings related to land degradation. Their approach is similar to the political ecology research framework (see also Long, 2001). The use of this methodology resulted adequate and promising for the broadening of a contextual ethnopedological research, revealing that conventional research findings about land degradation should be taken cautiously and compared with farmers' perception of land degradation, land-use and land management at local level.

Grounded theory methodology is an open research strategy seeking to go beyond standard research procedure of testing hypotheses derived from the work of a few theorists. This does not imply that grounded theory methodology operates in a theoretical vacuum. What is proposed is that theory should emerge from what is being observed (field-based studies and contextual analysis). The method seeks to collect information (ethnographic procedure), while constantly comparing it with previous information (ethnological procedure). Through this process, (a) categories of the information are constructed, (b) comparison continues until theoretical properties of the analyzed categories are recognized, and (c) categorizing information reveals which additional data are required to further develop categories. In so doing, a grounded theory is formulated, playing an important role in guiding on-going data collection.

Grounded theory avoids determinism. Individuals are seen as actors responding to local conditions and to the consequences of their action, and to their ever-changing and uncertain political, socio-economic and environmental outcomes. It is also assumed that multiple and complex socially constructed realities exist, but they are not governed by natural laws; therefore, methods that try to verify and falsify reality are in antithesis of this methodology (Guba and Lincoln, 1989; Mazzucato and Niemeijer, 2000a). Multiple and contrasting realities, issues, objects, relationships, causes and consequences are differently perceived by actors such as scientists, technicians, developers, policy makers, farmers, and local populations at large. Emphasis must be given to understanding the different perspectives around a problem (i.e. land degradation) or an issue (i.e. soil and water conservation), if the complexity of the problem is to be understood. Importance is also given to assessing different perspectives about the local soil knowledge, management and symbolism (the K-C-P complex).

A constructivist grounded theory allows to use already existing theories, non-academic publications, and personal and professional experiences to guide the collection of the data (Locke, 1996; Mazzucato and Niemeijer, 2000a). This constructivist paradigm takes into account at the same time the theories developed by conventional scientific analyses and the social theories held by local populations based on their experience with the natural and cultural contexts in which they live, struggle and work. It helps identify the endogenous development steps to be taken to satisfy local needs, desires and aspirations.

### 5.5.3. Local endogenous development

Endogenous development is a self-centered and conservationist process of growth or empowerment, which uses locally developed techniques, experience and knowledge regarding the conversion of available resources into specific end-products and services (van der Ploeg, 1992). Local endogenous development is more a perspective on rural development, strongly underpinned by value judgements about desirable forms of development, rather than a concept with clearly defined theoretical roots. It includes the local determination of development options, local control over the development process, and retention of the benefits of development within the locale (van der Ploeg, 1992, 1993; Long and van der Ploeg, 1994).

Developed at the Wageningen Agricultural University by rural sociologists, endogenous development was born as a bottom-up perspective in contrast to the conventional conceptualization and implementation of rural development as a planned top-down intervention (Long, 1989; Long, 1977, 2001; Long and Long, 1992; van der Ploeg, 1992, 1993, 1994; van der Ploeg and Dijk, 1995; van der Ploeg and Long, 1994; Arce and Long, 2000). However, endogenous development, which is founded on an actor perspective and centered on the implementation of grounded theory methodology, does not reject beneficial outcomes from the exogenous development process, as endogenous development is not exclusively based on local resources, neither is exogenous development purely the product of external elements. Both are a balance of internal and external elements. This balance results from the degree of control that local population possesses over the cultural elements, natural resources, technology and markets.

Endogenous development is recognized as a relational concept. Its essence is in contrast to exogenous development; hence, a comparative approach emerges as decisive. It is an open process and self-centered perspective searching for the understanding of the power of agency of individuals and communities on their capacity to process experience, decision-making and local action upon a series of factors, which include the specific linkages between the locality and more global constellations such as markets and policy, for example. The room of manoeuvre that globalization effects opens up for local groups and types of farming practice, and farm and commercial enterprises, is assessed to find emancipation and empowerment via local endogenous development. Methodological approaches aimed to evaluate the balance between local and external initiatives are gaining respect among scientists, policy makers and local populations through participatory research and development efforts (Toledo, 1994, 1996b, 1997; Masera et al., 1999).

The close dependency of endogenous development on local resources implies that it can have a positive impact on local interests and perspectives. However, management costs, related to labor, production and networking, are comparatively high in endogenous development, while exogenous development requires high levels of transaction and transformation costs. Therefore, compensating the costs contributes directly to local income and local investment capacities (van der Ploeg and Saccomandi, 1995b). The balance between transaction and transformation costs, on the one hand, and management costs, on the other, turns out to be decisive. In the case of endogenous development, local resources combined and developed in a local farming style are critical for assessing the utility of external elements. External elements may be used (internalized) in a local style of farming (i.e. multi-purpose natural resource management, or the maintenance and enhancement of agricultural diversity) after their deconstruction and re-composition (adaptation), so as to guarantee the maximum fit with local conditions, perspectives and interests.

The assessment of a given community to fulfill its own production-reproduction needs in a multi-purpose strategy and its cultural control and decision-making are, therefore, critical for the evaluation of local constraints and possibilities to successfully guide an endogenous development process (see section 5.4.2 in this chapter). However, both endogenous and exogenous development patterns are affected by dominant tendencies in the development of market and technology. In the first case, the production process is more skill-dependent, while in the second case it is more technology-dependent. Balancing these dependencies is a turning point towards local endogenous development success.

The study of local soil and land resources management practices and the social theories that inform them, should be guided by a political ecology research framework, based on grounded theory methodology, to assess their current and potential roles for local endogenous development, as these resources are critical for sustainable natural resource management and cultural decision-making. This turns to be an alternative way to assess the role of ethnopedology in the local endogenous development design and process.

## 5.6. Conclusion

Findings from this chapter show the importance, pertinence, scope and methodological approach of ethnopedology, as an hybrid and novel discipline seeking to understand local soil and land resources symbolism, knowledge and management (the K-C-P complex). It also discusses the pertinence and potential strength of linking ethnopedological findings with a broader political ecology research framework. As a field-based or contextual analysis, guided by grounded theory methodology, ethnopedology informs about the role that could embrace local endogenous development, by assessing past, contemporary and future constraints and potential for sustainable, bottom-up and participatory rural empowerment.

After briefly analyzing the historical development of ethnopedological research and discussing the outcomes and constraints of two conventional approaches, that is the ethnographic and analogical approaches, this chapter proposes an alternative integral approach. This emergent approach seeks to identify and mobilize the relationships between cultural and scientific information to stablish natural resource management models and modes of implementation, according to cultural, economic, political and environmental local contexts. A situated, actor-oriented and interdisciplinary approach intends to go beyond the self-limited role of ethnopedology as a discipline focused on comparing local and technical soil taxonomies, or graspping a ‘bit’ of local technical knowledge that could serve for conventional top-down rural development. To promote a step forward, the application of the K-C-P complex is encouraged, as ethnopedology is a subset of ethnoecology. Deconstructing ethnopedology requires a systemic approach that includes at least five operational dimensions (structural, dynamic, relational, utilitarian and symbolic), that guide fieldwork survey at various spatial and temporal scales. The main objective is to explore and formalize the social theory about soil and land resources that local populations put into practice. Of note is that this research approach allows to analyze social theories in locales ranging from small self-subsistence farmers to modern, highly technified and business-oriented rural enterprises.

A well-structured ethnopedological approach requires a post-positivist scientific theorization, seeking for a holistic perspective centered on the actors’ perspective and social tensions. Effort is required to overcome challenges that arise in globalized and uncertain social and natural contexts. That is the case, for example, of soil science, which requires re-centering its main objectives and goals to fulfill society’s needs and aspirations. In this way, ethnopedology could serve as a disciplinary bridge, seeking to integrate natural and cultural information on soils and land, held by different actors having heterogeneous and sometimes contrasting perceptions, knowledge and management schemes of the soil and land resources, and opposed decision-making and problem-solving procedures. In this sense, ethnopedology calls for a pluralistic approach that enhances biological, cultural and agricultural diversity for sustainable world lives and worldviews.

This chapter concludes by proposing to link ethnopedological findings to a political ecology framework, that allows understanding the complex realities that development may take, is taken or took, and how these challenges maybe turned into possibilities for local emancipation and empowerment. The role of local ethnopedologies, that is the social theories and practices related to soil and land resources, should be assessed if seeking for local endogenous development. Ethnopedology may offer insights about local ethics and moral values related to soil and land resources, and their practical consequences that led communities to historically sustain their livelihoods. using ethnopedology for future and friendly natural resource management strategies should be taken seriously if scientists, farmers and other involved actors are keen to resolve the expansion and acceleration of soil erosion and land degradation.

# CHAPTER SIX

## ETHNOPEDOLOGY IN A WORLDWIDE PERSPECTIVE

### 6.1. INTRODUCTION

In Chapter Six, the state of knowledge in ethnopedology is reviewed from an extensive literature research. This review recognizes and analyses relevant research topics and findings of ethnopedological studies (EPS) carried out around the world during the 20th century, and places EPS within different agro-ecological zones and countries having high linguistic diversity, high biological diversity and high agrodiversity. The purpose is to identify the links between current local soil and land resources knowledge and management in areas and countries having cultural and biological diversity and being (some of them) former centres of agricultural origin. This review also attempts to evaluate the imbalances of ethnopedological studies, using the Kosmos, Corpus and Praxis (K-C-P)complex as a research framework that reflects the holistic view of local peoples about nature, as discussed in chapters Four and Five.

Six main questions are addressed in this chapter. (1) What are the abundance and richness of EPS at global level? (2) Is it possible to recognize universal criteria when comparing local soil classification principles, categories and classes? (3) Is it possible to recognize links between ethnopedological richness and areas or countries having high cultural diversity, high biological diversity and high agrodiversity? (4) Is it possible to recognize common local agroecological management centred on soil fertility maintenance within similar agroecological zones at global level? (5) Are ethnopedological studies framed to integrate perception, knowledge and management of soil and land resources? (6) Which is the state of knowledge in ethnopedology?

Chapter Six is divided in seven sections. Section 6.2 attempts to recognize the main factors that influence the rapid expansion of EPS as part of major research trends in social and natural sciences developed during the last 20 years. Section 6.3 places EPS in a geographical perspective and analyses their distribution per continents and countries. Section 6.4 discusses the main ethnopedological findings and research trends. In section 6.5, ethnopedological richness is contrasted with cultural diversity, biological diversity and agrodiversity. In section 6.6, the thematic content of EPS is assessed against the K-C-P research framework proposed in chapters Four and Five.

The collection and analysis of EPS were done in a systematic way, using the software Endnote 3.0 by Niles Software Inc. (1997). Endnote 3.0 was used to build up an annotated ethnopedological database consisting of 900 references, most of which have an abstract and keywords covering four complementary topics: (1) the geographic entities having ethnopedological information; (2) the agro-ecological zones having ethnopedological information; (3) the ethnic groups being studied; and (4) the main thematic subjects (Barrera-Bassols and Zinck, 2000, 2003a). These four complementary topics allowed the sorting, processing, searching and retrieving of EPS, as a basis for making the analysis which follows. Nevertheless, further development is needed to reach a comprehensive review of the worldwide ethnopedological experience.

### 6.2. Rapid expansion of ethnopedology

Since the 16th century, foreign travelers, missioners and explorers have accounted for vast, complex and sophisticated perceptions of nature, pedological wisdom and land management systems possessed by the colonized 'noble savage" societies of Africa, America, Asia and Australia, as discussed in chapter Five. However, it was only recently that ethnopedology was recognized as a comprehensive discipline. The first structured attempts to acquire soil and land information from indigenous peoples came from social and cultural anthropologists. Cultural and environmental geographers, a few agronomists and some soil scientists have also contributed to the rapidly increasing collection of ethnopedological studies in diverse geographic entities, agro-ecological zones and ethnic territories of the world (Sillitoe, 1998; Barrera-Bassols and Zinck, 1998; Talawar and Rhoades, 1998; Niles, 1997; Winklerprins, 1999; Barrera-Bassols and Zinck, 2000, 2003a; WinklerPrins and Sandor, 2003).

During the last two decades, the number of ethnopedological studies considerably increased. Since 1989, the average production is 33 studies per year (Figure 6.1). This literature review includes 432 EPS covering 61 countries in Africa, America and Asia (Figure 6.2). The information refers to 217 ethnic groups, including a variety of indigenous people and small-farmer locations in three of the major and most fragile ecological zones of the world: (1) warm and moist lowlands, (2) warm and dry lowlands, and (3) cold and dry highlands (Barrera-Bassols and Zinck, 1998, 2000, 2003a).

Some specific cultural areas already have an extensive literature on indigenous soil and land knowledge. Middle America (Guatemala and Mexico) and the Andean region (Bolivia, Colombia, Ecuador and Peru) are the most important of such areas in America. West sub-Sahelian Africa, West Africa, East Africa, the Himalayas, India and Southeast Asia also have plentiful EPS. The studied cultural cores cover seven of the major areas of plant domestication and several countries with the highest biological and/or cultural diversity of the world. They have a set of relevant features in common:

(1) they form an important part of the major food-producing regions of the world;
(2) they are among the major rural regions of the world;
(3) they form part of the areas with the highest demographic growth rates, and
(4) they are facing increasing human-induced soil degradation (Table 6.1).

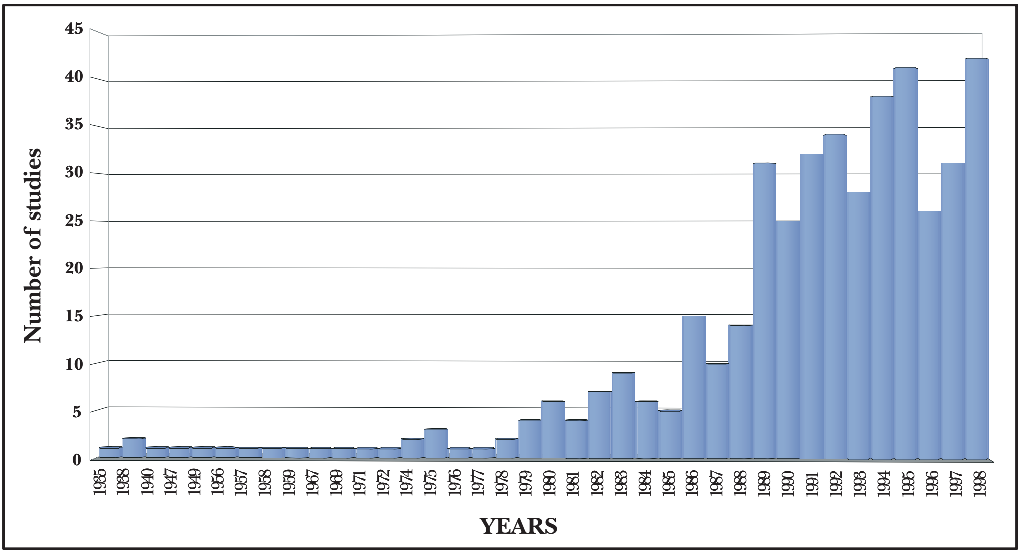



**Figure 6.1.** Number of EPS per year (1935-1998)

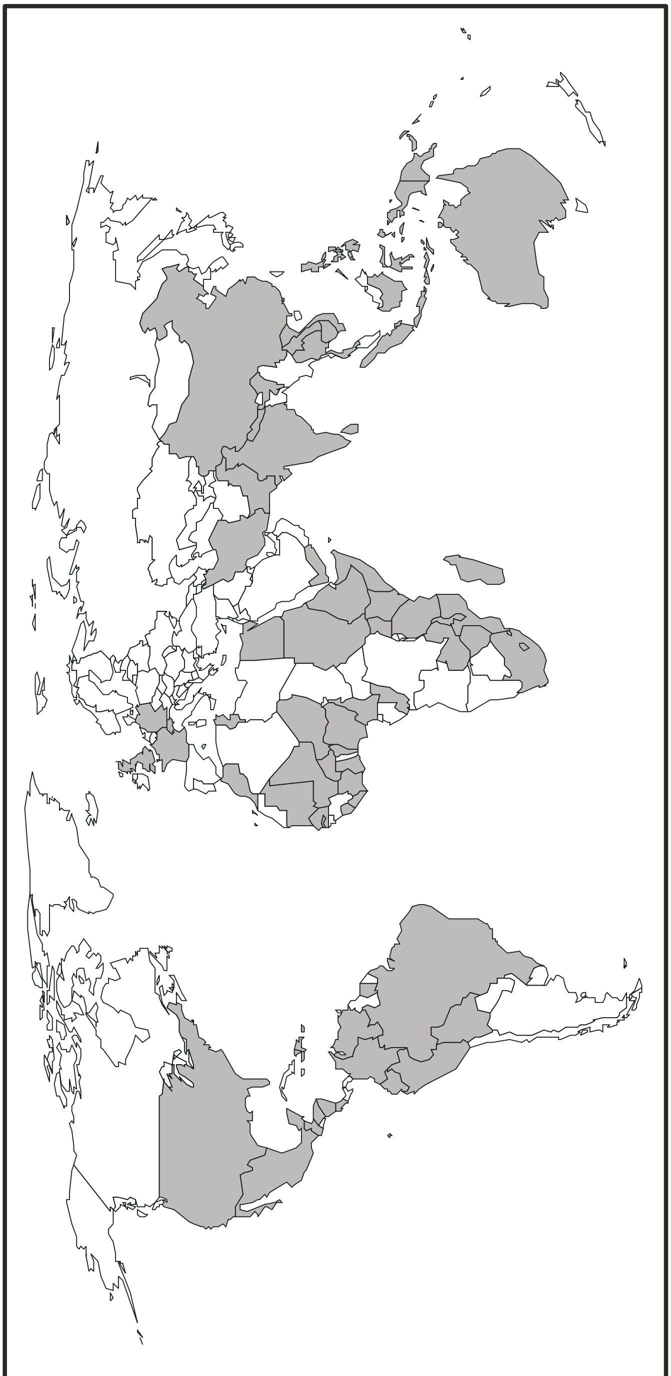


**Figure 6.2.** Worldwide distribution of EPS

**Table 6.1.** Socio-economic and environmental information of selected countries per continent having EPS

AFRICA

| COUNTRY | POPULATION (thousands) (1995)[1] | POPULATION DENSITY[1] per km² (1995) | % POPULATION GROWTH per YR [5,6] | % RURAL POP.[3] | % INDIGENOUS POP.[1,2] | NUMBER OF LANGUAGES[1] | % POP. EXTREME POVERTY[4,7] | % ANNUAL DEFORESTATION[8] | % SOIL DEGRADATION[11] | BIODIVERSITY RANKING[9] | CROP DIVERSITY[10] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BENIN | 5,573 | 49 | 2.5[6] | 59 | 82 | 51 | | 1.3 | 1,4 | | |
| BURKINA FASO | 10,382 | 36 | 2.8[5] | 92 | 90 | 71 | 58[7] | 0.7 | 4,2,1 | | |
| CAMEROON | 12,875 | 27 | 2.9[5] | 68 | 72 | 286 | 31[7] | 0.6 | 0,4,3 | | |
| CONGO | 2,289 | 8 | 2.8[6] | 44 | 87 | 60 | 29[7] | 0.2 | 0,1,2 | | |
| ETHIOPIA | 52,569 | 47 | 3.1[5] | 86 | 70 | 86 | 56[7] | 0.3 | 4,3,2 | | * |
| GHANA | 17,543 | 72 | 2.7[6] | 55 | 92 | 72 | 33[7] | 1.4 | 2,1 | | |
| IVORY COAST | 12,900 | 44 | 3.8[6] | 56 | 76 | 74 | 46[7] | 1.0 | 1,2 | | |
| KENYA | 25,732 | 49 | 3.1[5] | 78 | 99 | 61 | 26[7] | 0.6 | 1,3,4 | | |
| LIBERIA | 3,005 | 29 | 3.3[5] | 70 | 94 | 34 | 20[4] | | 0,1,2 | | |
| MADAGASCAR | 13,862 | 23 | 3.0[6] | 76 | 63 | 6 | 49[7] | 0.8 | 4,3,2 | 15 | |
| MALAWI | 9,950 | 83 | 3.0[6] | 86 | 82 | 15 | 46[7] | 1.4 | 0,1 | | |
| MALI | 10,878 | 8 | 2.6[6] | 84 | 80 | 32 | 55[7] | 0.8 | 0,4,1 | | |
| MOZAMBIQUE | 17,913 | 20 | 2.4[6] | 81 | 83 | 33 | 50[7] | 0.8 | 1,2 | | |
| NIGER | 8,313 | 7 | 3.2[6] | 89 | 78 | 21 | 67[7] | 0.4 | 0,2,1 | | |
| NIGERIA | 100,580 | 102 | 3.1[5] | 37 | 83 | 478 | 42[7] | 0.7 | 1,4,3 | | |
| RWANDA | 8,582 | 311 | 2.8[5] | 91 | 98 | 3 | 38[7] | 0.2 | 4,1 | | |
| SENEGAL | 8,448 | 43 | 3.1[5] | 74 | 50 | 39 | 49[7] | 0.7 | 2,3,4 | | |
| SIERRA LEONE | 4,726 | 58 | 1.8[6] | 67 | 99 | 23 | 59[7] | 0.6 | 1,3 | | |
| SUDAN | 29,116 | 11 | 2.5[6] | 68 | 85 | 142 | 42[7] | | 0,2,4 | | |
| SWAZILAND | 938 | 52 | 2.8[6] | 32 | 79 | 4 | 48[7] | | 3 | | |
| TANZANIA | 32,892 | 29 | 2.5[5] | 83 | 85 | 132 | 40[7] | 1.2 | 2,3,1 | | |
| ZAMBIA | 10,174 | 11 | 2.8[5] | 73 | 54 | 41 | 35[7] | 1.1 | 2,3,1 | | |
| ZIMBABWE | 11,352 | 28 | 3.2[6] | 66 | 82 | 20 | 17[7] | 0.7 | 2,1 | | |

AMERICA

| COUNTRY | POPULATION (thousands) (1995)[1] | POPULATION DENSITY[1] per km² (1995) | % POPULATION GROWTH per YR [5,6] | % RURAL POP.[3] | % INDIGENOUS POP.[1,2] | NUMBER OF LANGUAGES[1] | % POP. EXTREME POVERTY[4,7] | % ANNUAL DEFORESTATION[8] | % SOIL DEGRADATION[11] | BIODIVERSITY RANKING[9] | CROP DIVERSITY[10] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BOLIVIA | 8,421 | 6.9 | 2.7 | 44 | 75[2] | 45 | 22[7] | 1.2 | 0,3,4 | | * |
| BRAZIL | 153,725 | 18 | 1.3 | 18 | 1[2] | 236 | 29[4] | 0.6 | 0,3,2 | 1 | * |
| COLOMBIA | 34,939 | 31 | 2.0 | 23 | 11[1] | 98 | 11[7] | 0.7 | 1,3,2 | 2 | |
| COSTA RICA | 3,374 | 64 | 2.3 | 22 | 2[1] | 11 | 7[7] | 0.5 | 4 | | * |
| R. DOMINICANA | 7,915 | 159 | 1.8 | 20 | | 3 | 18[7] | 2.9 | 3,2 | | |
| ECUADOR | 12,314 | 39 | 2.0 | 28 | 31[2] | 22 | 15[7] | 1.8 | 1,2,4 | 8 | * |
| GUATEMALA | 10,621 | 97 | 2.6 | 50 | 44[1] | 53 | 35[7] | 1.8 | 4,3 | | * |
| HAITI | 7,148 | 231 | 1.6 | 65 | | 2 | 46[7] | 5.1 | 4 | | |
| MEXICO | 97,967 | 46 | 1.9 | 23 | 11[2] | 295 | 11[7] | 1.3 | 4,3 | 5 | * |
| PERU | 25,123 | 18 | 2.0 | 32 | 36[2] | 108 | 23[7] | 0.4 | 3,1,2 | 9 | * |
| VENEZUELA | 22,213 | 22 | 2.2 | 11 | 2[3] | 42 | 12[4] | 1.2 | 3,0,2 | | |

**Asia**

| COUNTRY | POPULATION (thousands) (1995)[1] | POPULATION DENSITY[1] per km² (1995) | % POPULATION GROWTH per YR [5,6] | % RURAL POP.[3] | % INDIGENOUS POP.[1,2] | NUMBER OF LANGUAGES[1] | % POP. EXTREME POVERTY[4,7] | % ANNUAL DEFORESTATION[8] | % SOIL DEGRADATION[11] | BIODIVERSITY RANKING[9] | CROP DIVERSITY[10] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **CHINA** | 1,214,221 | 124 | 1.1 | 71 | 7.5[1] | 206 | 17[7] | 0.7 | 2,4,3,0 | 4 | * |
| **INDIA** | 904,800 | 283 | 1.9 | 61 | 7[2] | 418 | 37[7] | 0.6 | 3,0,4 | 12 | * |
| **INDONESIA** | 195,623 | 102 | 1.6 | 53 | 85[1] | 717 | 21[7] | 1.1 | 2,3,4 | 3 | * |
| **KAMPUCHEA** | 9,205 | 55 | 2.9 | 73 | 89[1] | 17 | 52[7] | 1.0 | 2,3,4 | | * |
| **MALAYSIA** | 19,186 | 58 | 2.3 | 22 | 4[2] | 46 | 17[7] | 2.1 | 3,1,4 | 14 | * |
| **NEPAL** | 20,188 | 152 | 2.4[6] | 93 | 91[1] | 125 | 53[4] | 1.0 | 1,3,2 | | * |
| **PAPUA, N.G.** | 4,553 | 9 | 2.3[6] | 77 | 66[2] | 826 | 32[7] | 0.3 | 0 | | |
| **PHILIPPINES** | 69,922 | 221 | 1.9 | 41 | 1[2] | 171 | 18[7] | 3.4 | 3 | | |
| **SOLOMON IS.** | 389 | 13 | 3.4[6] | 75 | 51[1] | 71 | | | 2 | | |
| **SRI LANKA** | 18,320 | 274 | 1.7[6] | 46 | 89[1] | 8 | 21[7] | 1.4 | 4,3,2 | | |
| **THAILAND** | 59,605 | 115 | 1.4 | 59 | .8[2] | 76 | 12[7] | 3.5 | 4,3 | | * |
| **VIETNAM** | 75,030 | 218 | 1.8 | 70 | 94[1] | 87 | 26[7] | 1.5 | 4,3 | | * |
| **YEMEN** | 16,102 | 2 | 3.0[6] | 56 | 92[1] | 8 | 48[7] | 0.0 | 3,2 | | |

**Sources:**

(1) Grimes, B. F. 1996. Ethnologue. Summer Institute of Linguistics. Dallas, Texas, USA.
(2) Durning, A.T. 1992. Guardians of the land: indigenous peoples and the health of the earth. Worldwatch paper no. 12, Worldwatch Institute, USA.
(3) Toledo, V. M. 1994. La apropiación campesina de la naturaleza: un análisis etnoecológico. PhD Thesis, UNAM, Mexico.
(4) Poverty % of people living on less than US$ 1 per person per day, 1981-1995. The World Bank. 1997. World Development Report. Oxford University Press, UK.
(5) SPSS 7.5, World95m.sav. Population growth rates.
(6) UNDP. Human Development Report 1997, Oxford University Press, UK.
(7) HPI Index (Human Poverty Index): concentrates on deprivation in three essential elements of human life: (a) longevity (people not expected to survive age 40), (b) percentage of adults who are illiterate, and (c) the deprivation in a decent living standard in terms of overall economic provisioning (% of people without access to safe water, % of people without access to health services, and % of moderately and severely underweight children under 5). Human Development Report 1997, UNDP, Oxford University Press, UK.
(8) The World Bank. 1997. World Development Report, Forest and Water Resources (Table 10, Annual Deforestation, 1980-90), Oxford University, UK.
(9) Megabiodiverse countries. McNeely, A. 1988. Conserving the World's biological diversity, IUCN.
(10) Countries with high genetic diversity of crop varieties. Reid, W. V. and K. R. Miller. 1989. Keeping options alive: the scientific basis for conserving biodiversity. WRI, USA.
(11) ISRIC/UNEP. 1991. World map of the status of human-induced soil degradation. The Netherlands. Ranking values are (0) Stable, (1) Low, (2) Medium, (3) High, and (4) Very High. Ranking values shown per country cover more than 80% of their extent and are arranged per decreasing importance cover.

There are three major explanations for the increase of EPS during the last 20 years, paralleling a general increase of interest for social sciences as highlighted by Wallerstein (1996).

(1) Since the beginning of the 1980s, social scientists have shown more interest in understanding non-western societies as emerging subjects, facing specific and multi-facetted ecological, cultural and political challenges after the deepening of their economic crisis and the resulting poverty. The weakening of the national states due to the globalization process has increased ethnic autonomy claims, national minority violence, and the reappearance of racism and cultural conflicts (Appadurai, 1996).

(2) There is also a need to better understand local communities because rural development as the paradigm of modernization failed in many parts of the underdeveloped world, including the collapse of the Green Revolution and the resulting environmental degradation with uncertain food security in the coming future (Pretty, 1995).

(3) Local studies from the natural and social sciences focus on the political and ecological consequences of globalization and support the local sustainable production systems in traditional rural cultures. However, compared with the abundant biotechnological and crop-transgenic research -the new agricultural paradigm-, the lack of interest in exploring contextual solutions to pressing food production and distribution issues still reflects the mechanistic agronomic misconceptions of the rural world (Kloppenburg, 1991; Toledo, 1992A and 2000; Cleveland, 1998; Mooney, 1998).

## 6.3. Geographical distribution of EPS

From a total of 900 references analyzed, 432 (48%) correspond to EPS proper, the others being of broad ethnopedological interest. Ethnopedological studies are distributed over 61 countries of which 35% are in Africa, 34% in America, 26% in Asia, 4% in Europe and 1% in the Pacific area. Africa has the highest number of EPS (41%), followed by America (23%), Asia (23%), Europe (8%) and the Pacific (5%) (Figure 6.3). As continents have variable numbers of countries, in fact Africa, America and Asia have been equally addressed by ethnopedological research, with about 50% of the countries in each continent having one or more EPS. In contrast, Europe and the Pacific area have been less studied. Of all tropical areas, the Pacific is the most neglected, although it has an important rural population, many ethnic groups and the highest linguistic diversity. From a worldwide total of 5000 endemic languages, 1600 are spoken in the Pacific islands (Harmon, 1996). Linguistic diversity parallels ethnopedological richness, since oral tradition conveys the local wisdom and know-how from generation to generation (UNESCO, 1996). As many endemic languages are threatened with disappearance, ethnopedological knowledge will also get lost.

Among individual countries, Mexico, Nepal, Peru, Nigeria and India are the most studied, having more than 20 EPS each and concentrating 41% of all EPS (Figure 6.4). With 71 EPS, Mexico dominates. The current EPS abundance figures do not necessarily reflect intrinsic differences in ethnopedological richness between countries, as access to grey literature, NGOs promoting EPS in some privileged countries and other factors play a role as well.

## 6.4. Ethnopedological findings and research trends

Ethnopedological findings cover a wide topical array centered on four main subjects: (1) the formalization of local soil and land knowledge into classification schemes, (2) the comparison of local and technical soil classifications, (3) the analysis of local land evaluation systems, and (4) the assessment of agro-ecological management practices.

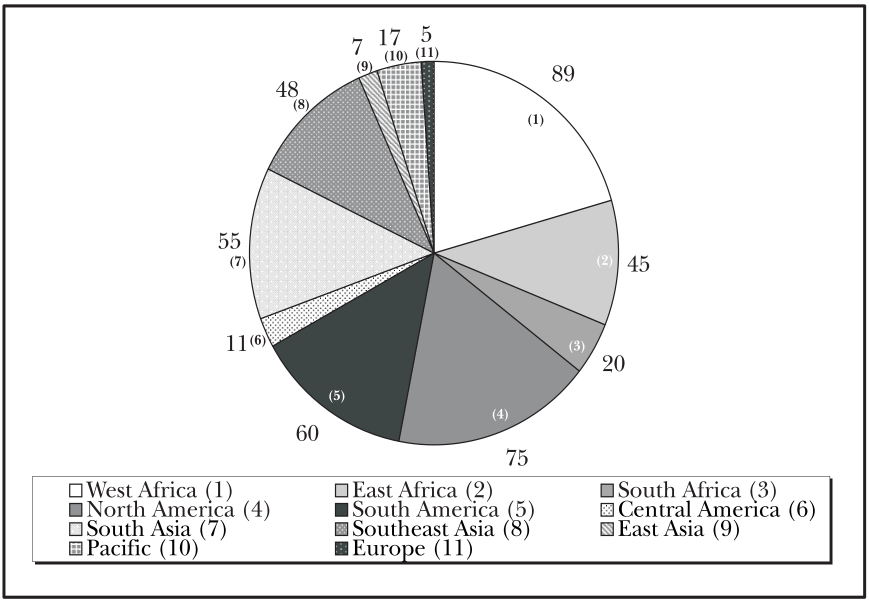



**Figure 6.3.** Distribution of bibliographic references according to continental and sub-continental areas (Number of EPS in bold)

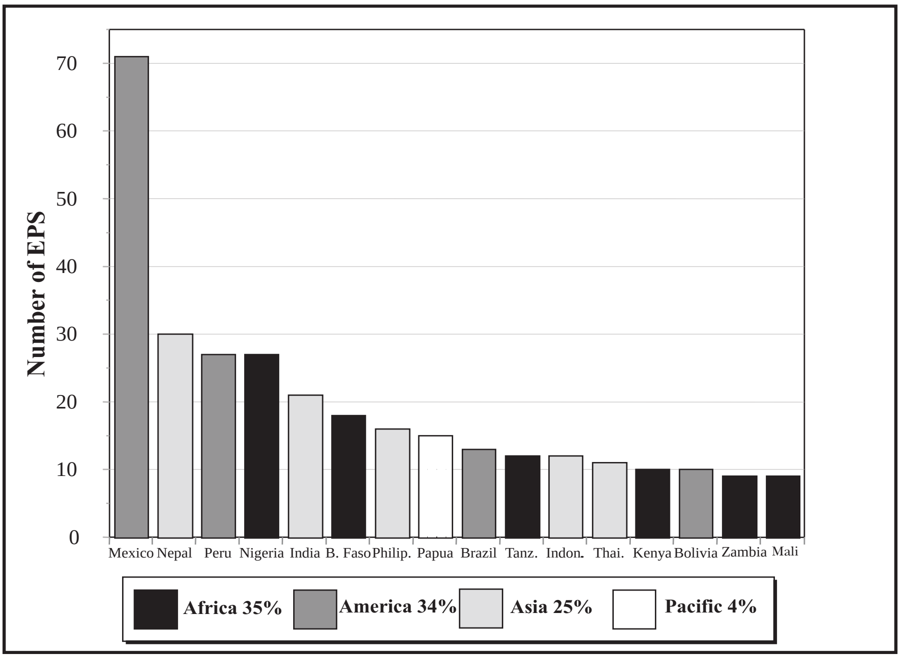



**Figure 6.4.** Countries with high numbers of EPS

### 6.4.1. Classification principles, categories and classes

Major approaches to soil and land classification by indigenous peoples were derived from the comparative analysis of a sample of EPS. These record traditional taxonomic systems implemented by 62 ethnic groups located in 25 countries in Africa, America and Asia (Barrera-Bassols and Zinck, 1998).

(1) In spite of methodological inconsistency among the reviewed studies, making the comparative analysis cumbersome, some general principles can be identified, including: (a) the existence of a complex system of indigenous knowledge about the hierarchical organization of the soil mantle; (b) the recognition and implementation of morphological attributes for soil classification, which are at the same time dynamic, utilitarian and symbolic; (c) the use of similarities and differences between soil bodies for constructing multi-categorical classification systems, and (d) the existence of universal criteria in all ethnopedological classification systems.

(2) Although indigenous knowledge about soil and land resources is widely shared by all members of a community, there are differences in wisdom among people according to age, gender, social status and experience. The same questions about the soil system might be given different answers by local people, which together constitute the ethnopedological knowledge of a community and its social theory of the soil system.

(3) The multi-purpose character of the ethnopedological classifications implies variable ways to organize and distribute the soil classes within a multi-level system. The inclusion or exclusion of given soil classes, their variable positioning in the categories of the system, all depend on the classification criteria assigned, which might be ecological, morphological, productive or symbolic, among others.

(4) Four sets of classification criteria are used by the sampled ethnic groups. The proportion of the groups implementing a given criterion is indicated as a percentage of the total number of groups. The four sets are: (1) color (100%) and texture (98%); (2) consistence (56%) and soil moisture (55%); (3) organic matter, stoniness, topography, land-use and drainage (between 34 and 48%); and (4) fertility, productivity, workability, structure, depth and soil temperature (between 2 and 26%) (Figure 6.5).

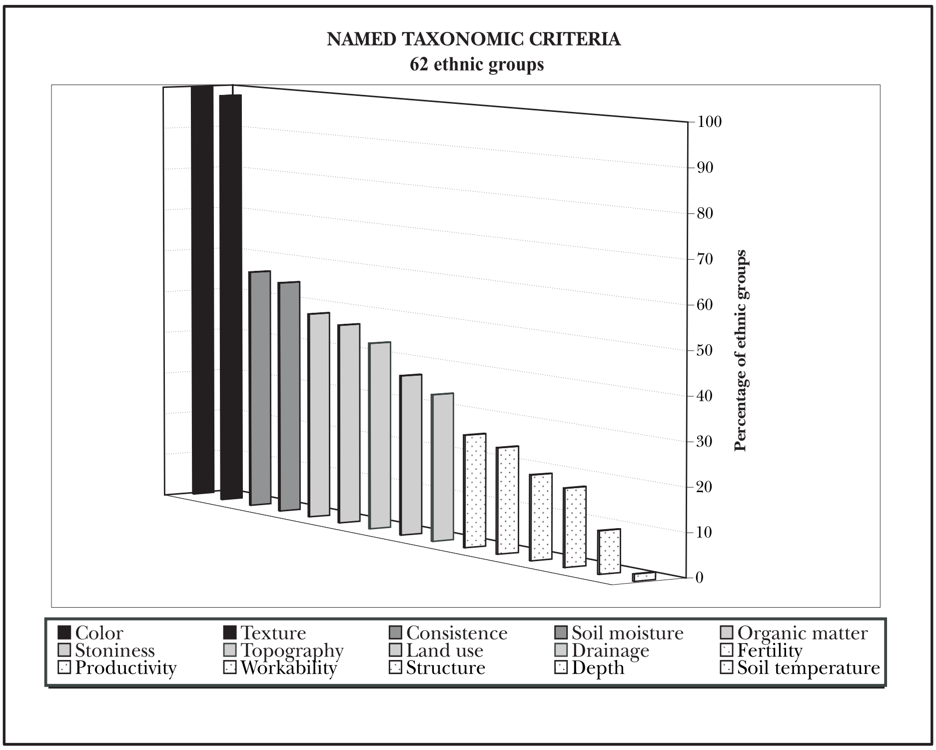



**Figure 6.5.** Characteristics and qualities used b y local peoples to classify soils.

(5) The diagnostic attributes most frequently used to label soil classes are morphological ones. Among these, color and texture are the most representative. More comprehensive attributes, such as fertility or workability, which are in fact land qualities, are indirectly implemented. Of note is that there is no clear-cut distinction between soil and land characteristics.

(6) Unlike the ethnobotanical and ethnozoological classifications (Berlin, 1992), the ethnopedological classifications generally start at the higher level of the system, with a comprehensive realm concept including all "soils", the equivalent of Plantae or Animalae in the other natural realms.

(7) Unlike the ethnobiological taxonomic systems, which cluster only selected species occurring locally (Berlin, 1992), the ethnopedological classifications generally include all or most of the soil classes encountered locally.

(8) Considering all studies included in the inventory, the number of taxa (soil classes) belonging to the different systems recorded varies from 3 to 24. The average number of taxa recognized per ethnic group is 12. More than half (56%) of the sampled groups work with 8 to 14 taxa.

### 6.4.2. Comparison of local and technical soil classifications

There are some significant similarities and complementarities between indigenous and scientific soil taxonomic systems showing potential synergism, especially for solving problems related with soil and land management (Talawar and Rhoades, 1998; Ericksen and Ardon, 2003). A few examples are provided to illustrate this potentially fertile research area.

A cluster analysis of related soil morphological attributes highlights a close correspondence with an indigenous soil classification system from northeastern Brazil. Thus, the empirical soil classification could be a useful framework for objectively grouping morphologically similar soils. The clustering of non-morphological attributes around key parameters, such as moisture and pH, and the comparison with main indigenous soil classes also show that indigenous soil taxonomy provides a reasonable framework for the preliminary stratification of soils for management purposes (Queiroz-Stacishin and Norton, 1992).

Ten years of ethnopedological research findings in the Himalayas demonstrate a close correlation between indigenous and conventional soil taxonomies (Tamang, 1993). Most of the indigenous classes can be readily converted into commonly used scientific classification schemes. Also, a close correlation between indigenous soil colour classes and soil chemical conditions reveals that farmers are well aware of the unique differences between soil colour and associated properties. Furthermore, there is a strong correlation between indigenous land classes and soil fertility. Local land quality classes for agricultural purposes correlate well with selected chemical properties (e.g. levels of cation exchange capacity and exchangeable cations), particularly in those soils, which have not been altered by chemical fertilizers (Shah, 1995).

Similarly, statistical analysis of physical and chemical properties has been used to show that local soil classification systems match or reflect scientifically defined soil properties. This is the case of the Hanunoo classification in the Philippines (Conklin, 1957), a local classification in Nepal (Shah, 1993), the Maya-Kekchi classification in Guatemala (Carter, 1969), a Mestizo classification in Mexico (Bellón, 1990), the Michiguenga classification in Brazil (Johnson, 1983), the Shipibo classification in Peru (Behrens, 1989), the Guidimaka classification in Mauritania (Bradley, 1983), the Fulani classification in Burkina Faso (Krogh and Paarup-Lauresen, 1997), and a small-farmers' classification in Ghana (Mikkelsen and Langohr, 1997).

Indigenous and conventional knowledge systems are equally limited in their abilities to mitigate or prevent soil erosion hazards in the Himalayas. Both, however, have also extensive complementarities, considering the time frame and spatial scale of the responses provided by each system. Indigenous knowledge responds primarily over the long-term and takes into account off-site effects of soil loss. Complex soil-landscape management and land-use planning strategies constitute local responses to each specific erosion event over a decadal perspective. In contrast, conventional science primarily formulates general responses to individual erosion events and operates fundamentally on the site and over the short-term. Structural and vegetative techniques are implemented to reduce downstream sedimentation. The complementation of local and conventional approaches and techniques in the Shivalik Himalayas in India promotes increased productivity and drastically reduces sedimentation in eroded agricultural lands (Scott and Walters, 1993). Similarly, local responses to soil erosion have been well studied in Africa (Reij et al., 1996; Warren et al., 2003), in the Andean region of South America (Zimmerer, 1992; Rist and Martin, 1993; PRATEC, 1996), in Middle America (Johnson, 1977; Donkin, 1979; Bocco, 1991) and in Asia (Leslie, 1997).

One of the main issues mentioned in several ethnopedological reports is the inconsistency of indigenous soil knowledge at regional scale. Indigenous soil and land classes are often named and characterized differently by members of the same ethnic group but from different villages, while technical soil surveys indicate a regional distribution of the same soil classes. This could result from the application of unsuitable research techniques or from real historical or cultural differences. Indeed, examples of ethnopedological research in Mexico reveal the existence of a region-wide soil knowledge among Maya, Nahua, Otomi and Purhépecha peoples, as shown in chapter Ten. The naming and characterization of soil and land classes are relatively homogeneous over thousands of square kilometers, forming a regional "folk soil culture" (Barrera-Bassols, 1988). Over the last 15 years, a methodological approach was developed in Mexico to map indigenous soil units at plot, local and regional scales; this contributed to strengthening the ethnopedological survey and rural land-use planning (Ortíz-Solorio, 1989 and Ortíz-Solorio and Gutierrez-Castorena, 2001). The combination of photo-interpretation and ethnopedological survey has revealed, in some cases, close correspondence between conventional soil map units and ethnopedological map units (Licona et al., 1992; Payton et al., 2003).

### 6.4.3. Local land evaluation systems

Many ethnic groups and small-farmer communities have created their own land evaluation systems for agricultural purposes. Assessment criteria, requiring a sophisticated micro-environmental knowledge, are used to establish multiple cropping systems (Osunade, 1992a and b; Gonzalez, 1994; Mafalacusser, 1995; Lawas and Luning, 1996). In general, land-use decisions made by local people are more accurate and better adapted than the technical recommendations forwarded by extensionists. The integration of both knowledge sources, using geographic information systems -GIS- (Gonzalez, 1995; Jarvis and MacLean, 1995; Weiner et al., 1995; Lawas and Lunning, 1997; Harmsworth, 1998, Gonzalez, 2000; Brodnig and Mayer-Schönberger, 2000; Oudwater and Martin, 2003) and knowledge-based systems -KBS- (Furbee, 1989; Guillet, 1989 and 1992; Guillet et al., 1995; Balachandran, 1995; Payton et al., 2003) for land evaluation and land-use planning, is a promising new stream of research and application.

### 6.4.4. Agroecological management practices

Land and water management by indigenous groups varies in accordance with the conditions prevailing in each ecological zone. In the warm and moist lowlands, the indigenous perception, knowledge and management of the land center on fertility conservation or restoration using complex agro-ecological systems. Farming strategies mobilize an accurate knowledge of the micro-local soil conditions to select a variety of adapted crop associations (Fujisaka et al., 1996). Usually, agricultural fields are densely covered with plants to maintain soil productivity. Color changes in the topsoil are used to monitor the fertility status and for early identification of potential productivity decline.

In the warm and dry lowlands, the main issue of crop production is the scarcity and irregularity of rain water supply. Local techniques have been developed for water harvesting and soil moisture conservation, especially in Africa (Critchley et al., 1994; Reij et al., 1996; Mazzucato and Niemeijer, 2000a). Common indigenous land management strategies include soil protection from erosion, salinization control, moisture maintenance in the arable layer, and disposal of sediments carried by intermittent streams. In the cold and dry highlands, indigenous wisdom concentrates on protecting the soil from erosion and mitigating the effect of natural hazards on soil fertility. A variety of ethnopedological studies has been carried out in the Andes (Sandor and Eash, 1995; PRATEC, 1996) and in the Himalayas (Tamang, 1993) to investigate the local techniques used for terrace and bench construction.

A growing number of ethnopedological studies focuses on the local perception, knowledge and management of soil fertility. In Africa, Amanor (1991) recognized a sophisticated soil fertility theory and management among small farmers from Ghana. Browers (1993) studied the Adja people's soil fertility management in Benin. Prudencio (1993) studied soil fertility management among the Mossi, while Mazzucato and Niemeijer (2000a) conducted a similar study among the Gourmantché, both from Burkina Faso. In Asia, Talawar (1991) and Rajasekaran (1993) studied the soil fertility theory and management of small farmers in semi-arid southern India, while Tamang (1993) conducted a similar study among small farmers of Nepal. In America, Wilken (1989) analyzed soil fertility management among small farmers of central Middle America. Hecht and Posey (1989) did an extensive research on the soil fertility knowledge and management among the Kayapó of Brazil. A large review of local soil fertility knowledge and management from several examples in Africa, America and Asia, was conducted by Kotschi et al. (1990a and 1990b) as part of what they call ecofarming practices. Several other studies have been carried out to analyze how local farmers match crops and crop varieties with the fertility status of different soils (Malinowski, 1965; Netting, 1968; Fujisaka, 1988a; Behrens, 1989; Talawar, 1991; Osunade, 1992a; Bellón and Taylor, 1993; Kerven et al., 1995; Sillitoe, 1996).

## 6.5. PEOPLES AND ETHNOPEDOLOGICAL DIVERSITY

Ethnopedological research is revealing high diversity and richness of the ways soil and land resources are perceived, known and managed according to a wide array of cultural, biological and agro-ecological contexts. The links between these dimensions and EPS are given in a worldwide perspective, in an attempt to recognize the importance and distribution of ethnopedological studies in the most diverse and fragile areas of the world. The amount of research needed to fully understand local responses to soil and land fragility, scarcity and degradation in the Third World is also emphasized.

### 6.5.1. Linguistic diversity and EPS

In total, 217 ethnic groups have one or more EPS, 35% in America, 33% in Africa, 28% in Asia and 4% in the Pacific area. Mexico and India together cover 18% of all ethnic groups having ethnopedological information. In Mexico alone, 41% of the country's ethnic groups (56 in total) have been studied from an ethnopedological point of view, as shown in chapter Ten. Taking into account the existence of about 5000 endemic languages (Harmon, 1996a; Maffi, 1998), barely 5% of the global ethnopedological knowledge has been addressed. Local languages, now used by small ethnic groups, are likely to vanish in about 90% during the next century (Maffi, 1999). This highlights the magnitude of the effort needed to inventory and analyze the peculiar forms of perception, knowledge and management of the soil and land resources by indigenous peoples before they disappear altogether. It is expected that the loss of linguistic diversity will be 500 times larger than that of biological diversity (Krauss, 1992). This means that the loss of ethnopedological knowledge might be of considerable proportions, qualitatively as well as quantitatively.

Eight of the 15 countries with the highest numbers of EPS (from 9 to 71) belong to the 19 countries with the largest linguistic diversity (Grimes, 1996). Linguistic diversity is extremely high (megadiversity) in Indonesia and Papua New Guinea, very high in India and Mexico, and high in Brazil, the Philippines, Tanzania and Nepal (Figures 6.6 and 6.8). There is thus a clear relationship between linguistic and ethnopedological diversities.

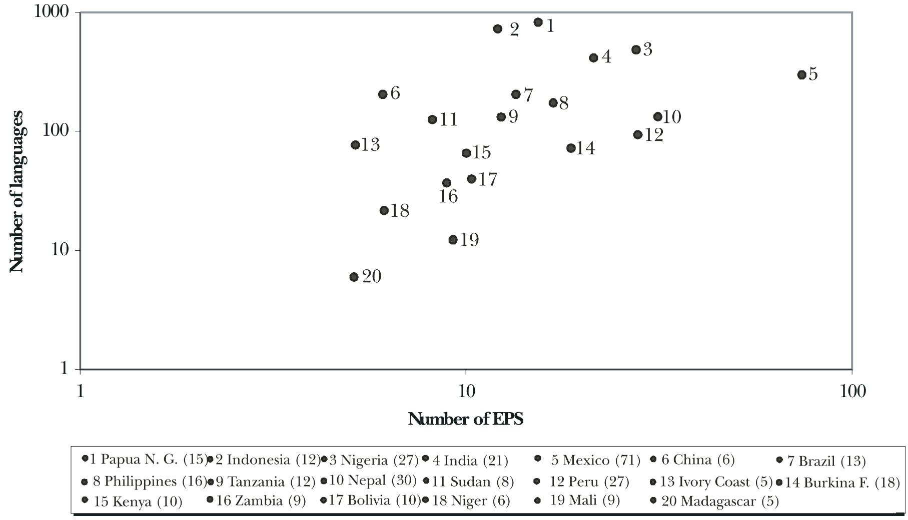



**Figure 6.6.** Relationship between variety of local languages and abundance of ethnopedological studies (EPS), considering 20 countries with highest linguistic diversity and with 5 or more EPS (From 5 to 71 EPS)

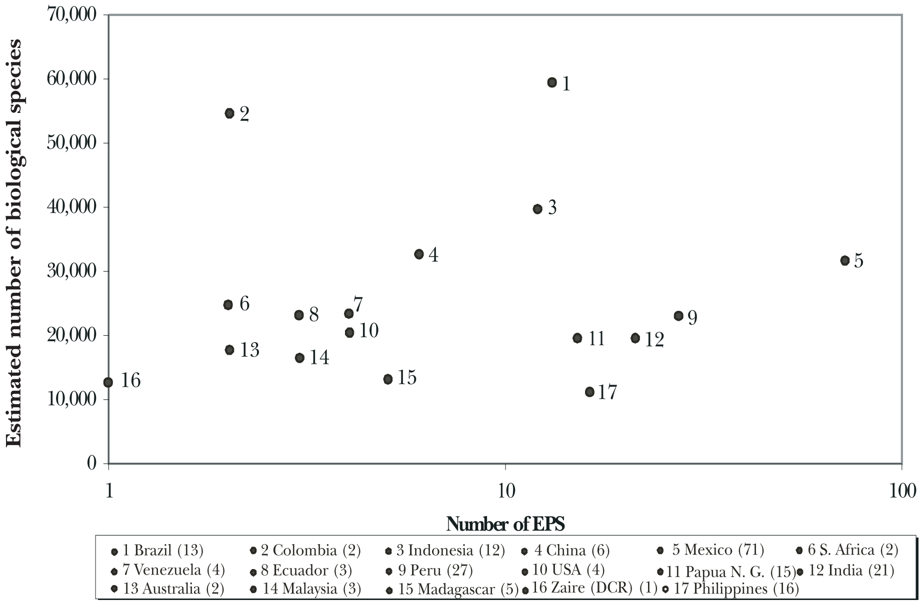



**Figure 6.7.** Relationship between variety of biological species (mammals, birds, reptiles, batrachians, and vascular plants) and abundance of ethnopedologicl studies (EPS), considering 17 countires with highest biodiveristy and with ethnopedological information (From 1 to 71 EPS)

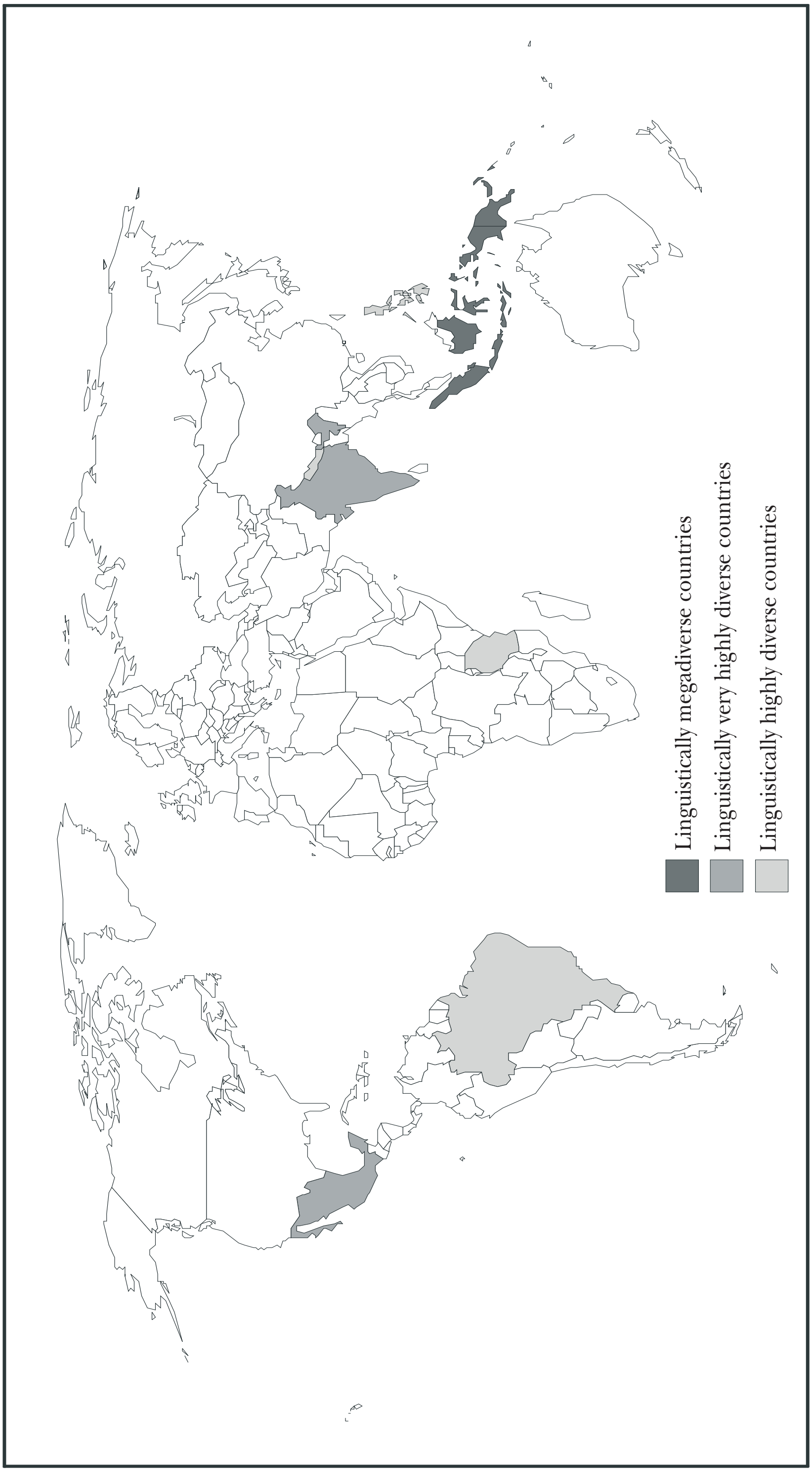



**Figure 6.8.** Distribution of EPS in countries with high linguistic diversity

**Figure 6.9.** Distribution of EPS in countries with high biological diversity

### 6.5.2. Biological diversity and EPS

A similar high correlation links ethnopedological richness to biological diversity. Countries with extremely high and very high biological diversity (ICF, 1998) and having, at the same time, large numbers of EPS include Brazil, Indonesia, Mexico, Peru, Papua New Guinea, India and the Philippines (Figures 6.7 and 6.9).

There is also a strong relationship between the original centers of plant domestication in the world (Vavilov, 1926) and the density of EPS (Figure 6.10). Eleven out of 15 countries with large numbers of EPS match six of the 12 early domestication centers. They include Mexico (South Mexico–Central America center), Peru and Bolivia (South America center), Brazil (Southern Brazil–Paraguay center), Nigeria (West Africa center), India and Nepal (India–Burma center), and Indonesia, Thailand, Papua New Guinea and the Philippines (Indo–Malaya center). These same countries also belong to the major food production areas of the world.

### 6.5.3. Agro-ecological zones and EPS

Agro-ecological zones, broadly defined from a loose combination of elevation, topography and climate, are appropriate environmental units to assess the abundance of EPS. This is the case since local peoples have developed, over time, knowledge and abilities to efficiently exploit and manage the ecological heterogeneity of the landscape (Figure 6.11).

A remarkable feature is that dry (arid and semi-arid) areas have attracted more ethnopedological research than humid areas. About 66% of the EPS analyzed have been carried out in dry-cold highlands and dry-warm lowlands. Semi-arid areas alone concentrate 37% of the EPS. From a total of 232 studies, which provide specifically agro-ecological information, 29% are located in dry areas. A few selected regions have received particular attention, including the Sahel and sub-Sahelian Africa, semi-arid India and northern Mexico. In these areas, local peoples have developed sophisticated land and water management practices to overcome water scarcity and unpredictable rainfall variability. These areas are also exposed to severe land degradation because of intensive land pressure following rapid population growth, resources depletion through uncontrolled over-exploitation, and mismanagement of irrigation schemes. Furthermore, dry environments are particularly sensitive to global climate change and therefore strongly famine-prone.

Comparatively, the tropical warm and moist lowlands have received less attention, concentrating 34% of the EPS, with 21% in the humid tropics and 13% in the sub-humid ones. Even less attractive have been so far the temperate environments, with only 13 EPS (mainly from Mexico), representing 5% of the studies recorded. Similarly, cold areas account only for 16% of the EPS, concentrated in the Himalayan and Andean highlands.

Altogether, the tropical zone has by far the highest number of EPS (186 studies, 72%). Within this general context, the most frequently studied areas include (1) the dry tropics in Africa, Asia and America, and (2) the moist tropical lowlands in Brazil, West Africa, Mexico and Southeast Asia. The 15 countries with the highest numbers of EPS cover the most fragile agro-ecological zones of the world and correspond to the countries with high indices of extreme poverty and severe land degradation.

## 6.6. TOPICAL DIVERSITY OF EPS

Peoples' cosmovision, including beliefs, perceptions and rituals (the Kosmos sphere) has been approached in only 69 out of 432 EPS (16%). This reflects relatively little interest for the subjective component of indigenous knowledge. The latter is, however, of fundamental importance when formulating development projects and planning rural land-use. Neglecting cultural context and rules has led to the failure of many development programmes in the Third World.

A large number of EPS (245 studies, 57%) addresses, among other topical fields, the analysis of the local cognitive systems, including knowledge and classification (the Corpus sphere). A significant research domain

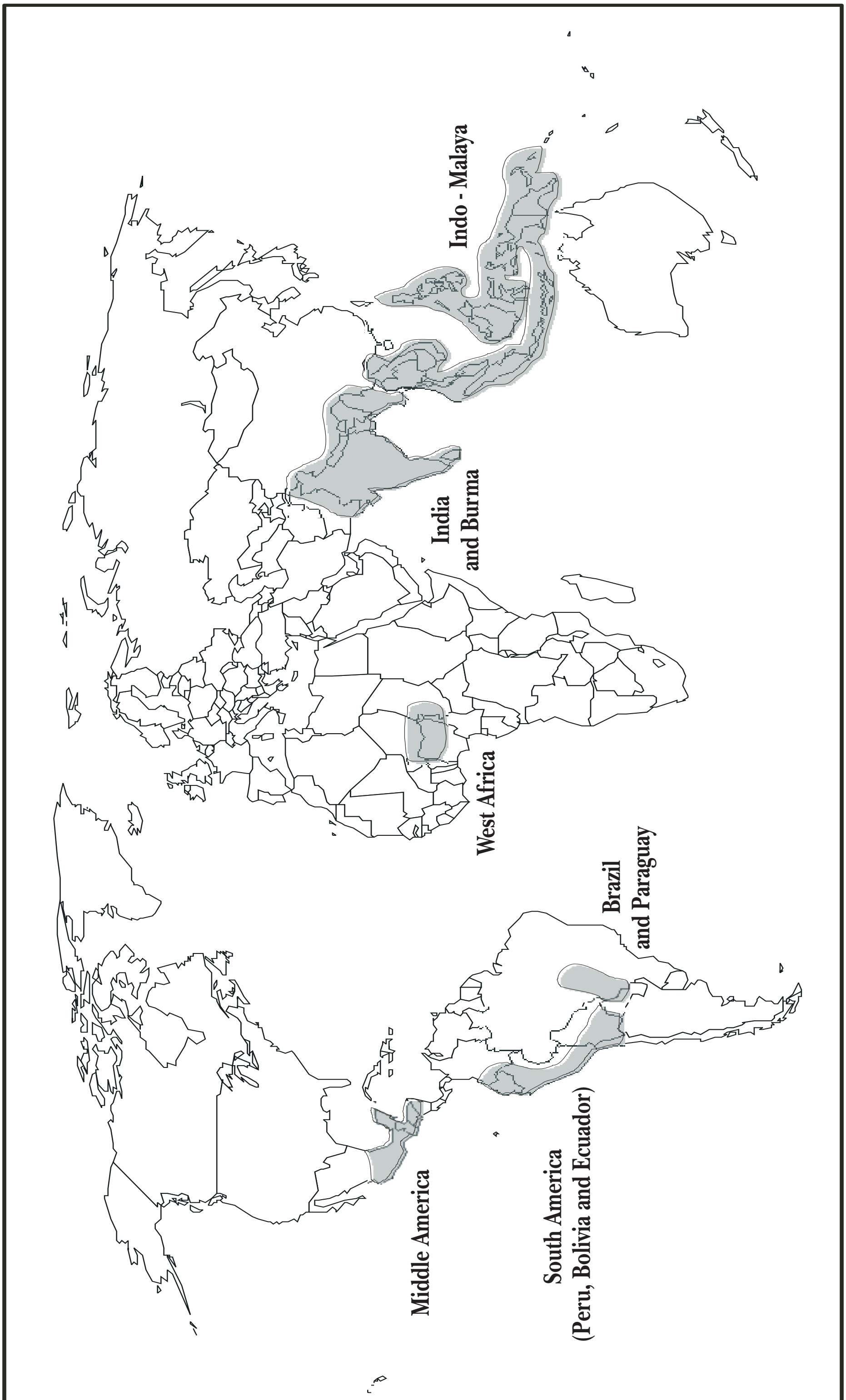



**Figure 6.10.** Centers of plant domestication having EPS

(158 EPS, 36%) is on ethnopedological taxonomies and the comparison of local and scientific soil and land classifications. A similar dominant trend exists in ethnobiological studies and other ethnosciences.

A third field of interest in EPS focuses on the inventory and analysis of local management practices (the Praxis sphere). This topic is not restricted to EPS and comes up frequently in studies of broad ethnopedological interest as well (in total 532 out of the 900 recorded references). Of note in this context is the importance devoted to the indigenous soil and water conservation practices (ISWC) in 113 EPS, carried out mainly in arid and semi-arid areas including the cold and dry highlands. These EPS focus on the inventory and implementation of local practices, mechanical as well as biological ones, but often neglect to scrutinize the cosmovision context that could explain why and when the practices are used.

A growing number of EPS deals with soil fertility management (72 EPS), soil conservation and erosion control (72 EPS), and soil management in general (92 EPS). This reflects an increasing concern for the land degradation issue and the importance of soil management at the field level. Also, more and more attention is given to spatial soil variability as related to the genetic diversity of cultivars, the pattern of intensive polycultural land-use, and the management of specific agro-ecological niches.

### 6.7. Conclusion

Peoples' knowledge about soils and their management constitutes a complex wisdom system, with some universal principles and categories similar or complementary to those used by modern soil science. Although an integral ethnopedological approach needs still to be developed, by combining the current trends, a promising bottom-up approach is gaining interest among scientists and farmers. Synergism could be strengthened by the implementation of GIS and KBS to integrate modern scientific and technical advances with historical wisdom and local needs.

At a worldwide scale, EPS are unevenly distributed. Some geographic entities from continental to village levels, have been privileged, others neglected. The frequency of studies decreases from Africa to America, Asia, the Pacific and Europe. Large differences in study density occur within subcontinents, countries and subdivisions of countries. Individual countries, which have particularly attracted the interest of researchers and provided a substantial number of the references, are Mexico, Nepal, Peru, Nigeria and India. Within countries, the village is the preferred study level, as the majority of EPS focuses on the perception, knowledge and management of the soil resource at the local level. Since most EPS are concentrated in a few countries, the result is that some ethnic groups have received more attention than others.

Communities living in harsh environments, with limited resources, have developed complex land and water management systems to compensate for resource scarcity. Surviving indigenous communities are often restricted to marginal lands, while the better soils are devoted to large-scale, market-oriented, mechanized agriculture. Therefore, EPS concentrate in a few broadly defined agro-ecological zones. Highest densities of EPS occur in dry lowlands and highlands, where the need of efficiently handling scarce natural resources has fostered intimate co-evolution of eco- and socio-systems.

The present imbalance of topical research between the Kosmos, Corpus and Praxis spheres, respectively, suggests that more emphasis should be given to analyzing the role of beliefs, perceptions and rituals in decision-making by local peoples about land-use management. Shifting the research emphasis on Kosmos needs the support of and interaction with the local communities, especially those which are still able to maintain their K–C–P systems active for the preservation of the soil quality and that of the agro– and biodiversity. Without the participation of the local actors in the formulation and implementation of rural development programmes, the EPS would lose their practical relevance, as is often the case of conventional soil inventories.

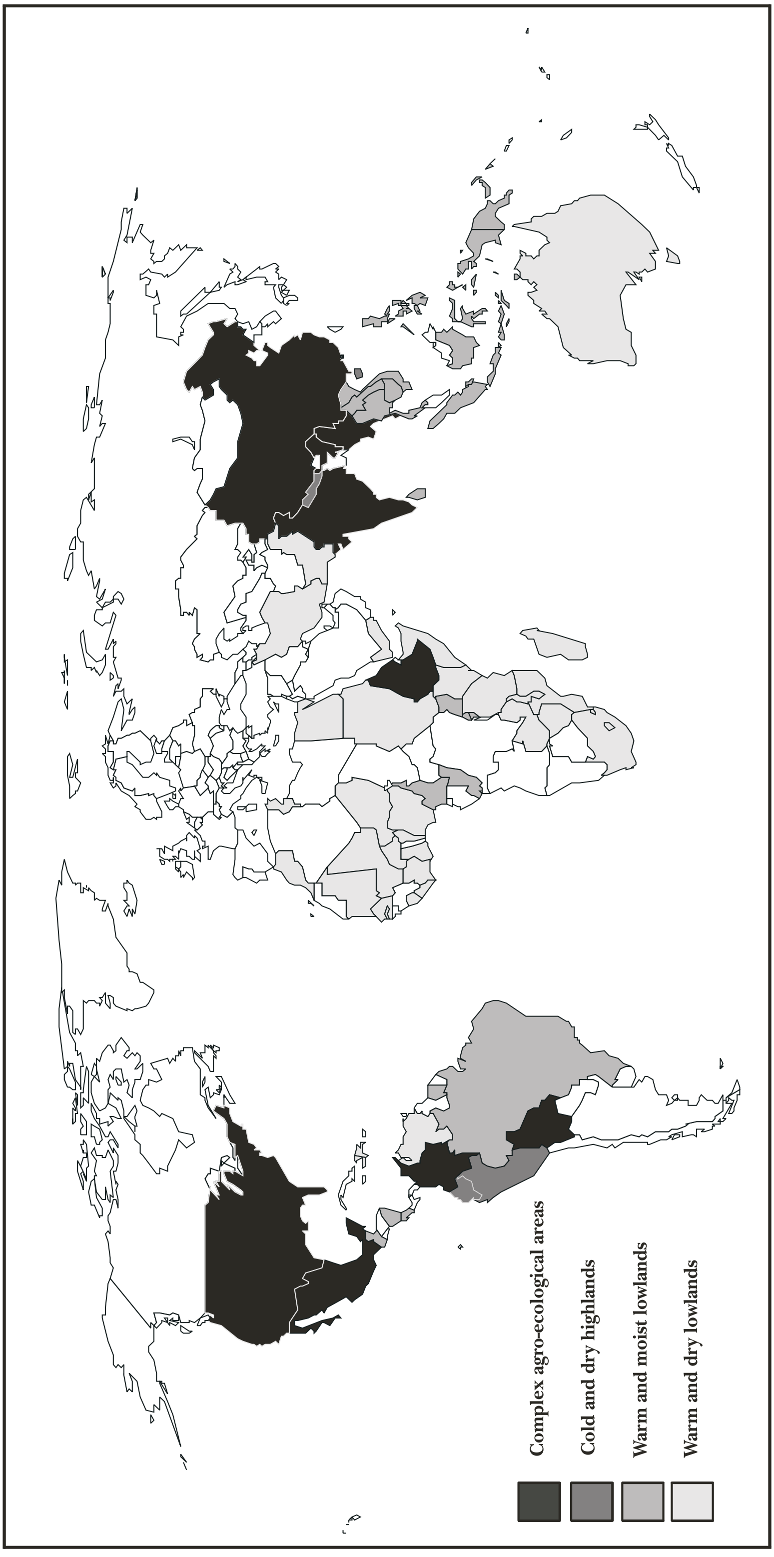



**Figure 6.11.** Worldwide distribution of ethnopedological studies per main agroecological zones

| AGRO-ECOLOGICAL ZONES | AGRO-ECOLOGICAL MANAGEMENT |
|---|---|
| **Warm and dry lowlands** | **Main biophysical constraints:** scarcity and irregularity of rainfall.<br>**Local measures:** mechanical, biological, and agronomic micro-local measures have been developed for water harvesting and soil moisture conservation to maintain land productivity, for soil fertility restoration and for salinization control.<br>**Agro-ecological land management practices:** bunds, mounds, terraces, benches, fences; intercropping, mulching, alley cropping, fallowing, and run-off agriculture. |
| **Warm and moist lowlands** | **Main biophysical constraints:** soil nutrient depletion and high biological competition.<br>**Local measures:** mechanical, biological, and agronomic micro-local measures have been developed to maintain or restore soil fertility and to prevent or diminish crop pests and diseases.<br>**Agro-ecological land management practices:** water control agrosystems, multicropping, slash-and-burn agriculture, agro-sylvo-pastoral systems; mulching, fallowing, alley cropping, and crop rotation. |
| **Cold and dry highlands** | **Main biophysical constraints:** relief steepness, low rainfall, and environmental hazards such as frost, soil erosion, and landslides.<br>**Local measures:** mechanical, biological, and agronomic micro-local measures have been developed to prevent, protect from and control erosion and to mitigate the effect of environmental hazards on soil fertility.<br>**Agro-ecological land management practices:** terraces, benches, fences; intercropping, mulching, alley cropping, fallowing, run-off agriculture, agroforestry, agro-ecological zoning according to elevation. |
| **Complex agro-ecological areas** | Include two or more of the single agro-ecological zones, usually in complex patterns. |

**Figure 6.11. Legend.** Worldwide distribution of ethnopedological studies per main agroecological zones

# Part Two

## Middle American ethnopedology: A regional perspective

# CHAPTER SEVEN

## CROPS AND LAND PERCEPTION IN PRE-COLUMBIAN MIDDLE AMERICA

### 7.1. INTRODUCTION

In the previous chapter, evidence of local soil and land knowledge and management systems around the world was discussed. It was argued that many of these systems reveal complex and sustainable ways to maintain, restore and improve soil quality, mainly in relation to crop cultivation. Local examples show how and why farmers' soil and land knowledge systems are dynamic and innovative according to different agroecological and cultural contexts. These knowledge systems are still actively applied in many areas of the Third World to cope with multiple environmental and socio-economic changing circumstances. Their versatility to cope with unpredictable environmental and economic circumstances constitutes a major advantage to maintain local subsistence strategies and, to some extent, prevent land degradation and soil fertility depletion. These findings reflect a rich mosaic of local pedologies and sound land management systems, but also the lack of understanding of these knowledge and management systems in scientific and development circles. Conventional assumptions about the lack of awareness of land degradation processes among farmers, the inappropriateness of traditional farming practices under increased population pressure and their consequent disintegration, hamper the importance of understanding local soil and land management practices.

The following three chapters (Seven, Eight and Nine) address complementary aspects of pre-Columbian Middle American ethnopedological knowledge systems; thus they should be seen as intimately related. The extensive information about pre-Columbian Middle American ethnopedologies covers three dimensions: (1) soil and land beliefs and symbolic representations (Kosmos); (2) knowledge systems (Corpus); and (3) management systems (Praxis). Ethnohistorical evidence of Middle American soil and land knowledge systems is discussed mainly in relation to soil nomenclature, soil characteristics, soil qualities, soil and water conservation, land management and crop cultivation.

Chapter Seven focuses on land beliefs and symbolic representations, providing an introductory description of Middle America (1) as a civilization core, (2) as a center of origin of plant domestication, and (3) as the original center of maize cultivation in the world. Crops and land are discussed within this framework. Section 7.2 presents a brief characterization of Middle America as a cultural area and explains some of the major historical trends that gave shape to the development of a civilization core. Section 7.3 discusses the importance of Middle America as one of the major centers of origin of plant domestication, where complex agricultural systems centered on maize cultivation evolved. Section 7.4 describes Middle American agricultural systems, while section 7.5 is dedicated to the complex symbolic representation of land in Middle American cosmology (MAC). Section 7.6 concludes this chapter, highlighting some of the particularities of crops and land in pre-Columbian Middle America.

### 7.2. MIDDLE AMERICA: A CIVILIZATION CORE

What is considered to be Middle America? How and why did this geographical area become a civilization core? Which are the main features of this cultural area? Middle America is considered by specialists as one of the two most important and complex pre-Columbian civilization cores of the American continent (Kirchhoff, 1943; Wolf, 1959; Bonfil, 1987b; van Zantwijk van et al., 1990; Adams, 1991; Coe, 1994; López Austin and López Luján, 1996). The Andean region in South America shares similar considerations (West, 1989). Both cultural areas evolved independently through thousands of years, giving shape to highly complex societies similar to those originated in China, India, Mesopotamia and Egypt (Braudel, 1974, 1978).

Middle America covered major parts of present Mexico, Guatemala, Belize, Honduras, El Salvador, Nicaragua and Costa Rica before the Spanish conquest (Figure 7.1). This extensive area was densely but unequally populated, with estimates ranging from 25 to 40 million inhabitants at the beginning of the 16$^{th}$ century (Borah and Cook, 1963; Gerhard, 1986; Butzer, 1992a; Niederberger, 1996), speaking more than 180 different languages just in what is now the Mexican territory (Cifuentes, 1998). Middle America developed as a cultural area with historical co-existence of different ethnic societies linked by complex and heterogeneous relations. These ancient relations structured permanent and multi-secular traditions and histories, with notable regional particularities evolved by constant inter-exchanges. Migrations and social mobility, power interests shared by elites of different political entities, domination of certain societies over less powerful ones, militarism, tributary and religious alliances, and political and economic conflicts over long periods were the main social processes that constructed the complex unity of this vast geographical area (López Austin, 1996). Figure 7.1 shows the geographical distribution of the six Middle American major regions and table 7.1 shows the main socio-historical trends of these regions, during a period of 4,000 years, until the Spanish conquest. The Middle American chronology shows three general trends with regional variations during three main historical periods: the Pre-Classic period (2,500 BC to 200 AD), the Classic period (200 AD to 650/900 AD), and the Post-Classic period (900/1000 AD to 1520 AD). This chronology helps understand Middle American agricultural evolution, linked to the development of knowledge systems and main economic and socio-political factors, all displayed in a complex way. Furthermore, this framework allows to better understand Middle American ethnopedologies.

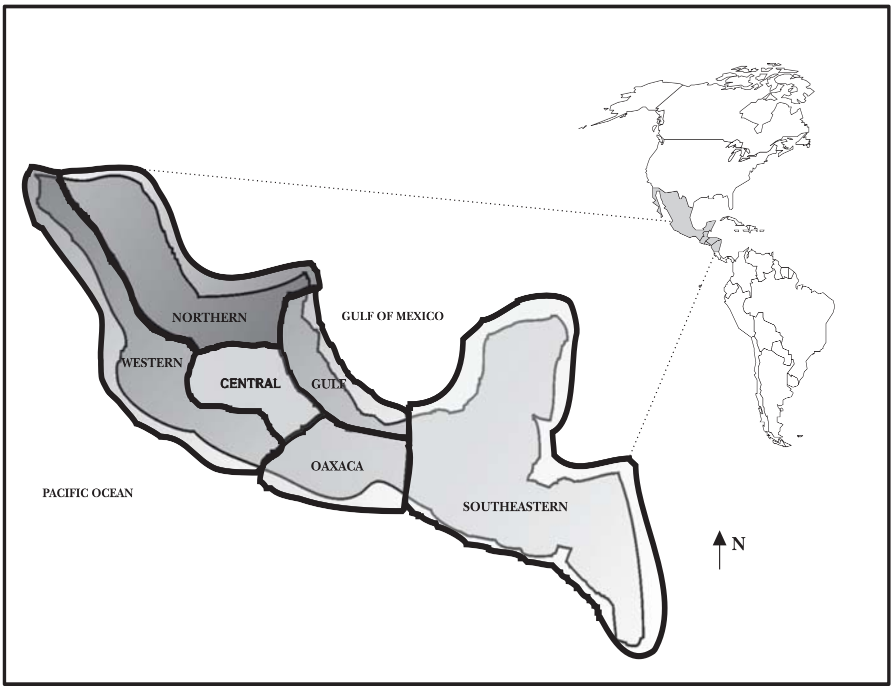



**Figure 7.1.** Middle America and its six cultural regions

**Table 7.1.** Middle American chronology

| Period | Phase | Southeastern | Gulf | Oaxaca | Central | Western | Northern | Years |
|---|---|---|---|---|---|---|---|---|
| POST-CLASSIC | LATE | Northern kingdoms / Quichés | Mexicas' conquest | | Aztec Empire | Purhépecha Empire | | 1500 |
| POST-CLASSIC | EARLY | Northern Mayans' splendor | Mixtecs' kingdoms<br>Toltecs' presence | | Chichimecs<br>Tula's power | Independent kingdoms<br>Toltecs' presence | **Abandonment** | 1200 |
| CLASSIC | LATE | Mayans' splendor | El Tajín | Monte Albán Power | Xochicalco Teotenango Cholula Cacaxtla | Metallurgy | Agricultural life in a territory shared by hunter-gatherers | 900<br>650 |
| CLASSIC | EARLY | Mayans' tradition development | Teotihuacans' Presence<br>**Rise of urbanism** | | Teotihuacans' power | Teotihuacans' presence | | 200 A. D. |
| PRE-CLASSIC | LATE | **Architectonic complexity** | **Complex writing system**<br>**Complex mathematics** | | **Architectonic complexity** | | **Agricultural advancement** | B. C. |
| PRE-CLASSIC | LATE | **REGIONAL CENTERS' RIVALRIES** | | | | | | |
| PRE-CLASSIC | INTERMEDIATE | Olmecs' presence | Gulf Olmecs | **First calendar notations** | | | | 400 |
| PRE-CLASSIC | INTERMEDIATE | **RISE OF HIERARCHICALLY-ORGANIZED SOCIETIES** | | | | | | 1200 |
| PRE-CLASSIC | EARLY | **DEVELOPMENT OF EGALITARIAN PEASANT SOCIETIES** | | | | | | |
| PRE-CLASSIC | EARLY | First ceramics | | | First ceramics | | | 2500 |

**Source:** López Austin and López Luján (1996)

### 7.2.1. The Pre-Classic Period

The development of egalitarian peasant societies, during the first 13 centuries of the Pre-Classic period, gave rise to the development of agricultural techniques, including the agro-hydraulic systems, which were the basis for labor specialization within the first hierarchically organized societies. All this shaped a continuum from important inter-regional exchanges to complex commercial long routes. At the end of this period, some Middle American societies, such as the Olmecs, possessed complex mathematics, calendar and writing systems, and produced massive architectonic complexes. Agriculture satisfied about 40% of the total food demand (García Cook, 1985).

### 7.2.2. The Classic Period

During the next 700 years corresponding to the Classic period, the development of intensive agricultural systems capable of supporting large demographic concentrations reinforced the rural-urban differentiation and allowed a notable population growth. Long-distance commercialization systems evolved as complex networks covering local, regional and supra-regional levels. The formation of strong regional traditions and the consolidation of governmental elites controlling politics and ideology permitted the insertion of religious institutions within governmental structures. The development of planned urbanism with massive architectonic complexes originated political power centers in the most important cities. The end of the Classic period coincides with the splendor of complex calendar and writing systems, mathematics and astronomy, but also with the decline and collapse of the great Classic centers such as Teotihuacan, Tajín, Monte Albán, Cholula and Cacaxtla. Agriculture satisfied about 60% of the total food demand (García Cook, 1985).

### 7.2.3. The Post-Classic Period

During the Post-Classic period that lasted over 600 years, Middle America became densely populated, with large migrations and retraction of the northern frontier. This allowed for ample diffusion of regional cultural elements and a wide exchange of commodities throughout all the territory, to Oasis-America in the north and to the Cibcha and Andean areas in South America. During the whole period, political instability reigned, together with the emergence and fall of different aggressive states. Militarism, conquest expansion, defense urbanism and the consolidation of despotic tributary systems were linked to new forms of religious cults. The Triple Alliance led by the Aztecs or Mexicas, the Purhépecha empire and the Maya-Quiche kingdom, included the most powerful tributary states until the Spanish conquest in 1521. Agriculture satisfied more than 75% of the total food demand on the eve of the Spanish conquest.

Middle America evolved as a complex cultural unit, with a history shared by societies of unequal complexity, and as a set of heterogeneous peoples that became co-producers of a common cultural substratum. This common cultural substratum gave shape to the Middle American tradition. Two main factors contributed to the shaping of this common cultural substratum: (1) Middle American societies from different origins, traditions and histories were able to build a civilization around maize cultivation as a common agrarian practice. Despite the cultural diversity of Middle America, similar peasantry societies developed sharing a tradition based on maize production for subsistence. Maize, in this view, can be considered as the Middle American cultural matrix; and (2) the complexity of Middle American physical geography and its high biological diversity were the eco-geographical bases that allowed the domestication of plants and the diffusion of agricultural activities. Due to the absence of big mammals, agriculture became the principal production activity for the majority of the population. The agrarian tradition based on maize cultivation created a common cosmovision and oriented the development of mathematics, astronomy, botany and agronomy as major Middle American scientific advances.

## 7.3. Middle america: A center of origin of plant domestication

### 7.3.1. Crop diversity and variety

Middle American social roots go back to 35,000 years ago, when the area was first inhabited by hunter-gatherer groups depending only on wild food, distributed according to a dispersed low-density pattern (López Austin, 1996). This area developed as a civilization core from 7,000 BC, when plant domestication originated and people became gradually dependent on agricultural activities (MacNeish, 1964; Mangelsdorf et al., 1967; Sanders and Price, 1968; Wilkes, 1972; Flannery, 1973 and 1985; Mangelsdorf, 1974; Palerm and Wolf, 1980; Coe, 1984; Rojas and Sanders, 1985; Rojas, 1990a,b and c; Whitmore and Turner II, 1992). An important number of cultivated plants is originally from Middle America (Table 7.2). This single area is the home of crops which occupied nearly one fourth of the worldwide cropland in the 20$^{th}$ century (Grigg, 1974). Recent ethnobotanical research recognizes the utilization of some 5,000 vascular plants just in the Mexican territory, roughly 23% of its flora, reflecting the mutual dependence that developed between humans and plants over time and space in this civilization core (Caballero, 1987; Bye, 1993). Archaeological, archaeobotanical and ethnohistorical research demonstrates that the domestication of plants such as maize (*Zea mays*), squash (*Cucurbita spp.*), common bean (*Phaseolus vulgaris*), tomato (*Lycopersicum esculentum*), chilli-pepper (*Capsicum annuum*), avocado (*Persea americana*), amaranth (*Amaranthus hypochondricus*), cotton (*Gossypium hirsutum*)

**Table 7.2.** Cultivated plants originally from Middle America

| VERNACULAR NAME | ENGLISH NAME | SCIENTIFIC NAME |
|---|---|---|
| **Root and tuber crops** | | |
| camote | sweet potato | *Ipomea batatas* |
| jicama | | *Pachyrrhizus erosus* |
| coyolxóchitl or zarzilla | | *Bomarea edulis* |
| **Cereals** | | |
| maíz | maize or indian corn | *Zea mays* |
| amaranto<br>huahutli | amaranth<br>amaranth | *Amaranthus cruentus*<br>*Amaranthus leucocarpus*<br>*Amaranthus hypochondricus* |
| chía grande<br>chía | | *Hyptis suavolens*<br>*Salvia hispanica* |
| huahuzontle | | *Chenopodium nuttaliae* |
| | | *Panicum sonorum* |
| **Pulses** | | |
| frijol común<br>frijol lima<br>frijol tepary | common bean<br>lima bean<br>tepary bean | *Phaseolus vulgaris*<br>*Phaseolus lunatus*<br>*Phaseolus acutifolius* |
| **Vegetables and spices** | | |
| calabaza<br>calabaza<br>calabaza<br>calabaza | squash-pumpkin<br>squash<br>squash<br>squash | *Cucurbita pepo*<br>*Cucurbita moschata*<br>*Cucurbita mixta*<br>*Cucurbita ficifolia* |
| chayote | | *Sechium edule* |
| tomate | tomato | *Physalis ixocarpa* |
| jitomate | tomato | *Lycopersicon esculentum* |
| aguacate<br>aguacate | avocado<br>avocado | *Persea americana*<br>*Persea schiediana* |
| chaya | | *Cnidoscolus chayamansa* |
| chile<br>chile | chili-pepper<br>chili-pepper | *Capsicum annuum*<br>*Capsicum frutescens* |
| epazote | | *Chenopodium ambrosioides* |
| vainilla | vanilla | *Vanilla planifolia* |
| **Fruits and nuts** | | |
| capulín | | *Prunus serotina* |
| chirimoya | | *Annona cherimolia* |
| anona | | *Annona glabra*<br>*Annona purpurea*<br>*Annona reticulata* |
| anona | sweet sop | *Annona squamosa* |
| guanabana | | *Annona muricata* |
| Ilama | | *Annona diversifolia* |
| ciruela amarilla | | *Spondias mombin* |
| ciruela roja | | *Spondias purpurea* |
| nanche | | *Byrsonima crassifolia* |
| papaya | papaya | *Carica papaya* |
| chicozapote | | *Achras zapota* |
| zapote blanco | | *Casimiroa edulis* |
| zapote amarillo | | *Sideroxylon spp.* |
| zapote negro | | *Diospyros ebanester* |
| matasano | | *Casimiroa sapota* |
| guayaba | | *Psidium guajava* |
| piña | pineapple | *Ananas comosus* |
| tejocote | | *Crataegus pubescens* |
| tuna | prickly pear | *Opuntia spp.* |
| cuajilote | | *Parmentiera edulis* |
| ramón | | *Brosimum alicastrum* |
| nanche | nance | *Byrosinima crassifolia* |

**Table 7.2 (Continued)**. Cultivated plants originally from Middle America

| VERNACULAR NAME | ENGLISH NAME | SCIENTIFIC NAME |
|---|---|---|
| | **Oil crops** | |
| Mirasol | sunflower | *Heliantus annuus* |
| Algodón coyuchi | upland cotton | *Gossypium hirsutum* |
| | **Fiber plants** | |
| Algodón | upland cotton | *Gossypium hirsutum* |
| Maguey | maguey | *Agave atrovirens* |
| Henequén | henequin | *Agave fourcryodes* |
| Sisal | | *Agave sisalana* |
| Agave tequilero | blue agave | *Agave tequilana* |
| | **Drugs, narcotics, fatigue plants** | |
| Cacao | cocoa | *Theobroma cacao* |
| Tabaco | tobacco | *Nicotina tabacum*<br>*Nicotina rustica* |
| Octli (pulque) | | *Agave spp.* |
| Balché | | *Lonchcarpus longistylus* |
| Ololiuqui | | *Turbina corymbosa* |
| Stramonio | jimson weed | *Datura stramonium* |
| Tecomaxochitl | | *Solandra spp.* |
| Tililtzin | | *Ipomea spp.* |
| Peyote | | *Lophphora williamsii* |
| | **Utility** | |
| Achiote | | *Bixa orellana* |
| Tecomate | tree gourd | *Crescentia cujete* |
| Añil or indigo | | *Indigofera suffruticosa* |
| Guaje | bottle gourd | *Legendaria siceraria* |
| | **Ornamental plants** | |
| Dalia | dahlia | *Dahlia coccinea*<br>*Dahlia excelsa*<br>*Dahlia pinnata* |
| Nardo | | *Polianthes tuberosa* |
| Oceloxochitl | | *Tigrida pavonia* |
| Cempoalxochitl | | *Tagetes erecta*<br>*Tagetes patula*<br>*Tagetes cantula* |
| Macuilxochitl | | *Tagetes canulata* |
| Eloxochitl | magnolia | *Magnolia dealbata* |
| Amacayo | | *Sprekelia formossisima* |
| Yolloxochitl | | *Talauma mexicana* |
| Verbanaceas | | *Lautana spp.* |
| Orquideas | orchids | *Laelia spp.* |

**Sources:** Harlan (1995), Niederberger (1996)

and tobacco (*Nicotiana tabacum*), originated in different regional centers of Middle America as independent domestication processes (Rojas, 1990a; Hernández X., 1993). Pilgrim squash or guaje (*Lagenaria siceraria*) is considered to be the oldest cultivar of the New World, about 8,000 years old (Flannery, 1986).

Mesquite (*Prosopis juliflora*) and nopal (*Opuntia spp.*) were also semi-domesticated since 7,000 years ago. Maguey (*Agave spp.*), a drought-tolerant plant from seasonal and dry environments, which concentrates liquid, carbohydrates and fiber, was consistently used since 4,000 years ago (Smith, 1967; Gentry, 1982). Archaeobotanical findings of common bean estimate its manipulation since 4,000/2,300 years BC.

Since 2,000 years BC, Middle American cultivation systems were enriched by crop variety diffusion when rustic agricultural settlements became important (Sanders, 1957; Flannery, 1985; McClung and Zurita, 1994-1995). Several factors contributed to the development of Middle America as a center of origin of plant domestication. Its bio-geographical diversity allowed the domestication of great varieties of plants. Its ample latitudinal distribution, ranging from 15° to 22° Lat. N., straddles the northern limits of the American tropics as a contact zone between North American (Neoarctic) and tropical American (Neotropical) flora and fauna, forming one of the most biodiverse areas of the world, as is argued in chapter Three. The diversity of its terrain configuration stems primarily from its complex geological history and its position within one of the regions of contemporary active mountain building. Its ample altitudinal distribution, which ranges from 0 to 5,800 m.a.s.l., produces, in conjunction with the latitudinal variation, complex weather and climate conditions. Almost the entire range of subtropical and tropical climates, as well as some mid-latitude types, occurs in this small segment of the world's surface. In few other areas of similar size are there, within short distances, such great variations of surface configuration, climate, soils, vegetation and animal life, as found in Middle America (West, 1964 and 1989; Ramamoorthy et al., 1993).

Cultural diversity of Middle American inhabitants and their long agrarian tradition constitute other intricate factors, that induced complex evolutive plant domestication in the area. A prolonged sedentary process of peoples from diverse cultural backgrounds, settled in biogeographical diverse and isolated areas, permitted a multilineal coevolution of human-plant continuum. Latter, the diffusion of a great number of tolerated, adapted and cultivated plants, enriched and diversified Middle American agroecosystems. During these prolonged processes, increasing population density and social complexity played twofold, as cause and as a consequence (Harris, 1989; Rindos, 1989; Rojas, 1990a and 1990b).

### 7.3.2. Maize: a bastard son

Maize, the most important staple crop of Middle America, is considered the 'cultural matrix' of the agrarian societies of this area. The origin of maize dates back to between 5,000 to 4,000 BC in central and northeastern Mexico (Mangelsdorf and Reeves, 1939; Sanders and Price, 1968; Beadle, 1972, 1977; Mangelsdorf, 1974; Heiser, 1979; Flannery, 1986; Wellhausen, 1988). The origins of this domesticated grass are not yet well understood by specialists (Challenger, 1998), although there is a tendency to consider a wild and perennial relative, *Teocintle* (*Zea diploperensis*), or father-maize in Nahuatl language, as one of the precursors of the current maize varieties (Wilkes, 1967; Galinat, 1971; Iltis, 1987). Other people consider that wild relative precursors (e.g. *Tripsacum dactyloides*) cannot intercross, in natural conditions, with maize but well with the perennial *Teocintle* (Eubanks, 1995). The origin of maize domestication is still a mystery (Benz, 1987) and maize is considered a 'bastard son' (Warman, 1989). Nevertheless, specialists agree that maize originated in Middle America (Wellhausen, 1988) and underwent the most drastic morphological changes of all domesticated plants. Human long-standing intervention adapted maize to the widest environmental conditions when compared to other cultivated plants (Beadle, 1972).

If the reproduction of all domesticated plants depends on human intervention, maize is the most dependent one (Rojas, 1990b). Maize cannot reproduce without human intervention because it lacks a seed-dispersal mechanism (Beadle, 1977). The evolution of this crop depended on natural and cultural selection and on diffusion and extinction processes (Johannessen and Hastof, 1994). The growth of maize cob constitutes an example of morphological changes through domestication, producing a gradual increase of maize yields per seed and per hectare during Middle American history (Rojas, 1990b). By 2,000 BC, Middle American agricultural landscapes were covered by diverse maize-bean-squash cropping systems and, by 1519 AD, maize distribution ranged from 0 to 3,000 m.a.s.l. in areas having annual rainfall higher than 500 mm. If maize is considered to be originally of Middle America, it was early disseminated all over the Americas (Harlan, 1995). Later, the re-introduction of superior maize races from the Andean region in South America had a major impact on the Middle American civilization (Mangelsdorf, 1974). This suggests also long-standing exchange systems between both civilization cores (Middle America and the Andes).

Some 40 distinct maize races evolved in Mexico, since it was domesticated some 7,000 years ago (Ortega-Pazcka, 1973; Ortega-Pazcka et al., 1991). Contemporary Mexico is considered having the highest maize genetic diversity in the world (Brush et al., 1988). Wellhausen and collaborators (1952) refer to four main factors that account for the racial diversity in Mexico: (1) the cultivation of primitive races; (2) the hybridization with *Teocintle*; (3) the influx of exotic races from countries further south; and (4) the fragmented geography of Middle America that creates several kinds of isolation mechanisms conducive to rapid differentiation. Brush and collaborators (1988) suggest that these factors are favoured at farm level due to (1) the highly out-crossing nature of *Zea mays,* (2) the environmental diversity within fields, and (3) the farmers' adaptation of the landraces to environmental heterogeneity and biological stress. The conscious selection and maintenance *in situ* of maize varieties and landraces, plus the tolerance of weeds within the fields, promote hybridization between maize and its weedy relative, *Teocintle*, as an effective route for the introduction of new germoplasm at farm level (Louette et al., 1996, 1997).

The long-standing historical relation between maize and Middle American farmers became central to the offspring and consolidation of the Middle American civilization. This relation gave birth to the connotation of Middle American inhabitants as 'Men of Maize' (Braudel, 1974). Besides its relevance to daily life, maize was considered a primordial sacred deity in Middle American cosmovision, religion and mythology. According to several archaeological and ethnohistorical sources (López Austin, 1994), maize played an important role in different versions of the Middle American myth of the origin of life on Earth. According to this, first man and woman were created by a principal god from maize flour. So human flesh is made of maize, which became thus a fundamental food (MNCP, 1982). As a paradigmatic living being, maize was personified in diverse deities. Sometimes, it appears as a male-deity and in other occasions as a female-deity, symbolizing the relation between opposite divine substances (masculine/feminine; hot/cold; dry/wet; day/night; light/dark; high/low; life/death; fire/water) and balancing a dualistic worldview by the fertilization act and the perpetuation of life and time on Earth (López Austin, 1981; Puite, 1990). In this worldview, maize anatomy and phenology were similar to the human life cycle and both were, since the beginning, inextricably linked. Agricultural activities in this worldview were conceived as the synthesis of the sacred and profane life cycle, like in many agrarian traditions.

### 7.4. Middle american agricultural systems: A typology

The intimate relation between the increase of cultural and social complexity and the agricultural evolution of Middle America has been discussed and theorized in diverse and sometimes contrasted ways (Flannery, 1986; Rojas, 1990b). Challenger (1998) summarizes the terms of the debate. The 'irrigation hypothesis' and the 'multiple land-use strategy hypothesis', based on extensive archaeological and ethnohistorical evidence, could be complementary and integrative for a comprehensive understanding of this process (Barrera-Bassols, 1995). The first hypothesis argues that the hydraulic development in Middle American agricultures, permitted high population densities and was an important mechanism to generate social stratification and complexity among the most important Middle American societies, such as the Olmec, Purhépecha, Maya and Aztec (Wittfogel, 1957; Denevan, 1982; Flannery, 1985; Sanders, 1985; Palerm and Wolf, 1980; Palerm, , 1973, 1980 and 1990). The emergence of labor division and a complex market network paralleled the emergence of crop surplus and the massive urban complexity, permitting the development of a high civilization status among Middle American societies (Palerm, 1980). The second hypothesis proposes that Middle American agricultural complexity not just evolved with the emergence of irrigation but was paralleled with the establishment of complex, diverse and multiple land-use strategies and markets of products from agrosilvicultural, gathering, extractive, fishing and hunting activities. Evidence also shows a process of domestication of a small number of animals, which was never as important as plant domestication (Helms, 1975; Barrera et al., 1977; Harrison and Turner, 1978; Coe, 1984; Whitmore and Turner II, 2001).

These general trends, widely extended throughout the area at the eve of the Spanish conquest, were adjusted to the complex geographical pattern, showing remarkable differences at a regional level, as it is shown in figure 7.2. A wide array of agroecosystems, from the most extensive to the most intensive ones, but most of all centered on the cultivation of the maize-bean-squash complex or *milpa* (a Nahuatl term meaning "on the crop-field" from *Milli*= crop and *Apam*= on the…), is shown in tables 7.3a, 7.3b and 7.3c. These tables summarize some of the most important features for each of the agricultural systems (e.g. shifting cultivation), subsystems (e.g. shifting cultivation with long fallow), and agricultural types (e.g. slope agriculture). They also give information on cultivation strategies (e.g. years of cropping), agricultural techniques (e.g. tillage), and relief modifications (e.g. terraces), and seasonal performance (e.g. number of crops per year) according to climatic conditions. The distribution of the agricultural systems is based on the six Middle American regions

(Figure 7.1) and specific local conditions, according to archaeological, ethnohistorical and ethnographic sources. Table 7.4 shows the nutrient contents in 100 grams of edible portions of the crops cultivated in the *milpa* complex. Table 7.5 shows the mineral and vitamin (complex B) contents in 100 grams of edible portions of the same crops, taking into account that these crops formed the basic daily diet among members of Middle American households.

## 7.5. LAND IN MIDDLE AMERICAN COSMOVISION

This section discusses the complex holistic perception and symbolism of soil and land resources in the Middle American civilization core, analyzing ethnohistorical literature information. Pre-Hispanic soil and land perception and symbolism (Kosmos) have not been under systematic scrutiny, despite their fundamental role in the development of Middle American agrarian societies. Their study would allow a comprehensive understanding of Middle American environmental knowledge systems, agricultural systems and cosmovision because MAC became the principal substratum that gave meaning to the universe and organized the social, political and economic relations of millions of people.

The review is divided in three parts: (1) a description of features of MAC from the Aztec cosmovision provided by ethnohistorical literature and archaeological information; (2) a discussion of *Tlalocan*, the underground world, as the land matrix according to MAC; and (3) the perception of soil and land resources in the central highlands of Middle America at the eve of the Spanish conquest. This exploratory overview intends to give an historical background of the permanence of contemporary Middle American soil and land perception and symbolism in Mexico and Guatemala.

### 7.5.1. Middle American cosmovision

Middle American cosmovision, evolved through thousands of years, became a general framework of perception/action shared by different societies (López-Austin, 1973, 1981, 1990, 1996; López-Austin and López-Luján, 1996). MAC explains the universe according to the social comprehension of the relations between the visible and invisible parts of the world. Three main characteristics of MAC are usually shared by a variety of peoples: (1) MAC as a system of profound and endured conceptions; (2) MAC as a rich collection of expressions and practices (calendars, myths, deity graveyards, geometric cosmic conceptions, religious organization systems, rituals, religious festivities, etc.); and (3) MAC as a polytheist system where human beings had a strong engagement with their gods as a cosmic principle and where deities invaded all living beings, as a counterpart of this cosmic principle.

The dialogue and negotiation between supra-natural and natural beings are central to the understanding of MAC (Lopez Austin, 1980 and 1996; López-Austin and López-Luján,1996). Middle Americans believed in the existence of a cosmic, invisible, marvelous, dangerous and mysterious domain. This domain was hard to comprehend and known, but men intended to find the rational structure of its destiny. In MAC, the importance of the calendar was to predict everyday events, but also to search gods' qualities and power performed on the surface of the earth. Supra-natural beings were ruling laws of causality. They were capable of producing transformations on the predictable side of the cosmos and their actions were a result of their own willingness. Their power was enormous and dangerous. Nevertheless, Middle American people believed that they could influence them by praying, convincing, promising and menacing them as if supra-natural beings were ordinary people. Supra-natural beings were not limited to a certain space, although the sky (*Tonatiuh Ichan* in Aztec terminology) and the underground (*Tlalocan* in Aztec terminology) were conceived as their domains. *Tamoanchan* was the part of the cosmos where deities from the sky and deities from the underground exchanged their forces and substances to give meaning to and ruling human life (Figure 7.3). Deities could also occupy human places, circulating on them and placing inside common people. Besides, supra-natural beings had different power, status and strength according to circumstances and places. They could also be dangerous among themselves, as they performed contrasting and opposite holy duties.

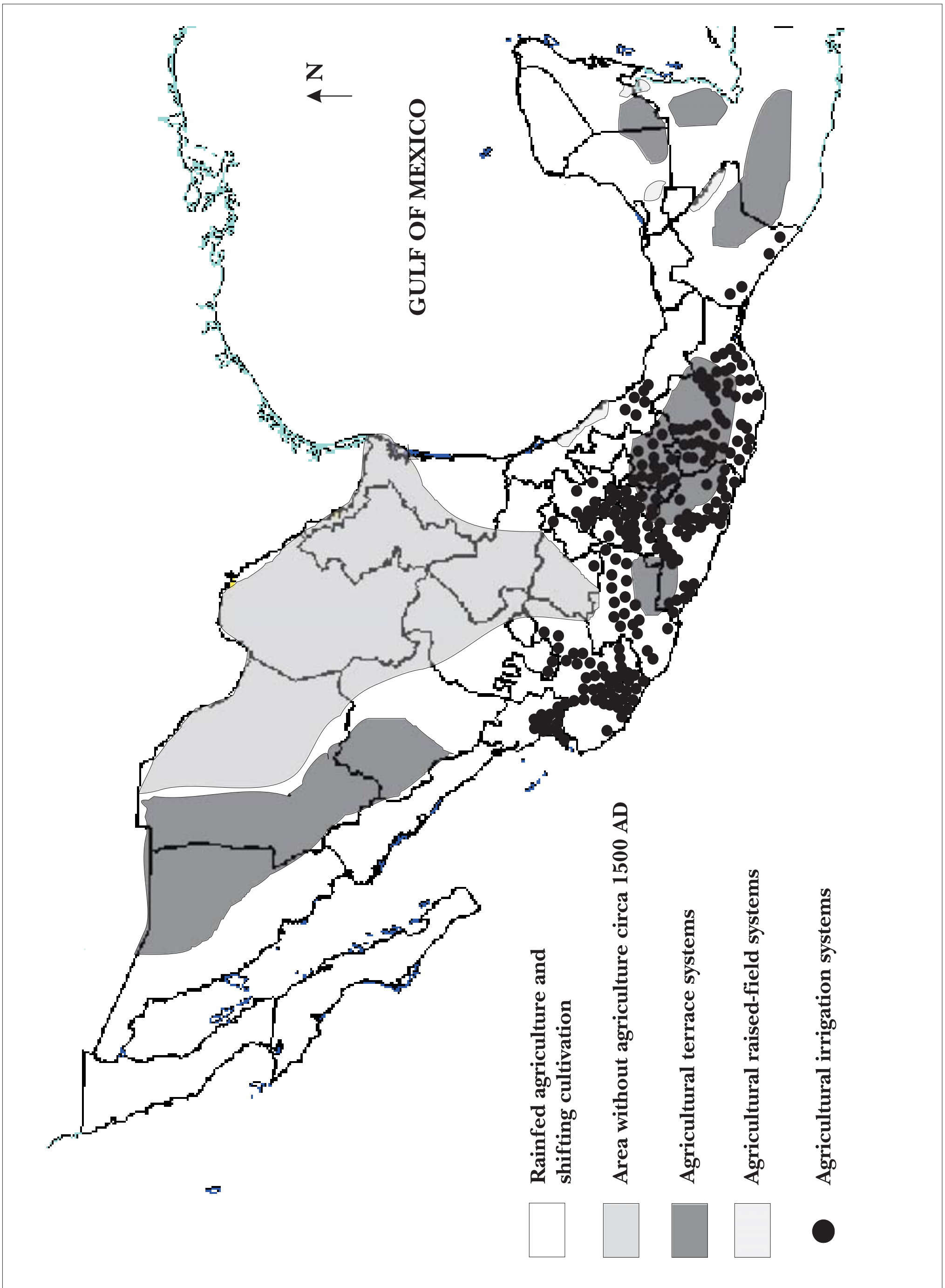



**Figure 7.2.** Middle American agricultural systems. **Sources:** Palerm (1955 and 1972); Barrera et al., (1977); Donkin (1979); Siemens (1989); Challenger (1998)

**Table 7.3a.** Middle American shifting cultivation systems

| Agricultural system | Agricultural sub-system | Years of cropping | Soil tillage | Relief modification | Agricultural type | Local name | Number of harvest per year | Crop cycle | Location | Climate |
|---|---|---|---|---|---|---|---|---|---|---|
| EXTENSIVE SHIFTING AGRICULTURE | Long fallow 5 to 50 years<br><br>(Forest and shrub stages) | 1 to 3 | Without | None | Slope agriculture | Tlacolol or Huamil | 1 | Spring-Autumn | **GULF, SOUTHERN and CENTRAL**<br>Sierra Madre Oriental; S. M. del Sur; S. Norte de Chiapas; S. Volcánica Transversal | Semi-dry and sub-humid warm climates |
| | | | | | Slope agriculture | Milpa and Tonalmil | 2 | Spring-Autumn Autumn-Spring | **OAXACA**<br>Sierra de Meztitlán, Oaxaca | Humid and warm to cold sub-humid climates |
| | | | | | Slope and flatland agriculture | Milpa and Tonalmil | 2 | Spring-Autumn Autumn-Spring | **GULF and SOUTHERN**<br>Coastal lowlands of Gulf of Mexico | Humid and warm climate |
| | | | | | Flatland agriculture | Yucatec milpa | 1 | Spring-Summer | **SOUTHERN**<br>Yucatec Peninsula Mayan lowlands | Sub-humid to humid warm climates |
| | | | | | Lowland agriculture | Milpa and Tonalmil | 2 | Spring-Autumn Autumn-Spring | **SOUTHERN and GULF**<br>La Chontalpa, Tabasco | Very humid and warm climate |
| | Intermediate fallow 3 to 5 years<br><br>(Shrub and herbaceous stages) | 1 to 3 | Slight plowing when cleaning | None | Slope agriculture | Milpa | 1 | Spring-Autumn | **OAXACA**<br>Sierra de Meztitlán, Oaxaca | Sub-humid and warm climate |
| | | | | | Slope and hilly agriculture | Milpa and Tonalmil | 2 | Spring-Summer Autumn-Spring | **GULF**<br>Coastal lowlands of Gulf of Mexico, La Huasteca | Humid and sub-humid warm climates |
| | | | | | Slope and flatland agriculture | Milpa and Tonalmil | 2 | Spring-Autumn Autumn-Spring | **GULF and OAXACA**<br>Chinantla, Oaxaca | Humid and warm to cold sub-humid climates |
| | | | | | Flatland agriculture | Yucatec milpa | 1 | Spring-Autumn | **SOUTHERN**<br>Yucatec Peninsula Mayan lowlands | Sub-humid and warm climate |
| | | | | | Lowland agriculture | Milpa and Tonalmil | 2 | Spring-Autumn Autumn-Spring | **SOUTHERN and GULF**<br>Chiapas lowlands | Humid and warm climate |

**Table 7.3b.** Middle American intensive agricultural systems

| Agricultural system | Agricultural sub-system | Years of cropping | Soil tillage | Relief modification | Agricultural type | Local name | Number of harvest per year | Crop cycle | Location | Climate |
|---|---|---|---|---|---|---|---|---|---|---|
| **INTENSIVE AGRICULTURE** | Rainfed agriculture<br>short fallow 1 to 3 years (herbaceous stage) | 1 to 3 | With tillage Organic fertilization | Terraces, ridged fields or camellones, and bancales or metepantles | Slope agriculture | Terraced milpa | 1 | Spring-Autumn | **NORTHERN, CENTRAL, WESTERN and OAXACA** North, Central, South, and Southeastern Highlands or "Altiplanos" | Sub-humid temperate to semi-arid warm and cold climates |
| | Rainfed and irrigated agriculture | Semi-permanent | With tillage Organic fertilization | Terraces, ridged fields or camellones, and bancales or metepantles, and dams or presas | Slope and flatland agriculture | Irrigated and non-irrigated terraced milpa, and irrigated flatlands | Several | Spring-Autumn (non-irrigated)<br>Most part of the year (irrigated) | **CENTRAL, WESTERN, OAXACA and SOUTHERN** Mexico basin (Teotihuacán and Texcoco); Toluca basin; Puebla and Tlaxcala; Oaxaca valleys; Chiapas and Guatemala Highlands; Belize | Humid and temperate, sub-humid and temperate, semi-arid and warm, and semi-arid and cold climates |
| | Soil-moisture agriculture | Permanent | With tillage Organic fertilization | Micro-topographic modifications | Lake and river bordering lands | Sunken fields, bancales, and cajetes | Several | Most part of the year to all the year | **CENTRAL and WESTERN** Lake basins of Central Mexico, Balsas river, Lerma river, etc. | Several |
| | Irrigated agriculture | Permanent | With tillage Organic fertilization | Dams or presas and micro-topographic modifications | Flatland agriculture | Channels, ridges, aqueducts, Dams | Several | All around the year | **CENTRAL, WESTERN and OAXACA** Valleys of Central Highlands and Pacific Flatlands | Sub-humid temperate to semi-arid warm climates |
| | Wetland agriculture | Permanent | With tillage Organic fertilization | Ridged fields, chinampas or floating gardens, drained fields | Flooded highlands and lowlands | Temperate and tropical cropping gardens | Several | All around the year | **CENTRAL, GULF and SOUTHEASTERN** Lake basins of Central Mexico, Lowlands of Gulf of Mexico and Yucatan Peninsula | Sub-humid temperate climate and humid warm climate |

**Table 7.3c.** Middle American agroforestry systems

| Agricultural system | Agricultural sub-system | Years of cropping | Soil tillage | Relief modification | Agricultural type | Local name | Number of harvest per year | Crop cycle | Location | Climate |
|---|---|---|---|---|---|---|---|---|---|---|
| **AGROFORESTRY SYSTEMS** | Homegardens | Permanent | Organic fertilization | None | Household backyard | Complex and diverse agro-sylvicultural systems (annual, biannual, and perennial species) | Several | All around the year | All Middle America | Several |
| | Orchards | Permanent | Organic fertilization | None or ridged fields, or terraces | Plantations | Fruit plantation | Several | perennial | All Middle America | Several |
| | | | | | | Cacao plantation (*Theobroma spp.*) | 1 | perennial | **GULF and SOUTHEASTERN** Tropical lands | Sub-humid to humid warm climates |
| | | | | | | Nopal plantation (*Opuntia spp.*) | 1 | perennial | **NORTHERN, CENTRAL and OAXACA** Highlands | Semi-arid to sub-humid temperate climates |
| | | | | | | Avocado plantation (*Persea spp.*) | 1 | perennial | **WESTERN, GULF OAXACA and SOUTHERN** Tropical highlands | Humid and warm climate |
| | | | | | | Maguey plantation (*Agave spp.*) | Several | perennial | **NORTHERN, CENTRAL and OAXACA** Highlands | Semi-arid to sub-humid warm climates |

**Adapted from:** Armillas (1949, 1961 and 1971), Barrera et al. (1977), Harrison and Turner (1978), Donkin (1979), Denevan (1980a and b, 1982), Palerm and Wolf (1980), Siemens (1989), Rojas (1990a and b), Palerm (1990), Challenger (1998)

**Table 7.4.** Nutrient contents of Middle American food per each 100 g. of edible portion[1]

| FOOD | Energy K cal | Proteins g | Fat g | Carbohydrates g |
|---|---|---|---|---|
| **Maize** | 350 | 8.9 | 4.3 | 72.2 |
| **Beans** | 332 | 19.2 | 1.8 | 61.5 |
| **Squash** | 18 | 1.2 | 0.1 | 3.7 |
| **Tomato** | 11 | 0.6 | 0.1 | 2.4 |
| **Quelites** | 39 | 3.2 | 1.0 | 6.4 |
| **Fresh chili-pepper** | 23 | 1.2 | 0.1 | 5.3 |
| **Pumpkin seeds** | 547 | 30.3 | 45.8 | 14.4 |
| **TOTAL** | **1320** | **64.6** | **53.2** | **165.9** |
| **RDA* per day**[2] | **2060** | **40** | | |

**Sources:** [1]MNCP (1982), *recommended dietary allowances, [2] NAS (2000)

**Table 7.5.** Mineral and vitamin contents of Middle American food pear each 100 g. of edible portion (Complex b)[1]

| FOOD | Ca g | P g | Vitamin A Mcg Eq | Thiamin Mg | Riboflavin Mg | Niacin Mg | Vitamin C Mg |
|---|---|---|---|---|---|---|---|
| **Maize** | 22 | 268 | 17 | 0.36 | 0.12 | 1.7 | 0 |
| **Beans** | 228 | 457 | - | 0.62 | 0.14 | 1.7 | 0 |
| **Squash** | 25 | 29 | 27 | 0.06 | 0.09 | 1.0 | 13 |
| **Fresh chilli-pepper** | 25 | 49 | 52 | 0.22 | 0.28 | 3.5 | 230 |
| **Tomato** | 13 | 27 | 507 | 0.07 | 0.05 | 0.8 | 17 |
| **Quelites** | 230 | 60 | 400 | 0.07 | 0.18 | 0.8 | 42 |
| **Pumpkin seeds** | 38 | 847 | 15 | 0.23 | 0.16 | 2.9 | 0 |
| **TOTAL** | **581** | **1,737** | **1,018** | **1.63** | **1.02** | **12.4** | **302** |
| **RDA* per day**[2] | **905** | **746** | **756** | **1.0** | **1.2** | **13.8** | **51.6** |

**Source:** [1]MNCP (1982), *recommended dietary allowances, [2]NAS (2000)

All living beings (water, stones, soils, fields, mountains, lakes, stars, meteors, animals, plants and humans were all conceived as living beings) were formed by two different substances: indestructible 'soft matter' and destructible 'hard matter'. The degree of predominance of each substance gave the correct position of living beings, according to a universal binary division. Also, the composition of these substances in living beings varied through time. The dualistic balance explained causality and controlled the universal laws ruling the natural and social worlds. The 'soft' and 'hard' matters were divided in two opposite groups (Table 7.6). The interrelation of these groups produced the balance needed for the perpetuation of life on Earth and the main action of perpetuity was the fertilization act. Maize, as the cultural matrix of MAC, structured agricultural and religious cycles and gave meaning to fertility as a central principle of life renewal, including the cycle of human existence. Linked to maize, land, rainfall and time were symbols with divine substance.

An example of the way MAC was conceived, organized and displayed is the post-Classic Aztec cosmovision that ruled millions of farmers' life in Middle America, just before the Spanish conquest. Aztec conceived cosmos divided in three main places, subdivided in 22 different 'floors' (Figure 7.3). *Chicnahutopan* (the nine floors which are above us) represented the sky as part of the eternal present or paradise. *Tlacticpac* (on the surface of the Earth or land), subdivided in four floors, was conceived as the place of temporal permanence and was the place where human and non-human beings coexisted. *Chicnauhmitlan* or *Mictlan* (the nine floors of death) was conceived as the underground of the eternal present.

These three places of cosmos originated at the moment of creation of time (*Ollin* in Aztec), when sun and moon were born as a designation of the gods living in the paradise to maintain time's renewal, according to the myth of origin. The three parts of cosmos, sky, land and underground were considered divine, but land or the surface of earth occupied by human and non-human beings was partly divine, sustained by a 'soft

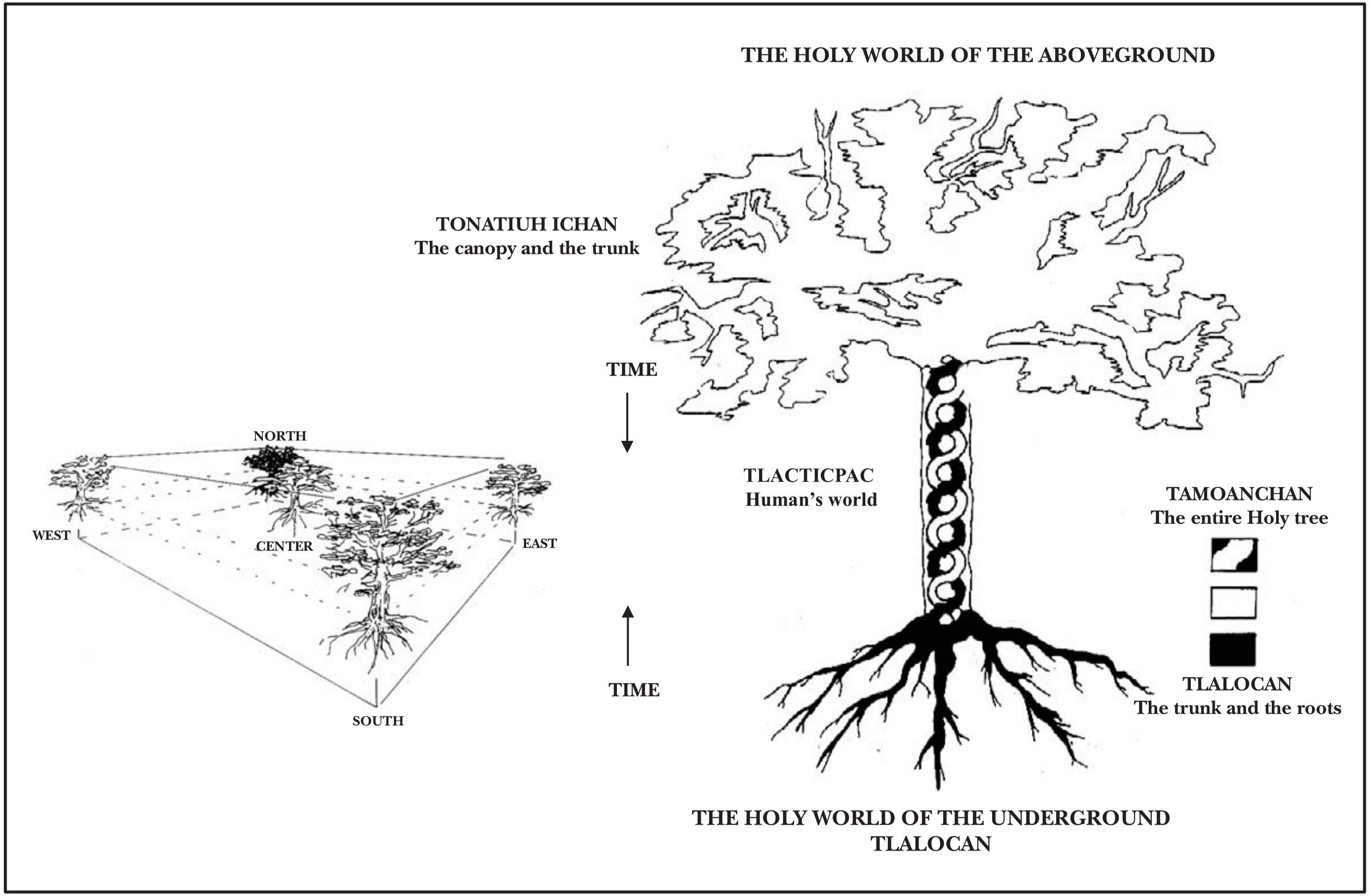



**Figure 7.3.** Worldview and the holy tree according to Middle American cosmovision. **Sources:** López-Austin (1994 and 1996)

matter', and partly secular, composed of 'hard matter'. Living beings on earth were the combination of soft and hard matters and they had a limited existence because of this; with a limited power, they were born and died. In this worldview, death became crucial as hard matter was visible or perceptible and predictable by living beings, whilst soft matter, the divine substance, was imperceptible, unpredictable by them. All living beings in this part of cosmos had a soul, and life had a limited duration, even the stones, minerals, land, plants and animals.

**Table 7.6.** Symbolic associations of the two domains of the Middle American cosmos (MAC)

| MOTHER | FATHER |
|---|---|
| Female | Male |
| Moon | Sun |
| Death | Birth |
| Soft | Hard |
| Cold | Hot |
| Below | Above |
| Underground | Sky |
| Dark | Light |
| Night | Day |
| Jaguar | Eagle |
| Nine | Thirteen |
| Weakness | Strength |
| Sickness | Health |
| Fetid | Perfume |
| Wet | Dry |
| Water | Fire |
| Sea | Rainfall |
| Minor | Major |
| **Ascendant influence** | **Descendant influence** |

**Sources:** López Austin (1996); Puite (1990)

According to the myth, once the world was divided in three main places, the sky or aboveground corresponded to masculine substances, the descendent influences; the underground corresponded to feminine ascendent substances. This was the higher division of the cosmos into female and male places, whilst the land, where all human and non-human beings co-existed, was the 'interface' or substratum where masculine and female substances interplayed. This substratum played the role of a womb, where the intersecta between descendent and ascendent substances gave life to a limited existence, resembling the cycle of animals, plants and humans, but also resembling the climatic cycle and the agricultural cycle.

To maintain the separation between the three main places of cosmos, it was necessary for the ruling gods to establish five sacred trees in its four corners and in the center of the cosmos, respectively. These sacred trees are Ceiba (*Ceiba pentandra*) among the Maya; Amatl (*Ficus spp.*), Ahuehuetl (*Taxodium spp.*) and Ahuexotl (*Salix bompladiana H.B.K*) among the Aztec and other ethnic groups, grown in each of the five cardinal points. These five trees were the pillars of the cosmos (Figure 7.3). Their role was to hold the three levels of the cosmos, rooted in the underground and maintaining the sky with their branches, whilst procuring the circulation of masculine, or descendent substances (deities), and feminine or ascendent substances (deities). In their hollow trunks, two interweaving conducts or veins allowed the two mentioned substances to flow. The main purpose of these avenues was to communicate the aboveground and the underground as two parts of the same paradise, but also to procure the multiplication of living beings on the land or surface of the earth. Fertilization played a crucial role in maintaining the renewal of destiny, balancing birth with death and regulating the life cycle.

Maize represented the sacred synthesis of all this. Having masculine and feminine organs, the plant is capable to autocross and produce food, dying after that. Incapable to disseminate seeds on the soil because of the cob morphology, maize needs human intervention to renew the crop cycle, maintain temporality, renew the birth-death cycle, and procure destiny. Maize, then, was conceived as a result of gods' willingness, the intersection between soft and dry matters -masculine and feminine substances–, and human intervention. Temporality was divided into rainy period, when maize grows, and dry period, when maize dies. Moreover, to maintain the temporal balance, maize needed the intercourse with other two divinities: water and land.

### 7.5.2. *Tlalocan*: the land matrix

The Aztecs conceived *Tlalocan* as the underground part of *Tamoanchan* or the cosmos. It was conceived as the roots and the cold conduct of the trunk of the sacred tree. It was dominated by the dark, cold and humid forces of the regeneration cycle: the place of death. Ruled by the ascendant female forces, *Tlalocan* -the Mother- (*Tlalli*= land; *an*= in the…) was the homeland of abundance of cropland (*milpas*), orchards and gardens; it was the womb of paradise, always green. *Tlalocan* was the domain of reproduction dominated by aquatic and terrestrial deities; a great source where seeds surged and returned after completing the secular stage of their divine cycle. *Tlalocan* was also conceived as a large open recipient, symbolizing the richness of cosmos. It was represented as the 'heart of earth and sea', the 'great hollowed hill', and the homeland of agricultural and water abundance, and animal and mineral richness. *Tlalocan* was the great recipient of water from which rain and streams surged to the surface of the Earth. As an open cave, *Tlalocan* received the influence of deities of the sky, the masculine forces and substances, to recreate temporality and complete the cycle of birth and death. *Tlalocan* was represented and conceived as all the 'hearts of the hills' and was the source of ground.

*Tlaloc*, the ruling god of the underground, was represented both as a male (the god of the celestial water) and a female, *Chalchiuthlique* (the goddess of the terrestrial water), depending on the circumstances. He/she could be generous to humans when providing rainfall for the good performance of the crops, or malefic when provoking flooding, hale, wind, storms and thunders to destroy crops. He/she could be an aquatic deity (*Tlaloc*) or a terrestrial deity (*Tlaltecuhtli*). *Tlaloc* was not alone in the *Tlalocan*. As the father/mother of the Moon and dead, he/she shared the underground with other aquatic and terrestrial deities, each one having specific forces and substances to help the maintenance of secular life. Among them, the Goddess-Mother helped *Tlaloc* maintain water springs, water streams and the sea and produce rainfall and wind. Other deities living in *Tlalocan* are mentioned hereafter:

(1) *Coatlique* (Skirt of snakes) was the Goddess-Mother of land and the owner of the hearts of fecundation; snakes were part of the feminine deities symbolizing germination.
(2) *Tonantzin* (Our venerable Mother) was the goddess of the abundance.
(3) *Toci* (Our Grand Goddess-Mother) was the deity of delivery, hot springs and earthquakes, and also the mother of *Cintéotl*, the god of maize.
(4) *Tlalzoltéotl* (The Goddess-Mother of stain) was the deity of sex.
(5) *Mayahuel* (the Goddess-Mother of the moon and the pulque) and *Itzapapálotl* (The obsidian-butterfly Goddess-Mother) were other deities of sex. Moon, the female counterpart of the sun, ruled the temporality of reproduction and the pulque, a hallucinogenic beverage made of maguey (*Agave spp.*), that inspired sexual activity among humans. The obsidian-butterfly represented a meteorite or flashing star, symbolizing the aquatic and terrestrial fertility.

*Tlaloc's* sisters/brothers were the important deities of maize, represented by *Xilonen* (the Goddess-Mother of tender maize) and *Chicomecoátl* (The Goddess-Mother of mature maize). With their male counterpart *Cintéotl*, they symbolized the milky stage of maize-corn, considered the 'milk of land', with a female dominant essence, and the dried maize-corn, with a more masculine dominant essence. Land, water, fertility and maize were the main forces controlled by these relevant deities, which lived in the womb, the storehouse of abundance and the hollowed underground center of *Tamoanchan*.

In addition, the ancestors, men and women who were the beginners of human diversity, had the privilege to stay in the *Tlalocan*. After death, they became protectors and guardians of *Tlaloc* and other deities, playing a central role as germination, maturity and reproduction force givers with the action of their hearts or essences. They symbolized perpetuity of life on the surface of the Earth. The bones of the ancestors were considered the semen (soft essence) that fertilized land. Through the reproduction act, new generations arose, closing the birth-dead cycle whilst maintaining perpetuity at the surface of the earth.

Finally, other four relevant deities had an important commitment as auxiliary forces of *Tlaloc*. Living in the Four Corners of the Underground part of the cosmos, the *Tlaloques*, the Four Pillars of *Tlalocan*, regulated the flux of time when distributing four classes of rainfall at eastern, western, northern and southern places of the world. These deities had the commitment of opening and closing the great vessel or container of abundance: the *Tlalocan*. They had control on the forces of growth of the vegetation, economizing the fluxes of water and wind according to the temporality of the year cycle. By feeding the land with rainfall in diverse quantitative and qualitative ways, *Tlaloques* allowed or not the growth forces to arrive to the seeds or 'hearts' of non-humans, and permitted or not the strength of the land and its capacity to be fertilized. They were the administrators of the Heart of the Land (*Tlalli Iyollo*) and the Heart of the Hills (*Tepeyollotl*), symbolized by the jaguar. They shared duties with other two important deities, *Cihuacóatl Quilaztli* (The Mother Snake Provider of Vegetables), who was the Goddess-Mother of pregnancy and delivery and controlled human and vegetation cycles, and *Xochiquétzal* (Wonderful Flowered Feather), the Goddess-Mother of love.

Table 7.7 synthesizes the alternation of feminine and masculine forces that gave equilibrium to the opposite qualities and permitted the balance in this dualistic conception of MAC. Deities ruled the soft matters to maintain the balance of the world, centered on the vegetation cycle and specifically the maize cycle, as a divine and secular living being. The presence or absence of the opposite forces dominated this dualistic worldview during the year, ruling temporality of nature and human activity and giving a divine causality to the ecological cycle and the perpetuation of human existence. In this dualistic worldview, land was considered as the place of procreative vitality and part of the *Tlalocan*. It was ruled by hundreds of deities, each one having a specific divine duty according to the agrarian and religious calendars. That was the importance of *Tlalocan* as the vessel of abundance in MAC and the source of human ethics. Figures 7.4, 7.5, 7.6 and 7.7 show the intimate relations and dominance of feminine and masculine deities over maize performance in different ecological settings, according to the 16$^{th}$ century Aztec codices.

### 7.5.3. Land perception

MAC considered land as a divine domain as well as a natural living being of the underground. The relevant role of land in the cosmos and on the surface of the Earth was to procure fertility and provide basic needs for other living beings, including humans. It was the interface where feminine and masculine forces and substances copulated to maintain the vegetation, animal and human cycles, according to temporality as a divine causality and as a product of human workforce. Land had a 'heart' allowing it to behave in a cyclic way, as all other living beings. During the rainy season, the green period, land was influenced by female forces and substances, being fertile, dark, cold, soft and humid, but also prone to provoke sickness and death. Land was considered dirty, as the womb where fertilization occurred. All procreation was conceived as an obscene act, performed in the dirty land. Humans provoked fertilization when penetrating the land with the planting stick (*Coatl*= snake in Nahuatl) and introducing the maize seed, allowing opposite substances to interchange forces and renewing, with the divine permission, the birth-dead cycle. This was the season of activity, the nurturing time. During the dry season, land was dominated by masculine forces and substances, becoming 'tired', light colored, hot, hard and dry. This was the resting period, the abundance period and the fallowing season. Propitiatory rituals were important to restore the strength of the land, to restore what was given as a loan: abundance and procreation. Human offers to land during this season intended to restore the balance of opposite forces to maintain divine destiny, the perpetuation of life on the earth surface as part of the world. Sacrifices at the top of huge pyramids resembled the eruption of volcanoes and the explosion of the hearts of sacred hollowed hills. Natural phenomena had a divine causality, and this was used by the elites to control farmers, land and production.

**Table 7.7.** The cycle of life and the equilibrium between opposite qualities in the Aztec cosmovision

| **SUMMER-AUTUMN**<br>Xopan<br>(Green season) | **WINTER-SPRING**<br>Tonalco<br>(Sun season) |
|---|---|
| **RAINY SEASON** | **DRY SEASON** |
| Domain of cold and humid feminine-ascendent forces and substances | Domain of hot and dry masculine-descendent forces and substances |
| **CONCLUSION OF THE SEASON:**<br>The day of the Death<br><br>(X Huey Miccailhuitl)<br>1st and 2nd of November | **CONCLUSION OF THE SEASON:**<br>The day of the Cross<br><br>(IV Huey Tozoztli)<br>3rd of May |
| Ceremony offered to<br>**MICTLANTHECUTLI**<br>**(God of Dead)** | Ceremony offered to<br>**CHICOMECOATL**<br>**(Goddess of Mature Maize)** |
| **MAIZE CYCLE** | |
| **SEASON OF ACTIVITY**<br>Land preparation<br>Seeding<br>Cleaning | **SEASON OF LEISURE**<br>Burning<br>Harvest<br>Storage |
| **MOTHER-FATHER DEITIES OF TLALOCAN** | |
| **PRESENCE**<br>Rains | **ABSENCE**<br>Smoke |
| **SYMBOLIC REPRESENTATIONS** | |
| Jaguar<br>Snake<br>Caiman | Eagle<br>Parrot<br>Quetzal |

**Sources:** Broda (1991 and 1996), Heyden (1981), López Austin (1996a and 1996b)

Land in MAC was conceived as a polysemic dominion (different meanings) and as a polyvalent resource (multiple uses). Land was also conceived as a landscape with two opposite extremes: the hill (*Tepetl*) and the valley (*Apam*). The hollowed hills, considered sacred entities composed of caves, were open repositories of water and other treasures. Hills were also the originators of rain and wind, and sources providing flowing water from springs, temporal streams and rivers to the valleys, where part of the agriculture was carried out. Rainfall irrigated fertile lands at the bottom of the valleys. Valley land was penetrated with feminine, soft and humid substances, where maize grew, providing humans with the sacred staple good, and died after completing its duty at the end of the rainy season. The residual straw was burned during the dry season causing two effects: the renewal of the strength of the land and the recycling of rainfall forces, with the liberation of water from the land via smoke, resembling the eruption of volcanoes. The divine causality of the water cycle was replenished. Ashes, from burning of vegetation and from the bones of the ancestors, gave new strength to the land, replenishing what was offered to humans as a loan. The intimate relation between rainfall, land and agriculture was controlled by Mothers-Fathers of *Tlalocan* and their master: *Tlaloc*. Moreover, land continuum from the upper to the lower parts of the landscape was recognized, named and classified according to soil qualities at the eve of the Spanish conquest. The long history of agrarian societies developed complex and sophisticated soil and land knowledge, partially preserved in ethnohistorical documents, as discussed in the following chapter.

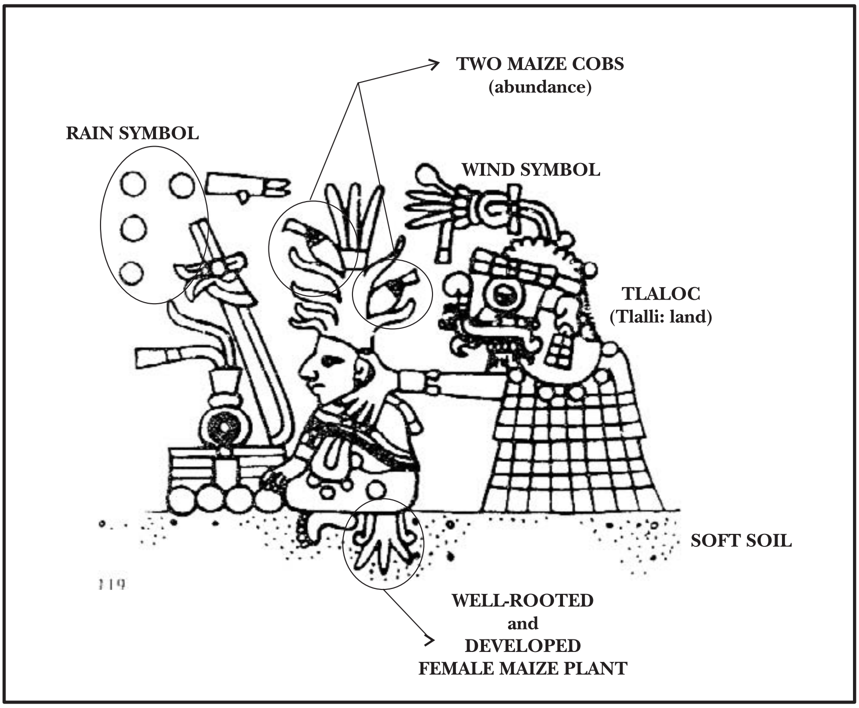



**Figure 7.4.** *Tlaloc* influencing female maize performance. Fejérváry–Mayer Codex (n.d.)

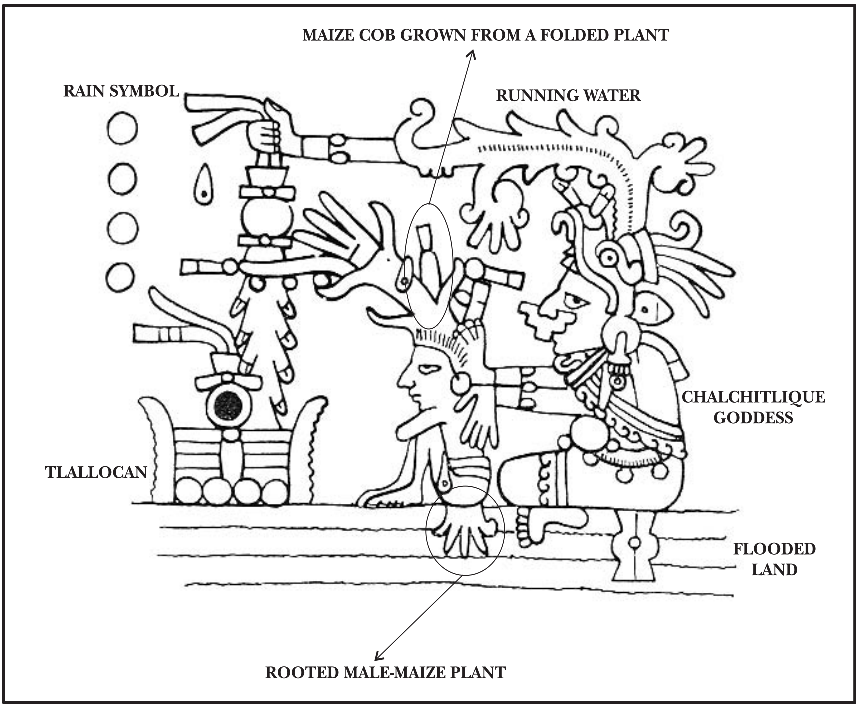



**Figure 7.5.** *Chalchitlique* Goddess influencing male maize performance. Fejérváry–Mayer Codex (n.d.)

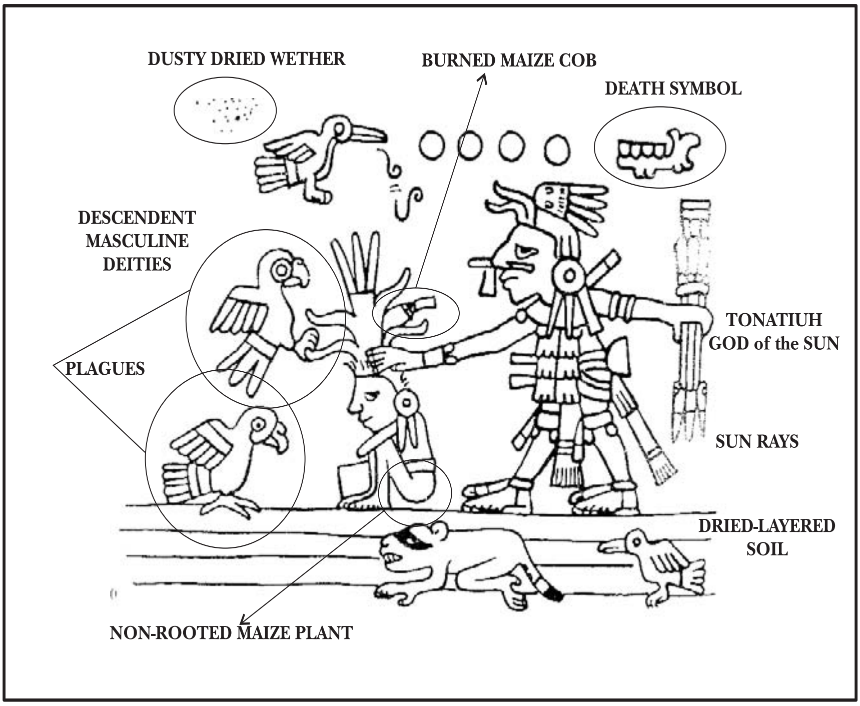



**Figure 7.6.** *Tonatiuh* God influencing male maize performance. Fejérváry–Mayer Codex (n.d.)

### 7.6. Agriculture, science and power in post-classic middle america

At the eve of the Spanish conquest during the beginning of 16th century, Middle American agricultural systems were complex, diverse and widely spread throughout the whole territory. These systems provided food for a population estimated at about 40 million people (Garcia Cook, 1985). The *milpa* complex was the most important cropping system adapted to a variety of environmental niches, with hundreds of maize landraces evolved locally during a period of 5,000 years. The adaptation of the *milpa* system required a profound environmental knowledge from the producers and the elite who controlled economy and politics (Broda, 1996; Niederberger, 1996). Elite control was supplemented by sophisticated religious and ideological systems from the Middle American tradition, rooted by long-standing agrarian societies (López Austin, 1996). The legitimization of the elite had an important support from the Middle American cosmovision as a knowledge macro-system, integrating practical experience, cognitive systems and subjective knowledge: a holistic organization of facts and values as an explicative order of ample comprehension of the world (López Austin and López Luján, 1996). The Middle American cosmovision was a structured view and a coherent combination of notions about the environment where humans lived and about the cosmos within which human life was situated (Broda, 1991).

One of the most important premises of Middle American cosmovision was the control of time (Broda, 1996). The implementation of accurate agricultural and sophisticated religious calendars was meaningful for more complex observations about nature, due to the practical need of controlling social activities over time and space (Edmonson, 1995). The increase of social complexity was linked to a sophistication of the observation and development of calendars that, at the same time, were sources of more elaborated symbolic structures of the cosmovision.

Astronomy was a fundamental source for the development and assessment of the calendars (Broda, 1991). The systematic observation of the Sun, Moon, Venus, Milky Way, Pleyades, other constellations and stars led to

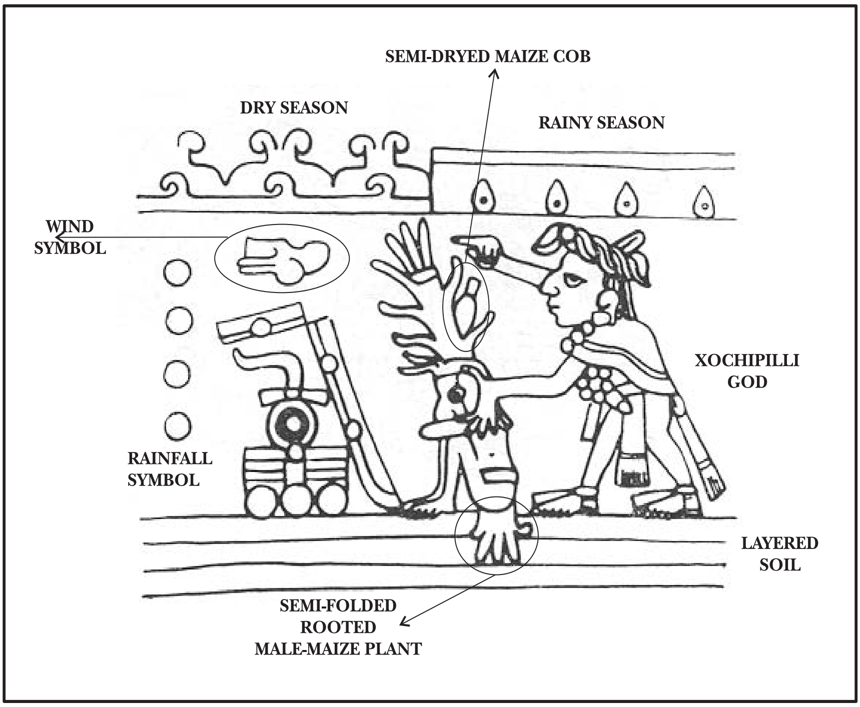



**Figure 7.7.** *Xochipilli* God influencing male maize performance. Fejérváry–Mayer Codex (n.d.)

a sophisticated knowledge system, and their measurement became crucial for the social, economic, political and religious life. These measurements were linked to the accurate observation of nature, such as climatic cycles and meteorological phenomena on the one side, and to the observation of agricultural activities, soil and land resources, and plant phenologies, on the other. As part of this, architectural orientation was based mainly on the sun cycle, which has specific characteristics in the tropics as the sun's first moment over the zenith coincides with the beginning of the rainy season, a crucial moment of social life in Middle American latitudes. The orientation of buildings according the sunrise, sunset or other stellar phenomena on specific days was linked to the celebration of certain ceremonies and rituals performed by the religious-political elite.

Broda (1996) suggests that the link between calendars, astronomic measurements and buildings' orientation, according to sunrise and sunset projections over the local horizon, gave great significance to specific days, according to economic, politic and religious life of communities. Legitimization of control by religious-political elite was based on their monopoly to perform the cult. Cult depended on the recurrence of astronomic and climatic phenomena, necessary for the good performance of plants and agricultural cycles, and then, after first observations, cult was integrated to induce such phenomena. Cult as a social action produced a transfer of associations inverting cause-effect relations, where natural phenomena appeared because of the correct execution of the ritual (Broda, 1996). Mathematics, botany, zoology, agronomy and hydraulic engineering became accurate knowledge systems, inextricably linked to cosmovision, religion and rituals. Sophisticated and complex soil and land knowledge formed part of Middle American environmental knowledge systems, as is revealed by archaeological and ethnohistorical evidence.

## 7.7. Conclusion

This chapter analyzed ethnohistorical, archaeological and ethnographic evidence of pre-Columbian Middle American symbolic representations of soil and land resources (Kosmos). Middle American cosmovision (MAC) was discussed as the cultural template that guided pre-Hispanic conceptions and interpretations of land

and maize, mainly according to the Post-Classic Aztec cosmovision. The chapter offers relevant information highlighting the importance of Middle America as a civilization core, as a center of plant domestication and as the center of origin of maize, the staple crop and cultural matrix of Middle American peoples.

This overview permits to frame the evolution of agricultural activities linked to the multilineal development of socio-cultural and economic patterns in different Middle American societies and territories during the last 4,000 years. Cultural diversity, a long agrarian tradition, and the biogeographical complexity and diversity of the Middle American civilization core, permitted a multilineal co-evolution of the human-plant continuum, giving shape to agricultural specialization as the main socio-cultural activity practiced by the majority of Middle American inhabitants.

This chapter also discussed why and how the Middle American long tradition, based on *milpa* (maize-beans-squash) cropping, constructed a common cosmovision and oriented the development of mathematics, astronomy, botany and agronomy as major scientific fields. This is why Middle American ethnopedologies have their roots in the evolution of *milpa* production and are framed in MAC and religious practices, making them unique. Middle American ethnopedologies share commonalities as all of them are centered on maize production and similar symbolic representations, despite been evolved by different peoples and agro-ecological settings.

Land was conceived as a supra-natural and natural being in MAC, inextricably linked to water-maize-fertility and human existence. Land played a sacred and vital role for the continuation of life and the perpetuation of human beings in a cosmovision that perceived natural phenomena as ruled by divine causality. In this context, cult as a social action produced transference of associations inverting cause-effect relations, where natural phenomena appeared because of the correct execution of rituals. This cosmologic template that organized the everyday life of common people and their economic and religious cycles, ruled the relations between humans and land and their specific engagements, positioning the divine and secular roles of land and human existence and their relationships. The Aztec elite used MAC and applied the scientific fields, both evolved by the ancient agrarian societies of Middle America, to control the livelihood of common people, at the eve of the Spanish conquest. That is why, a comprehensive understanding of Middle American ethnopedologies requires the analysis of Kosmos-Corpus-Praxis as inextricably linked spheres of human existence, always framed by specific socio-economic power (domination/subordination) relations.

# CHAPTER EIGHT

# SOIL AND LAND RESOURCES IN PRE-COLUMBIAN MIDDLE AMERICAN KNOWLEDGE

## 8.1. INTRODUCTION

Middle American agrarian societies developed complex knowledge about soil and land resources, through thousands of years of agricultural activities. It is still possible to trace the ways plants, animals, soil and land resources were understood, named and classified, although most pre-Columbian evidence of understanding natural resources got lost during the conquest. Missionaries, a few conquerors and proto-scientists gave an account of their perceptions of Middle American knowledge systems in their diaries, describing and inventorying the natural richness of the 'new land', in the hands of the Spanish crown. While substantial and rich evidence of plant knowledge was preserved after the conquest, only a few written documents from the 16th century remained to give a limited but extraordinary overview of the complex soil and land resources knowledge systems.

This chapter explores some of the documented evidence, mainly from central Middle America and specifically from the Nahua society, which was ruled by the Aztecs at the beginning of the 16th century. Four main sources were used: (1) ethnohistorical documents written by Spanish colonizers, (2) codices written by the Aztecs, (3) documents written by both Indians and colonizers, and (4) contemporary studies using the above mentioned documents, specially research done by Williams (1972; 1975; 1980a, 1980b and 1980c; 1981; 1982; 1984; 1985; 1994), who was the first one interested in reconstructing the Aztec ethnopedology.

The chapter is divided in six sections. Section 8.2 analyzes Nahua recognition about soil types and soil attributes, according to pre-Hispanic and 16th ethno-historical evidence from central Middle America. Section 8.3 discusses Nahua soil-plant relationship information extracted from the Badiano and de la Cruz Codex, an ethno-historical document written during the earlier colonial period. Soil information is given in either exlcusive or combined ideographic, glyphic or lexicographic ways, offering evidence of the complexity of the 16th century Nahua soil-plant relationship cognitive system. Section 8.4 is dedicated to the analysis of the soil resource as a descriptor of cultural landscapes, according to pre-Hispanic Nahua toponyms from central Middle America. Evidence show that toponyms carry soil and land resources information and reflect the social perception and appropriation of natural resources, according to cosmological views and environmental and productive qualities of the landscapes. Section 8.5 explores relations between pre-Hispanic soil knowledge and tributary policies implementation at the eve of the Spanish conquest. Middle American soil knowledge for tributary purposes was similar to taxation policies implemented by officilas in Egypt , India and China, before the Christian Era. Finally, section 8.6 concludes this chapter, highlighting the complexity of pre-Columbian Middle American pedological knowledge.

## 8.2. SOIL TYPES AND ATTRIBUTES

Sahagún (1963), a Spanish missionary, wrote between 1548 and 1585 one of the most complete documents about the 16th century Middle America, covering ethnographical, historical, cognitive and religious aspects of the recently conquered peoples. With the aid of Indian writers, he produced the Florentine Codex, a 12-book document written in Castilian and Nahuatl (1980) as part of his General History of the Things of New

Spain (1963). The 11th book of the Florentine Codex gives the most complete record of soil knowledge among the Nahua. Forty-five soil types are described according to Nahuatl terminology and descriptors. To name the soils, Nahua used attributes belonging to eight classes, including: (1) texture, consistence and structure, (2) color, (3) organic matter, (4) topographic position, (5) drainage condition, (6) parent material, (7) soil genesis and soil forming factors, and (8) fertility.

Nahua soil classification was complex and mainly utilitarian, built up to recognize soil and land differences for the best performance of agricultural production, according to diverse agro-ecosystem conditions. From 36 Nahua soils referred to in different ethnohistorical documents (Sahagún, 1963; Gibson, 1984; Williams 1981), the percentage of named soil descriptors is the following: (1) 33% corresponds to soil texture, structure or consistence; (2) 17% corresponds to soil organic matter and chemical contents; (3) 14% corresponds to soil fertility; (4) 11% corresponds to soil color; (5) 11% corresponds to soil drainage condition; (6) 8% corresponds to soil genesis or agent, and (7) 6% corresponds to topography (Table 8.1).

The volcanic axis of central Middle America, with its mountainous and lacustrine landscapes, was the environment where multiple land-use systems evolved and the Nahua soil classification was built up. According to Williams (1981), Nahua farmers were aware of local differences in soil resources, their qualities, dynamics and problems related to crop productivity. By recognizing these differences, local farmers were able to ameliorate soil and land conditions to improve the performance of the cultivars. The adjustment of the agricultural activities to increase productivity according to soil-crop relationships was one of the main factors that enhanced soil and land knowledge among farmers.

Land-use decisions to improve land productivity, at plot and village levels, were based on soil attributes. Texture, organic matter and elemental chemical contents, drainage, color and topography were used to assess the agricultural productivity of soils. Texture was assessed for soil workability. Soil color was an important attribute to assess soil fertility in similar ways as in many other ethnic groups and small-farmer communities around the world (see Chapter Six). Black and yellow soils were considered having high agricultural productivity, whilst reddish and white soils were considered less fertile (Williams, 1981). Organic matter and chemical contents of soils were linked to soil color, to recognize and ameliorate soil productivity. Organic fertilization was applied to some soil types, adding animal and plant residues. Nahua farmers recognized organic decomposition, and the arable layer was considered the most important factor for soil-crop performance. In contrast, there is little evidence of recognizing successive soil horizons, a fact which could be related to the incipient stages of soil development in central Middle America, where most of the soils lack a clear horizonation.

Although there is a limited number of named soil descriptors related to topography, Nahua used soil-geomorphology relations to classify soils and manage the land. Soil-relief positions, soil forming factors and processes, and drainage conditions were well recognized in the Nahua soil classification. Soil erosion and sedimentation were assessed and managed to ameliorate land productivity. Terracing (*metepantlli* or *tlaltenampa*), land leveling, planting ridges on hill slopes, tributary *barrancas* (gullies) and places enriched with fresh alluvium from periodical floods, constitute strong evidence of management of sediment transportation and deposition and soil erosion control. These practices took advantage of natural and probably human-induced soil erosion (Donkin, 1979). Irrigation systems in the flatlands and *chinampas* on the margins of lakes are other signs of soil amelioration practices, widely managed to take advantage of soil sedimentation (Williams, 1981). In general, terraces were designed to overcome the disadvantages of slope agriculture in conditions of pronounced dry season, thin soils and inadequate soil moisture. The maintenance and restoration of soil fertility were met by an array of management practices, reflected in the Nahua soil classification (Sagahún, 1963). Table 8.2 shows soil description models according to Nahua farmers' interpretation.

The systematic application of the Nahua soil classification by farmers and the ruling elite are reflected by the incorporation to their written tradition (Gibson, 1984). Decipherment of the Nahua soil types in the 16th century ethnohistorical documents can be interpreted pictographically, ideographically or syllabically (Williams, 1984 and 1994). Hieroglyphs depicting soil types appear in these documents. As Williams (1981) demonstrated, most soil glyphs were combinations of two or three graphic elements, including: dots, stone,

**Table 8.1.** Sixteenth century Nahua soil names and soil descriptors

| Nahua soils | Nahuatl descriptors | Spanish soil names | English soil names |
|---|---|---|---|
| **Tlalli, Alli, Lli or Tla: soil or land** | | | |
| **TEXTURE, STRUCTURE and CONSISTENCE** | | | |
| **TEPETATL** | Te-petatl: stone bed | Tierra tepetatosa | Tepetate (hardpan) soil |
| **TELTLALLI** | Tetl: stone | Tierra pedregosa | Stony soil |
| **XALALLI** | Xalli: sand | Tierra arenosa | Sandy soil |
| **TEZOQUITL** | Te-zoquitl: hard-clay | Tierra arcillosa | Clayey soil |
| **TEHUTLALLI** | Tehutlli: dust | Tierra polvillo | Powdery soil |
| **ZOQUITL** | Zoquitl: mud, swampy | Tierra lodosa, pantanosa | Gley soil |
| **TEPOXCATETLALLI** | Te-poxca: soft pumice stone | Tierra gravosa | Gravelly soil |
| **XALTETLALLI** | Xalli-tetl: sandy-like gravel | Tierra gravosa arenosa | Gravelly sandy-like soil |
| **APAMXALLI** | Apam-xalli: alluvial-sandy | Tierra de aluvión arenosa | Alluvial sandy-like soil |
| **ATOCTLI** | Atl-toctli: water-muddy | Tierra de aluvión | Alluvial soil |
| **TEXONTLALLI** | Texontli: pumice basaltic rock | Tierra pedregosa de Tezontle | Pumice-stony soil |
| **ORGANIC and CHEMICAL CONTENTS** | | | |
| **CUAUHTLALLI** | Cuauhitl: forest | Tierra estercolada con madera podrida | Forest-humic soil |
| **TOLLALLI** | Tolli: semi-aquatic plant | Tierra de tule podrido | Mucky soil |
| **TLAZOLALLI** | Tlazolli: plant compost | Tierra estercolada de hierbas | Organic soil (compost) |
| **TLALILLI** | Tlalli: potting | Tierra para maceta | Potting soil (compost) |
| **TEQUEZQUITLALLI** | Tequezquitl: saline | Tierra de Tequezquite | Saline soil |
| **TIZALTLALLI** | Tizatl: gypsum | Tierra de Tiza | Gypsic soil |
| **NEXTLALLI** | Nextli: ash | Tierra de cenizas | Ashy soil |
| **FERTILITY** | | | |
| **CUITLATLALLI** | Ocuitl-tla: animal compost | Tierra estercolada | Animal-compost soil |
| **TLALCOLLI** | Colli: infertile | Tierra infértil | Infertile soil |
| **TLATLAHUIYIC** | Huiyic: ameliorated | Tierra mejorada | Fertile-ameliorated soil |
| **CHIAUHTLALLI** | Chiauhtli: sopping, soggy | Tierra fértil pero inundable | Soaked soil |
| **COLOR** | | | |
| **TLILTLALLI** | Tlilli: black | Tierra negra | Blackish soil |
| **TLACOZTLI** | Coztli: yellow | Tierra amarilla | Yellowish soil |
| **IZTACTLALLI** | Iztac: white | Tierra blanca | Whitish soil |
| **TLALCHICHILLI or CHICHILTLALLI** | Chichilli: reddish | Tierra rojiza o bermeja | Reddish soil |
| **DRAINAGE CONDITION** | | | |
| **CHIHUATLALLI** | Chihuauhtli: humid | Tierra siempre húmeda | Ever humid soil |
| **NANTLALLI** | Nantli: saturated, inundated | Tierra impermeable | Saturated soil |
| **ATLALLI** | Atl: water, irrigated | Tierra irrigada | Irrigated soil |
| **ATLITLALLI** | Atli: infiltrated | Tierra infiltrada | Infiltrated soil |
| **GENESIS AND AGENT** | | | |
| **ATOCTLI** | Atl-toctli: riverine alluvial | Tierra acarreada de corriente | Riverine-alluvial soil |
| **CALLALLI** | Calli: house; man-made | Tierra hecha | Man-made soil |
| **TLALZOLLI** | Zolli: worn-out | Tierra deslavada | Worn-out or washed soil |
| **TOPOGRAPHY** | | | |
| **TEPETLALLI** | Tepetl: hill | Tierra cerril o de monte | Hilly soil |
| **TLAIXTLI** | Ixtli: slope | Tierra de ladera | Sloping soil |
| **APAMTLALLI** | Apam: valley or flatland | Tierra en planada | Flat land |

**Sources:** Sahagún (1963), Williams (1981) and Gibson (1984)

mat, spine, lips, corncob, green maize stalk, eye, hill, teeth, excrement, water, reed, a specific grass named *zacate*, gully or channel, arrow, digging stick, and shading. These pictographic elements were widely used for different purposes when referring to soil types, subtypes or mixtures. One remarkable example of the combination of pictographic, ideographic and syllabic interpretation of soil classes is the Codex Badiano and de la Cruz (1995), titled *Libellus de Medicinalibus Indorum Herbis*. This document, written in 1552 by a Nahua traditional healer (*curandero* in Spanish) and translated to Latin by a Spanish doctor, reveals the complex

Nahua knowledge of medicinal plants and their uses to cure severe diseases. Although this codex is specialized in medicinal plants, it gives a rich information about the knowledge of soil-plant relations and the medicinal use of certain soils. Main sources of soil knowledge in this document come from the use of (1) soil glyphs, (2) some pictorial representation of rooted plants over colored soils, (3) the name of certain plants, and (4) the Latin and Nahuatl descriptions of the properties and uses of plants, animals, minerals and soils, to cure specific diseases (Maldonado-Koerdell, 1996).

**Table 8.2.** Nahua soil knowledge as shown in the Florentine Codex

| SOIL TYPE | SOIL DESCRIPTION |
|---|---|
| ATOCTLI | "Water-borne yellow soil, water-borne sand. It is soft, porous, very porous; good, good smelling, well considered: it is food producing" |
| QUAUHTLALLI | Another type of fertile land where maize and wheat grow well. Its name means soil fertilized with decomposed wood; it is fine-bonded, yellow and porous land" |
| TLACOZTLI | "It is another type of fertile land; yellow land which means fertile land" |
| XALATOCTLI | "It means sandy soil brought by water coming from the upland; it is soft land to crop" |
| TLAZOTLALLI | "Another type of fertile land; soil where vegetation decomposes and fecundates it when buried" |
| XALALLI | "Sandy soil; it is poor soil; infertile soil" |
| CALLALLI | "This is the land upon which a house rested, and the surrounding houses. It is fertile; it germinates" |
| TLALAUIYIC | "This is the land that is good, which produces, which is mellow: I fertilize it. I add humus to it. I make it mellow, I make it good" |
| ATLALLI | "This is the irrigated field: It is water garden, one that can be irrigated. Land, which becomes wet, becomes muddy. It is good, fine, precious; a source of food; esteemed: a place of fertility, it has substance. It is (*a place*) to be planted with maize, to be planted with beans, to be harvested. I work the irrigated land. I form myself an irrigated garden. I work the irrigable land. I eat on irrigated land" |
| TEPETLALLI or XIMMILLI | "This is the top soil of a mountain, the upland, the slope. It is also called *Ximmilli*. It is dry, clayey, ashy, sandy soil, ordinary soil, rainfed. It is the growing place of mature maize, amaranth, beans. It is the sprouting place of tuna and maguey; of trees. Trees form shoots, herb sprouts, grass sprouts: It becomes grassy. The grasses thicken, trees thicken" |
| TETLALLI | "It is the land on the mountain; rocky, gravelly, loose graveled. It is very rocky, gravelly, rough, dry; it is dry deep down; a productive place, the growing place of *Teocintle* maize. It hardens; if it becomes wet, it produces" |
| TLALUITECTLI | "This is the land which is worked, worked down, crumbled. I beat the land. I work the land with blows" |
| TECHIYAUITL | "It is just the same as *Tetlalli*. Hence it is called *Techiyauitl*, because when it gets water it does not dry off quickly; it just lies moist; it becomes workable; it becomes wet" |
| CHIAUHTLALLI | "Soggy land. It always lies wet, although un-irrigated. It has substance; it is food producing. When it rains heavily, the maize perishes, but when the rain is not heavy, it brings joy, it brings contentment. There is rejoicing therefore" |
| TLACOLLI | "It is called *Tlacolli*, bad soil, because nothing can be grown there. It is the growing place of nothing useless, productive of nothing. It is worked in vain; it fails. It is worn-out land: it becomes worn-out land" |
| TEQUIZQUITLALLI | "Saline soil; infertile soil; it is whitish, sterile; non-productive" |

**Source:** Sahagún (1963)

### 8.3. SOIL-PLANT RELATIONSHIPS

A preliminary exploration of the Nahua soil-plant relationship information extracted from the Badiano and de la Cruz Codex (1995) is discussed in this section. Full understanding would need deeper analysis, because the 16th century Nahua soil-plant relationship cognitive systems offer more new research questions than conclusive results. Fifteen examples of medicinal plant pictographic and textual representations provided with soil information were chosen to explore the Nahua soil-plant relational knowledge. Soil information is given in either exclusive or combined ideographic, glyphic and lexicographic ways. This information source offers evidence of the complexity of the 16th century Nahua soil-plant relationship cognitive system.

Ideographic soil representation consists of drawings reflecting soil characteristics (color, texture, soil layers, structure and soil moisture), as a component of plant pictorial representations, offering visual information. Soil glyphic information is presented as conventional written symbols to label soils according to the Nahua tradition, whilst lexicographic soil information is provided by morphemes of Nahua plant nomenclature. Additional textual soil information refers, in some cases, to plant habitats or to soil curative properties used to prepare medicinal potions in combination with other natural resources, mainly plant, animal, mineral and water resources. Therefore, textual information concerns either soil-plant ecologies and/or soil medicinal properties.

Four main conclusions can be drawn from the analysis of the soil descriptors: (1) phonetic morphemes used to label soils were also used to characterize plant physiognomy, therefore Nahua soil descriptors were used in a more fashionable way to describe natural resources; (2) soil knowledge was used to label plant life forms; (3) soil knowledge was applied to characterize plant eco-physiology or habitat; and (4) soil resources were used for medicinal purposes.

Twenty-four medicinal plant names from the 15 pictorial examples analyzed, are composed of a Nahuatl soil morpheme (*Tla*= land) and/or stone morpheme (*Tetl*= stone), either at the beginning or at the end of the plant lexeme (e.g. ***Tla**nextli xihuitl*: ashy land herb; ***Tet**zapotl*: hard or wild Zapote). In some cases, these morphemes are represented twice (*Tlatla* or *Tete*), possibly referring to the abundance or predominance of a certain type of soil or stony land (e.g. ***Tlatla**olton* or ***Tete**zhuatic*). However, some plant names have soil or stone morphemes which do not necessarily refer to soil elements, but to plant physiognomy or morphology. This is the case of the herbs ***Tlatla**ncuaye* (herb with knees or knotty stems) or ***Te**xiyotl* (stone-like scarce herb). The pictorial representation of these two medicinal plants shows, in fact, a soil-like texture (coarse) or a stone-like consistence (hard) as part of their anatomy. A similar case could be the plant ***Xal**tomatl* (sandy-like tomato), which has sandy-textured leaves and not necessarily grows on sandy soils. The complete ideographic description of *Tlatlancuaye* and *Texiyotl* gives additional soil information. Both pictorial representations show a brown-blueish soil with glyphic elements related to clayey soils, according to Nahua convention (Figure 8.1). *Tlatlancuaye* pictorial representation shows a repetition of clayey soil glyph elements, that correlate with the repetition of the soil morpheme (*Tlatla*) within the plant lexeme, highlighting the abundance or predominance of a humid (blueish) clayey soil. The ideographic, glyphic and syllabic soil information given in this pictorial representation includes elements of plant physiognomy as well as plant eco-physiology or habitat. The same applies to the *Texiyotl* pictorial representation (Figure 8.1).

The most remarkable example of Nahua soil-plant relationship knowledge in the Badiano and de la Cruz Codex is the *Teoyztacquilitl* (white sacred edible herb) plant representation (Figure 8.2). The ideographic representation shows a layered soil, with a humic surface horizon and patchy colored pockets (whitish, reddish, yellowish and brownish) in a illuvial subsurface horizon. In addition, the soil type name is written as a *Chilchiltic* ***tlalli*** (reddish soil). Sahagún (1963: 703) refers to the same type of soil as ***Tla**chichilli*, "a land that is (red-ochre iron) reddish and used to varnish pottery, because it gives a good red color". Certainly, Sahagún is referring to a clayey soil still used to make pottery in various regions of central Mexico. *Chilchiltic* ***tlalli*** or ***Tla**chichilli* is the habitat where *Teoyztacquilitl* grows and, according to the text written below the pictorial representation, this plant and others, such as ***Tla**nextli* (herb of ashy land), ***Tetla**huilt* (herb of stony land) and ***Tlatla**coztli* (herb of abundant yellow land), usually grow on stony land. Common stony landscapes (*pedregales*) in central Middle America are recent lava flows covered by incipient mineral soils with a humic surface horizon, where scarce vegetation grows. These thin clayey soils are made of volcanic ash and basaltic minerals, having similar colors and pockets as shown in the *Teoyztacquilitl* plant pictorial representation.

The same text gives additional information in relation to the medicinal properties of soils and minerals. *Teoyztacquilitl* was used by Nahua people to treat a sore throat. The medicinal potion was prepared with the liquid of ***Tla***_nextli_ (herb of ashy land) mixed with powder of basaltic pumice (*piedra pómez* in Spanish), white earth, honeybee and *Teoyztacquilitl* herb. Although the text does not give information about the specific type of soil having medicinal properties, remarkable is that six of the 24 medicinal plant pictorial representations analyzed mention white earth and, in some cases, reddish earth as important elements of the curative potions. Also important to remark is that white earth was specifically used to cure respiratory illness and fever. According to Quiróz (1983) and West (1989), white soils of central Middle America are young, thin lime-enriched soils, developed from volcanic-lacustrine materials, with high amount of volcanic ash, and located mainly in flat or hilly lands. These mineral soils are moderately alkaline, saline or not saline, with high amounts of calcium, sodium, phosphorous and potassium. Possibly, the medicinal properties and curative uses of these soils are related to their mineral content. Another remarkable aspect derived from textual information refers to the medicinal uses of 17 different minerals to cure a wide range of diseases. Table 8.3 shows minerals used for curative purposes.

Finally, in some cases, the use of a soil morpheme (*Tla*) as part of plant nomenclature or lexeme refers to its life form. That is the case of herbs (*Pahtli* in Nahua) and shrubs (*Xihuitl* in Nahua). The inclusion of the soil morpheme was used to refer to plants growing on the land surface or small plants and/or buried tubercles. ***Tlal***_ehecapahtli_ (wind herb) and ***Tla***_cacamohtli_ (a buried tubercle) are nomenclature examples of herbs and tubercles, whilst ***Tlal***_mizquitl,_ a legume (*Prosopis spp.*), and ***Tla***_palcacauatl_, a variety of peanut, are examples of shrubs. Figure 8.3 shows *Tlalmizquitl* and *Tlatlauhcapahtli* medicinal plants

Nahua knowledge of soil-plant relationship was complex and vast. A preliminary exploration of this specific knowledge, as recorded in the 16th century document, reveals different ways of understanding natural resources. There is a need for systematic research on the comprehensive understanding of Middle American soil and land knowledge systems. Some possible research directions are: (1) the analysis of plant eco-physiology to recognize the specific landscapes and soilscapes where plants naturally grew; (2) the analysis of the medicinal properties of certain soils; and (3) the analysis of the links between this information and other ethnopedological pre-Columbian sources.

**Figure 8.1.** *Tlatlanqueye*, medicinal plant (left), and *Texiyotl* and *Tememetla* (right) medicinal plants. **Source:** Badiano and de la Cruz (1995)


**Figure 8.2.** Example of plant-soil relation according to 16th century codex. **Source:** Badiano and de la Cruz (1995)

### 8.4. Soil as a descriptor of cultural landscapes: The toponyms

In general, toponyms carry soil and land resources information and reflect the social perception and appropriation of natural resources, according to cosmological views and environmental and productive qualities of the landscapes. In addition, some site names reflect peoples' construction of cultural landscapes when providing information about the historical ecology of a given society, group or community (Crumley, 1994). Place names as linguistic descriptors can be analyzed to understand social knowledge about nature and cultural adaptation to the environment.

Nahuatl toponyms reflect soil and land resources knowledge and management in pre-Columbian central Middle America. If the Badiano and de la Cruz Codex (1995) offers specific evidence about Nahua soil-plant relationships knowledge, Nahua toponyms documents (Peñafiel, 1885; Macazaga, 1979) are sources to interpret soil and land knowledge and their relation with other landscape factors. These sources are ideographic and lexicographic representations and their interpretation is similar to that of the medicinal plant codex discussed above.

**Table 8.3.** Minerals having medicinal properties according to the 16th century Badiano and de la Cruz Codex

| MINERAL ACCORDING TO NAHUATL NOMENCLATURE | SPANISH TRANSLATION | ENGLISH TRANSLATION |
|---|---|---|
| IZTLI | OBSIDIANA | OBSIDIAN |
| NEXTLI | CENIZA VOLCANICA | VOLCANIC ASH |
| ACAMALLOTETL | AMBAR o ESPUMA DE MAR | AMBAR |
| | BERILO | BERILIUM |
| | BRONCE | BRONZE |
| CHILCHILTIC TAPACHTLI | CORAL | CORAL |
| EZTETL | CUARZO | QUARTZ |
| | PERLA VERDE | GREEN PEARL |
| | PERLA BLANCA | WHITE PEARL |
| QUETZALIZTLI | JADE AMERICANO o NEFRITA | AMERICAN JADE |
| | ONIX | ONIX |
| TAMAMATLATZIN | ROCA RIOLITICA | RYOLITIC ROCK |
| TEOXIHUITL OR CHALCHIHUTL | TURQUEZA SAGRADA | TURQUOISE |
| TEQUEZQUITL | NITRATO DE POTASIO | POTASIUM NITRATE |
| TEXOXOCTLI | NEFRITA o JADE | JADE |
| IZTACQUEQUETZALI | OBSIDIANA VERDE | GREEN OBSIDIAN |

**Source:** Badiano and de la Cruz (1995) and Maldonado-Koerdell (1996)

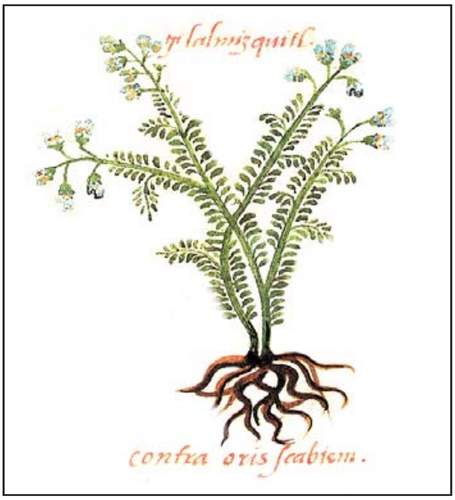



**Figure 8.3.** *Tlalmizquitl* and *Tlatlauhcapahtli* medicinal plants. **Source:** Badiano and de la Cruz (1995)

A set of 44 place names and their pictorial representations were chosen from toponym documents (Peñafiel, 1885; Macazaga, 1979) to interpret Nahua soil and land resources and their relations with other landscape factors. These place names have in common the inclusion of a soil morpheme (*Tlalli*), as part of the place lexeme, and an ideographic representation of soil or land characteristics or types according to Nahua convention. Table 8.4 shows the 44 selected Nahua place names, their etymology and their linguistic interpretation. Lexicographic and pictorial interpretation of Nahua place names can be synthesized as follows:

(1) Soil attributes and land qualities were widely used when referring to the landscape surrounding human settlements.

Two examples are *Acamalcingo*, “on the cropland or milpas”, and *Actopan*, “on the fertile land” (Figure 8.4). Both place names refer to land productivity and soil fertility, respectively. In its pictorial representation, *Acamalcingo* shows a yellowish-black flat soil glyph, with a well-standing maize plant in green, its flower in red and a maize cob in yellow. The pictorial representation of *Actopan* or *Atocpan* shows a well-standing flowering maize plant with two cobs, the latter referring to the high productivity abundance of an *Atoctli* soil type, assessed as a humid and fertile soil (Tables 8.1, 8.2, and 8.4).

(2) Soil and land characteristics were assessed in relation with other factors such as relief, water availability, moisture holding capacity, mineral contents, soil biota and agricultural production.

Three examples of contrasting soil–relief relationships are *Xalapa*, *Xaltepec* and *Xalatlaco* (Table 8.4). All three place names and pictographic representations refer to the same soil type, *Xalli* or sandy soil, expressed by a set of dots, but located in different landscape positions (Figure 8.5). Sandy soils are located in (a) a humid valley with water springs, as is the case of *Xalapa*; (b) in a hilly land, as is the case of *Xaltepec*; and (c) in a gully or barranca, as is the case of *Xalatlaco*.

Two place names and pictorial representations show contrasting relationships between soil type and moisture holding capacity: *Atlitlaquian* or “land where water infiltrates” and *Tlacuechahuayan* or “on the humid land” (Table 8.4). Both examples show a rainfall symbol or water symbol in a vertical position and a flat soil. The first case represents a sandy soil (dots) and the second case represents a well-structured black soil with a shellfish, implying the verb “to moisten” (Figure 8.6). According to Nahua convention, sandy light-colored soils were less productive or fertile than black well-structured soils. Sandy soils were also assessed as dry soils, while black soils were assessed as humid soils (Tables 8.1, 8.2 and 8.4).

Three examples of soil mineral content or mineral deposits are *Tizapan* “on the calcareous land”, *Nextitlan* “on the volcanic ash deposit” and *Xaltipan* “on the gravelly soil or on the gravel deposit at the bottom of the valley” (Table 8.4 and figure 8.7). All pictographic representations are circles referring to deposit, but showing different types of dots according to their size and shape. *Tizapan* shows fine particles or dots, characteristic of some calcareous powdery soils occurring in volcanic-lacustrine landscapes of central Middle America. *Xaltipan* shows medium subrounded dots referring to gravelly soils, while *Nextitlan* pictographic representation is an open grey mouth with teeth, possibly referring to a crater or cave with an ash deposit.

Two examples of soil biota abundance are *Ocuilan* “where earthworms live” and *Xaltocan* “on the sandy soil where moles live” (Table 8.4 and figure 8.8). Earthworms were conceived as feminine animal deities giving soil fertility according to Nahua cosmovision. Moles were considered feminine animal deities, representing *Tlaloc* in Middle American cosmovision.

Four place names and pictorial representations refer to agricultural production systems (Table 8.4 and Figure 8.9). *Xochimilco* “on the flowering cropland” is the famous pre-Hispanic village, situated in the south of the Mexico Basin, where the *chinampas* system was established on the borders of the Tenochtitlan Lake. *Chinampa* is considered the most intensive and productive Middle American agricultural system. Pictographic representation of *Xochimilco* shows two flowers (abundance) growing on a well-structured black soil. *Tlaltenampan* “on the earthy-walled agricultural terraces” has a pictorial representation of agricultural terraces with earthy walls on a slope. These terraces were cultivated with maguey (*Agave spp.*) and temporarily irrigated by upstream water channels, taking advantage of sediment transportation to fertilize and level the anthropogenic soils of these systems. Pictorial representation of *Tlahuelilpan* “on the valley of irrigated orchards” shows a pot spilling water over a flat well-structured soil. This irrigation system was widely used in orchards and home gardens of central Middle America. Pictorial representation of *Tlatlauhco* “on the irrigation channel on a mucky land” shows the symbolic representation of irrigated agricultural systems, widely distributed in Middle American flatlands (Armillas, 1949; Palerm and Wolf, 1972).

(3) The relation between soil characteristics, relief and water availability was widely labeled to assign place names. The relationship between these factors was used to assess agricultural land productivity and as land-use decision-making factors.

**Table 8.4.** Nahua place names referring to soil and land resources

| NAHUATL TOPONYMS | ETYMOLOGY | PLACE NAME |
|---|---|---|
| Acamalcingo | Acatl: maize stalk; milli: cropfield; tzinco: place | On the cropland or milpas |
| Acamalixtlahuacan | Acatl: maize stalk; milli: cropfield; ixtlahuacan: valley | On the flatland where maize is abundant |
| Actopan | Atoctli: fertile soil, alluvium; apam: flatland | On the fertile land |
| Acuitlapan | Atl: water; tecuitlatl: muck; apam: flatland | On the mucky land |
| Atlitlaquian | Atl: water; tlalli: soil, land; tlalaqui: sinking; yan: place | Land where water infiltrates |
| Chinantlan | Chinamitl: living fences; tlalli: land; an: place | On the cropland surrounded by living fences |
| Ichcaatoyac | Ixcatl: cotton; atoyatl: river | On the foamy white river |
| Izteyocan | Izteyotl: obsidian; am: place | Where obsidian is polished |
| Nextitlan | Nextli: (volcanic) ashes; ti: in between; tlan: place | Within ashy flatland |
| Nextlalpan | Nextli: (volcanic) ashes; tlalli: land; apam: over | On an ashy hilly land |
| Ocuilan | Ocuili: earthworm; tlan: place | Where earthworms live |
| Teacalco | Tetl: stone; calli: house; atl: water; co: place | On the stony irrigation channel |
| Tecmilco | Tetl: stone; milli: cropland; copilli: royalty | On the royal lands |
| Tecozautla | Tetl: stone; coztli: yellow; tlalli: soil | On the abundant yellow gravelly land |
| Tepechpan | Tepetatl: tepetate; tepechtli: consolidate; pam: over | On the consolidated tepetate |
| Tepetlahuacan | Tepetla: mountain range; hua: plural; can: place | On the mountain range |
| Tepetlaoztoc | Tepetatl: tepetate; oztoc: cave | In the hardpan cave |
| Tepetlapa | Tepetatl: tepetate; tlalli: soil, land; apam: valley | In the valley of hardpan |
| Tepoxaco | Tetl: stone; tepoxactli: pumice stone; poxatic: spongy; co: place | Place of the pumice stone |
| Tequisquiapan | Tequezquitl: compaction of soda carbonate with natural salt; apam: flatland | In the valley full of saline crusty soil |
| Tizapan | Tizatl: calcium carbonate; tlalli: soil, land; apam: flatland | In the valley of calcimorphic soil |
| Tizatepec | Tizatl: calcium carbonate; tlalli; land, soil; tepetl: hill | On the hill of calcimorphic soil |
| Tlacozahutitlan | Tlalli: land, soil; coztli: yellow; titlan: near the abundant | Near the abundant yellow lands |
| Tlahuelipan | Tlalli: land, soil; tlaahuilli: irrigated orchard; apam: flatland | In the valley of irrigated orchards |
| Tlatlauhco | Tlalli: land, soil; tlallatl: mud; atlauhtli: irrigation ditch | In the irrigation ditch |
| Tlacuechahuayan | Tlalli: land, soil; cuechahua: to get wet; yan: place | On the land where water infiltrates |
| Tlatelolco | Tlalli: land, soil; tlatelli: gravel; tetl: stone; olotic: deposit | On the gravel deposit |
| Tlaltenampan | Tlalli: land, soil; tlaltenamitl: terraces; pam: over or on | On the earthy-walled terraces |
| Tlatizapan | Tlalli: land, soil; tizatl: calcium carbonate; apam: flatland | On the white saline land |
| Tlatlauhquitepec | Tlalli: land, soil; tlatla: abundance of soil; auhqui: reddish, ochre; tepetl: hill | On the red soil hill |
| Xalac | Xalli: sand; atl: water; co: place | In the sandy river |
| Xalapa | Xalli: sand; atl: water; apam: flatland | Sandy water spring |
| Xalatlaco | Xalli: sand; tlalli: land, soil; co: place | On the sandy barranca or ravine |
| Xalatlan | Xalli: sand; atl: water; tlan: within or near by | Within the sandy land where water springs |
| Xaltepec | Xalli: sand; tepetl: hill | On the sandy hill |
| Xaltianquizco | Xalli: sand; tianquiztl: market, storage, deposit; co: place | On the sand deposit |
| Xaltipan | Xalli: sand; xaltetl: gravel; apam: flatland | In the gravelly sandy valley |
| Xaltocan | Xalli: sand; tozan: mole; an: place | On the sandy land where moles live |
| Xaxalpan | Xalli: sand; xaxa: abundance of sand; apam: flatland | On the sandy land |
| Xochimilco | Xochitl: flower; milli: cropland; co: place | On the flowering cropland |
| Yancuitlalpan | Yancuic: new, recent; tlalli: land, soil; apam: flatland | On the new (white) lands |
| Zoquiapan | Zoquitl: mud, marsh; apam: flatland | In the marsh |
| Zoquitzinco | Zoquitl: mud; marsh; tzinco: place | In the marsh |

**Sources:** Peñafiel (1885), Macazaga (1979) and the author's interpretation

The relation between these factors is recognized as follows: (1) 76% of the 44 chosen place names and their respective pictorial representations refer to soil–relief relations, either as uniquely related factors or as part of other related factors; (2) soil–relief relation is referred to as uniquely related factors in 31% of the place names; (3) soil – relief – water availability relation is recognized in 15% of the place names; (4) soil–relief–agricultural productivity is referred to in 15% of the place names; and (5) soil–water availability relation is referred to in 15% of the place names.

A principal component analysis (PAC) was done to recognize statistical distribution of (a) land, (b) relief, (c) water, (d) stone, (e) agricultural production, (f) mineral and (g) vegetation, as main independent variables,

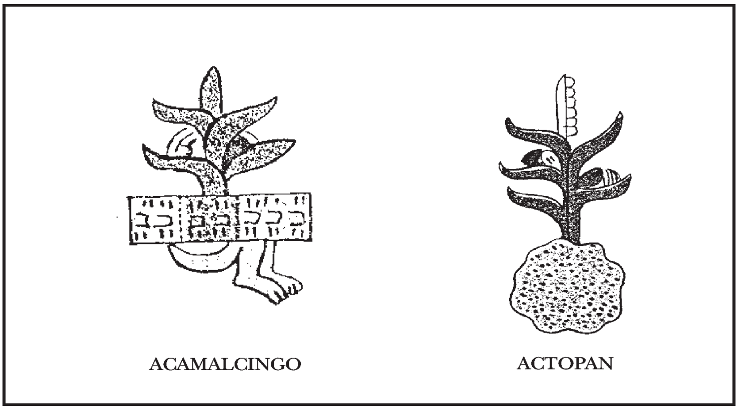



**Figure 8.4.** Pictorial representations of *Acamalcingo* and *Actopan* toponyms
**Source:** Peñafiel (1885) and Macazaga (1979)

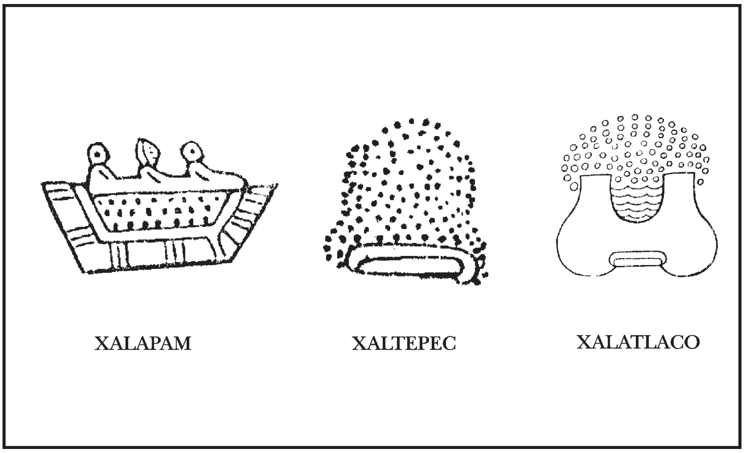



**Figure 8.5.** Pictorial representations of *Xalapam, Xaltepec* and *Xalatlaco* toponyms
**Source:** Peñafiel (1885) and Macazaga (1979)

from the linguistic and pictographic analysis of the selected place names and their pictorial representations (Table 8.4). The bipolar presence-absence representation of the independent variables and place names shows that land constitutes the first principal component (FPC), explaining 57.5% of the variance of the place names, as it was expected due to the way place names were chosen (Figure 8.10). Water (positive) and relief (negative) represent the second principal component (SPC). Both independent variables are correlated with land, explaining the main statistical variability of place names. These three independent variables are highly significant, accounting for 77.3% of the variance of the place names. While clusters A, B, and C are highly correlated, cluster D, dominated by water, corresponds to the most homogeneous group (Figure 8.10). According to the latter, land or soil, relief and water availability were important interrelated factors to assign place names, according to the qualities of the surrounding landscape for agricultural production.

(4) A wide array of soil descriptors is named in Nahuatl toponyms and represented in a pictorial way, including: (1) relief, (2) texture, (3) humidity, (4) productivity, (5) fertility, (6) structure, (7) stoniness, (8) color, (9) chemical composition, (10) consistence, and (11) soil biota (Figure 8.11).

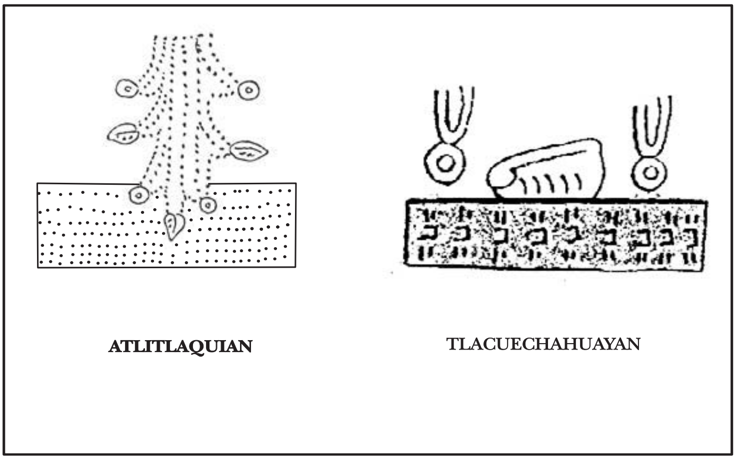



**Figure 8.6.** Pictorial representations of *Atlitlaquian* and *Tlacuechahuayan* toponyms
**Sources:** Peñafiel (1885) and Macazaga (1979)

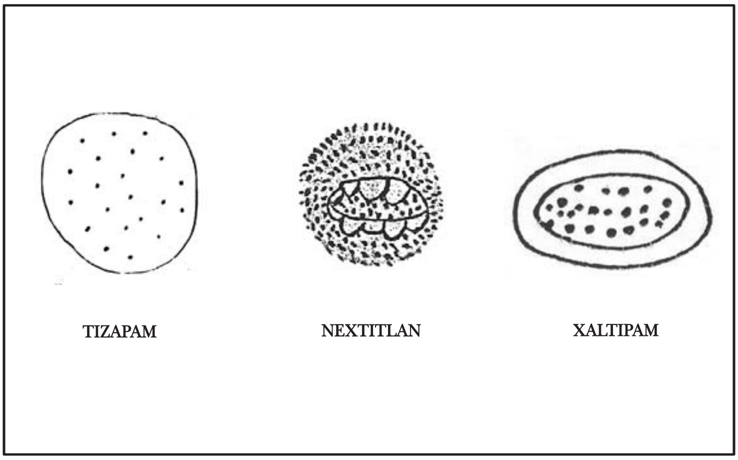



**Figure 8.7.** Pictorial representations of *Tizapam, Nextitlan* and *Xaltipam* toponyms
**Sources:** Peñafiel (1885) and Macazaga (1979)

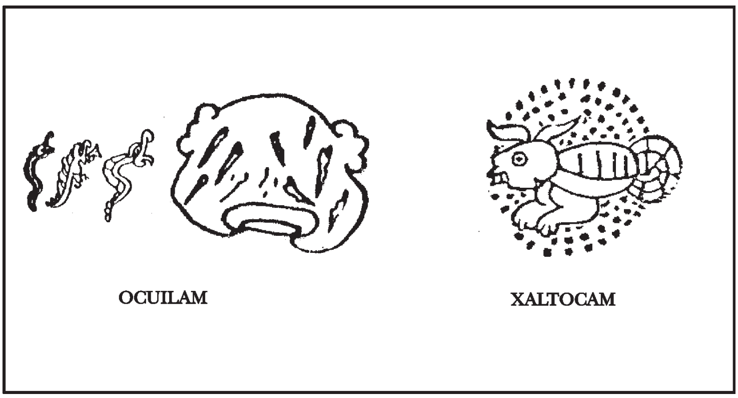



**Figure 8.8.** Pictorial representations of *Ocuilam* and *Xaltocam* toponyms
**Sources:** Peñafiel (1885) and Macazaga (1979)

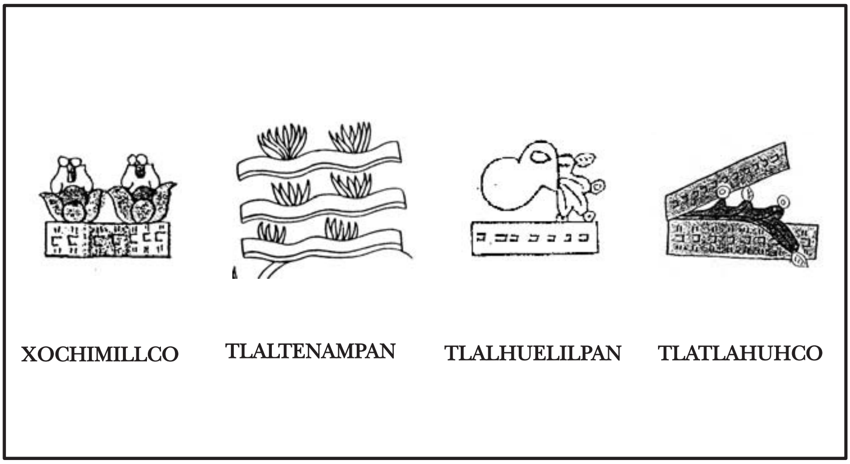



**Figure 8.9.** Pictorial representations of *Xochimilco*, *Tlaltenampan*, *Tlahuelilpan* and *Tlatlahuhco* toponyms. **Sources:** Peñafiel (1885) and Macazaga (1979)

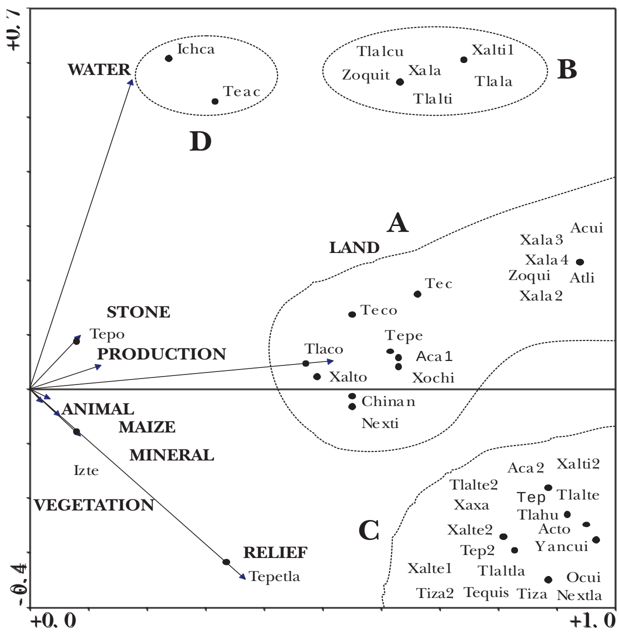



**Figure 8.10.** Principal component analysis of toponym descriptors and place names

Soil descriptors were used to label land productivity and, because of this, soil descriptors were named or pictographically represented to assign some place names. If we consider that Nahua soil classification was mainly utilitarian, place names referring to soil descriptors, as land qualities or land restrictions for agricultural purposes, reflect land-use specialization of the landscapes surrounding the villages. Complex soil information was given in some place names and by their pictorial representation, as is suggested by a PCA of the soil descriptors as independent variables and the statistical distribution of place names as dependent variable. Figure 8.12 shows a bipolar presence-absence clustering distribution of both components. In this case, relief (as flatland in the graph) does not control the variability of the main clusters. Clusters A and B are heterogeneous or mixed clusters. Both cases show that place names and pictorial representation distribution are defined by many independent variables. Furthermore, there is no correlation between compaction (positive) and fertility (negative) as clustering independent variables, reflecting a sharp separation between fertile and infertile soils.

Two main conclusions can be drawn from this. First, the heterogeneity of cluster A reflects the complexity of the soil descriptors used to assess land qualities for agricultural productivity. Secondly, soil fertility, as a land quality, was a main factor to label some places. Cluster B shows the distribution of place names correlated with soil humidity, cropland and fertile soils, while cluster C represents place names correlated with chemical composition and soil compaction, as constraints to soil workability and agricultural land productivity (Figure 8.12).

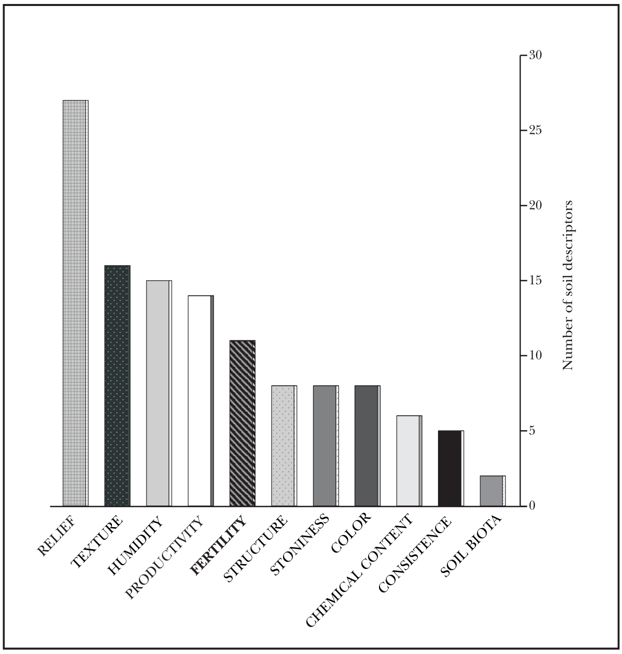



**Figure 8.11.** Soil descriptors pictorically represented and named in Nahua toponyms

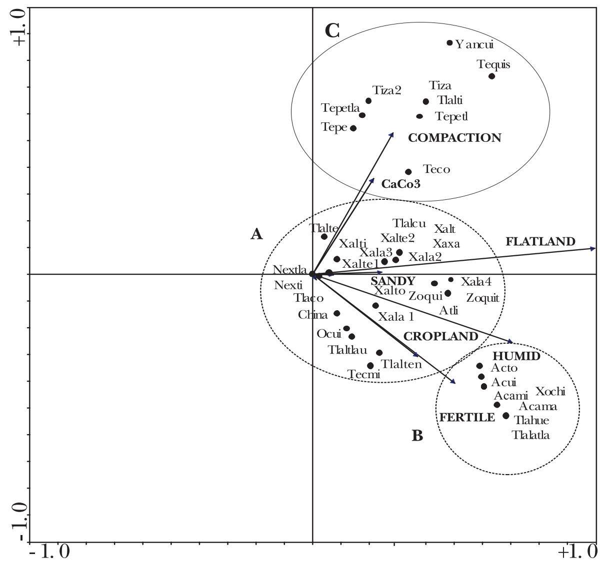



**Figure 8.12.** Principal component analysis of soil descriptors and place names

Soil descriptors were used to assign place names and describe the landscapes surrounding the human settlements. The Nahua procedure to identify and qualify soil characteristics was complex and interrelated with other ecological and productive factors. Further research is needed to support these preliminary conclusions. One procedure could be to overlay the location of place names on topographic, soil, hydrological and land-use maps to detect spatial correlation.

## 8.5. Soil knowledge for tributary purposes

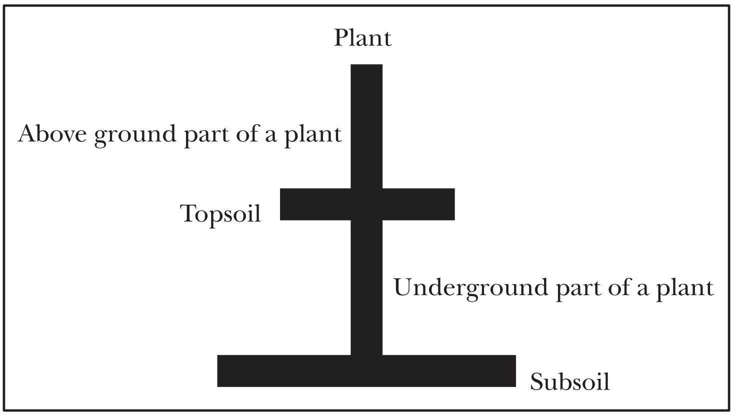
### 8.5.1. Soil knowledge for tributary purposes in ancient civilizations

Complex developments of non-Western civilizations before the Christian Era were associated with governmental centralization and agricultural advancement via irrigation, giving place to tributary systems. China (Needham and Gwei-Djen, 1981; Chingkwei and Shenggeng, 1990), India (Abrol, 1990; Abrol and Nambiar, 1997) and Egypt (Chadefaud, 1998) ressemble Middle America in this respect. In these regions, there is ethnohistorical and archaeological evidence of the use of soil information provided by local farmers to impose taxation by state bureaucracies. A brief review of the Chinese, Indian and Egyptian soil knowledge applied for taxation purposes is given, before describing the particularities for tributary purposes in Middle America.

(1) The Chinese example

In China, for example, officials of the Xia Dynasty in charge of agriculture developed a land-use evaluation system to assess soil productivity in the Shaanxi Province, more than 4,000 years ago (Chingkwei and Shenggeng, 1990). Further development of this land evaluation system was published in the Yugong geography book, between 400-300 BC, and is considered the first soil classification, soil cartography and land-use evaluation written in China (Needham and Gwei-Djen, 1981). Soils were classified according to color, texture, consistence and moisture regime. Land qualities and soil management were assessed in different soil regions to determine agricultural taxation to local farmers (Chingkwei and Shenggeng, 1990). This document, contemporaneous to

**Figure 8.13.** Chinese Han Dynasty pictographic representation of soil




the pre-Socratic philosophers in Greece, offers information about the distribution of soil types, relief, hydrology and vegetation. Crop and tree adaptability was assessed by means of the analysis of the above factors. Yields were determined in accordance to soil qualities and tribute commodities were assigned at provincial and local levels (Wan Guangwei, 1935; Wan Gouding, 1956; Zhang Hanjis, 1959). This complex knowledge about soils was intimately linked to ancient Chinese cosmovision. A God of the soils (*She* or *Zhong ti*) was venerated with sacrifices and offerings on his altar. Moreover, the five cardinal points of the world were represented on the altar by five soil colors. Green represented the East and white the West, whilst black represented the North and red the South. The fifth cardinal point was the center, represented by yellow soils. Needham and Gwei-Djen (1981) recognized these soil colors as representative of each of the main soil regions of the territory subjected to the Han Dynasty.

During the Han Dynasty (206 BC to 226 AD), an ideographic Chinese character was written when referring to soil, expressing the upper and lower parts of the land. This pictographic representation shows soil with two layers, the top and the subsoil layers (Figure 8.13). Land evaluation for agricultural taxation during the Han Dynasty gave the right use of land, which involved knowledge of crop-plants and trees and implied the understanding of soil diversity on which crop-plants and trees would most effectively grow (Needham and Gwei-Djen, 1981).

(2) The Indian example

Ancient soil knowledge in India was vast and complex, as it is reflected in the Vedic Texts (ancient scriptures) written over a long period between 1500-600 BC (Abrol, 1990). Complex water and soil conservation measures and agricultural irrigation systems, together with Vedic hymns, maxims, proverbs and other written manuscripts, constitute archaeological and ethnohistorical evidence of complex knowledge and management of soils, during the Indus Valley civilization (3000-1500 BC) (Abrol et al., 1998; see also Clarke, 1995,1999).

In Ancient India, agriculturalists were quite aware of the relation between soil properties, water regime and crop production (Abrol, 1997). Gangopadhyay (1932; see Arbrol 1997) described an ancient soil classification based on soil fertility and soil–crop suitability assessment. Manure was labeled and managed according to soil-plant relationship knowledge. Soils were classified according to color, taste, and manure application. The Arthshastra document (ca 315-291 BC) provides detailed information on land and soil classification in relation to productivity, outlining rules which enabled differential assessment of production systems to meet the needs of the state and of the cultivators. This land evaluation procedure separated rainfed systems as less valued from irrigation systems as highly valued, according to rainfall, inundation and relief assessment of arable lands.

(2) The Egyptian example

There is also archaeobotanical, archaeological and ethnohistorical evidence of complex soil and land knowledge applied to impose state taxation to local farmers in Ancient Egypt (Butzer, 1976; Chadefaud, 1998). Ideographic, pictorial and lexicographic information analyzed by Chadefaud (1998) shows the ways Egyptian agriculturalists assessed silt deposition on arable lands, within cyclic high floods of the Nile river, to predict crop yields and evaluate land qualities, since at least 4,000 years ago. *Kemet* or dark alluvial soil was used as a term to describe the Nile Valley, where sophisticated irrigation systems evolved through thousands of years. Butzer (1976) showed that the Nile river floodplain was the natural scenario of unexpected continuity in environmental exploitation strategies over thousands of years, between the prehistoric communities of the Pleistocene and the highly complex and sophisticated civilization of historical times. Since at least 3,000 years, artificial floodwater farming along the Nile Valley allowed the increase of cultivated areas by controlling the length of time water remained in natural flood basins (Butzer, 1976; Denevan, 1995).

Land and water were fundamental resources to be assessed for the best performance of agricultural activities and for plant domestication at local and regional levels, according to changing conditions over long time periods. Resource assessment was done throughout the Nile floodplain, but also on the surrounding drylands. Ancient Egyptian characterization of landscapes was complex and dynamic in accordance to environmental dynamics. Landscapes were labeled according to the intimate relations between natural and productive factors. Relief, climatic conditions, water availability, flooding regimes, siltation, soil productivity and vegetation were the most important factors assessed to label land qualities, allocate agricultural land-use and impose state taxation. The recognition of landscape dynamics was supported by the dependence between '*Kemet*' and water. The Nile river regime was considered the primary source for soil fertility renewal and dark soils were perceived as being fecundated by siltation, allowing the re-greening of the floodplain (Chadefaud, 1998).

Bureaucracies from the Pharaonic to the Greco-Roman periods drew particular attention on farmers' sophisticated environmental knowledge to assess land qualities for land taxation, registration and allocation. Land cadastre, water administration, hydraulic engineering and agricultural productivity were controlled by the in-turn ruling state, since the Ancient Dynasty, about 3,000 years BC. Fiscalization was ruled from a previous land evaluation, which divided arable lands into two main categories: the irrigated highlands producing one annual crop harvest, and the inundated and more fertile lowlands, subdivided into old and new territories. Pictographic representations of sophisticated land-use systems, land cadastre and registration, irrigation systems, crop-trees and vegetation types can be found in archaeological sites and ethnohistorical documents, constituting primary sources to reconstruct Ancient Egyptian environmental geography (Chadefaud, 1998).

### 8.5.2. Nahua soil knowledge for tributary purposes

The complexity of Nahua soil knowledge and its application for agricultural land productivity assessment to impose state taxation to local farmers are reflected in the 16$^{th}$ century Aztec tributary codices. Ethnohistorical and ethnopedological research done by Williams during the last 25 years (Williams, 1972; 1980a; 1980b; 1980c; 1981; 1984; 1985; 1994), from the analysis of these documents, demonstrates a sophisticated local soil knowledge applied by the Aztec bureaucracy to control agriculture and impose taxation in central Middle America. Assumably, tributary policies arose in central Middle America during the Late Pre-Classic Period, when complex writing systems and mathematics evolved together with the emergence of centralized urban societies. These centralized systems were ruled by a religious-political elite, such as the Aztec Empire, emerging around 2,500 years ago (López Austin and López Luján, 1996). However, there is not enough information that documents the evolution of the taxation system over this long time period.

The most detailed non-Western ethnohistorical documents referring to local soil qualities, as a factor of land cadastre and state taxation, are much probably the Códice Santa Maria de Asunción (Ms. 1947 bis, Biblioteca Nacional de México) and the Codex Vergara (Ms. Mex. 37-39, Bibliothèque Nationalle de Paris). These are Nahuatl pictorial manuscripts drawn ca. 1543-1544 from *Tepetlaoztoc* in the eastern Basin of Mexico (Williams, 1994). Both cadastral codices depict 1,500 agricultural parcels, pertaining to some 360 households located within a sparse settlement of 17 named localities belonging to the *Tepetlaoztoc* village and covering approximately 200 hectares (Williams, 1990). The pre-Hispanic cadastral area covered main portions of the present *Tepetlaoztoc* village, situated on the northern slope of the Tlaloc volcano facing the Teotihuacán Valley, eight kilometers northeast from Texcoco city (Williams and Ortíz Solorio, 1981).

Both cadastral documents give specific information of each household's land holdings. Information about the name of the landholder, number of members per household, number of parcels pertaining to each household, type of soil of each landholding, perimeter dimensions and field area per each landholding is provided. Landholding information is drawn twice in separate sections. The first section, the *Milcolcoli* convention, gives information of each landholding in its approximate shape and perimeter information is depicted using the Nahua-Texcocan measurement unit *Quahuitl* (2.5 meters) (Harvey and Williams, 1981; Williams, 1990). The second section, the *Tlahuelmantli* convention, gives also information of each landholding, but in this case parcels are drawn in a rectangular shape and land area information is given in square *Quahuitl* (6.25 square meters) (Harvey and Williams, 1981; Williams, 1990). Both sections give soil information at parcel level and Nahua soil glyphs are drawn in the center of each parcel (Figure 8.14). The duplication of soil glyphs at parcel level reflects the consistency of the Nahua soil classification convention.

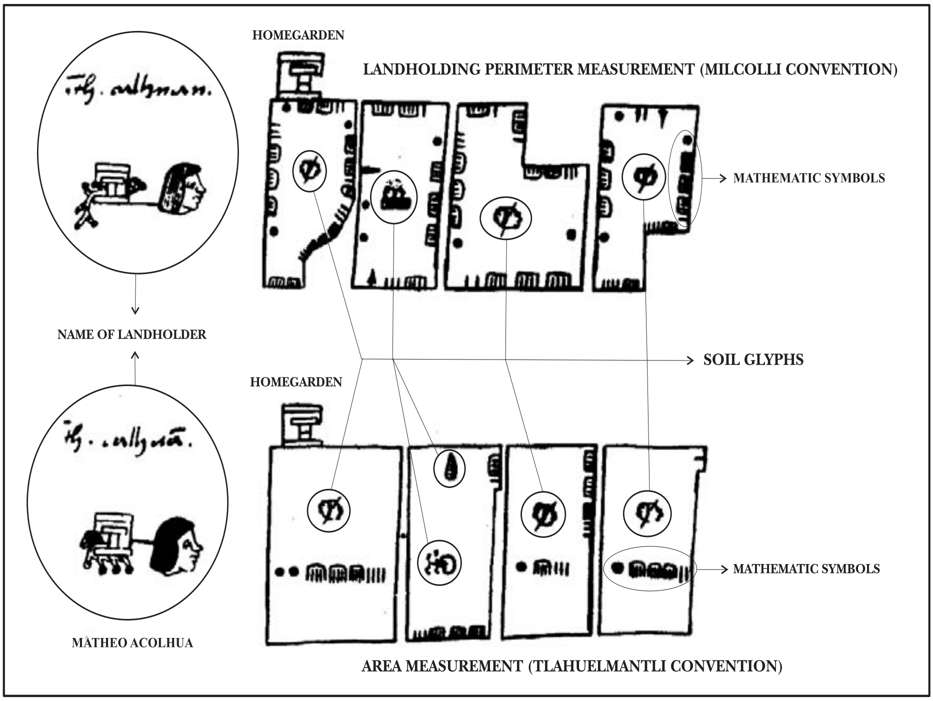



**Figure 8.14.** 16th century cadastral codex from *Tepetlaoztoc* showing soil information at parcel level.
**Source:** Williams (1990)

According to Williams' findings (1994), the analysis of detailed differences between all soil glyphs represented on both documents gave 104 variants in 200 hectares. The same author suggests that the high number of glyph variants may represent more than one defining criterion of soil class, or soil intergrades, or they may record descriptive phrases labeling some outstanding feature of the soil rather than the soil type lexeme. Despite these uncertainties, findings show that detailed soil information was acquired at parcel level, revealing the complexity of the Nahua soil knowledge. Furthermore, Williams clustered glyph variants into 19 soil taxa labeled at three taxonomic levels: seven generic, nine specific and three varietal, according to the principles of folk taxonomy proposed by Berlin, Breedlove and Raven (1973) to classify biological phenomena (Figure 8.15). These 19 soil taxa were analyzed in a lexicographic way and contrasted with other ethnohistorical manuscripts providing Nahua soil information.

Although the Nahua soil classification appears to have few generic types, it includes many soil intergrades and soil mixtures, labeled by descriptive phrases. Spatially, soil differences were perceived at local and microlocal levels, and agricultural practices were adjusted to soil variability and soil diversity. In some cases, glyphs depict generic

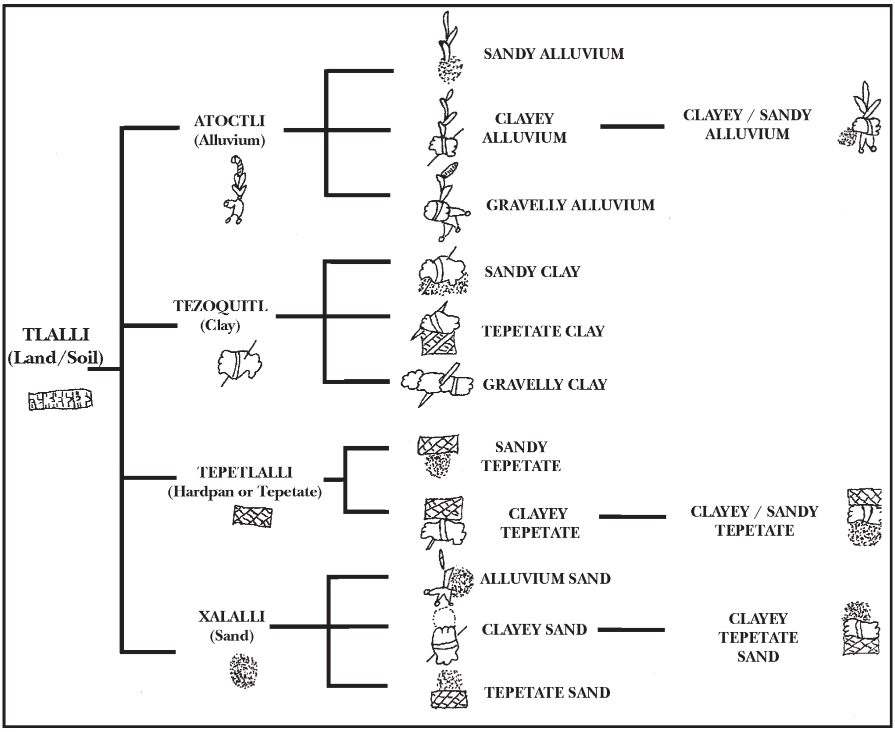



**Figure 8.15.** 16th century Nahua soil taxonomy. **After:** Williams (1981)

taxa; in other cases, they refer to subordinate taxa or descriptive attributes. The Nahua soil classification successfully conveyed the structure and complexity of the local soil domain. Ethnopedological and soil surveys were conducted in the same area and surrounding villages to recognize contemporary farmers' soil knowledge and to classify and map local soils according to technical convention (Williams, 1981). Contemporary ethnopedological survey and technical soil classification at local level show that local farmers recognize only four soil classes, while three soil types were identified by technical procedures (Williams and Ortíz Solorio, 1981).

Other relevant findings of Williams' work showed that homegardens (*Calmilli*) were established adjacent to residences and managed intensively on fertile soils, including alluvium (*Atoctli*), clayey (*Tezoquitl*), yellow (*Tlacoztli*) and sandy (*Xalalli*) soils. On the contrary, *milpas* were established on the drier piedmonts and managed less intensively on less fertile soils, including stony (*Tetlalli*), hilly (*Tlaixtli*), compacted (*Tepetatl*) and sandy (*Xalalli*) soils (Williams, 1985). Furthermore, Williams (1990) elaborated a model to estimate maize production and consumption in one residential area of pre-Hispanic *Tepetlaoztoc*, using 16th century cadastral information to determine possible excedent production available for re-distribution via market or taxation. The model assumed normal and subnormal climatic conditions, on the basis of amount and distribution of rainfall during the maize production cycle (1,000 – 700 mm/year). The settlement Tlanchiuhca had, at the beginning of the 16th century, 91 inhabitants living in 15 households, managing 55 agricultural parcels covering 27.5 hectares. Seven Nahua soil types were ranked in three classes according to potential maize productivity, to estimate maize yield per agricultural system recognized locally, adjusting all possible production conditions during the 16th century (Table 8.5). An estimated 160 kg of maize per capita per year was taken as mean consumption rate to determine the production-consumption relationship, according to assumptions made by Sanders, Parsons and Santley (1979).

Extrapolating the maize production-consumption ratio per household in *Tlanchiuhca* to the total area having 16th century cadastral information in *Tepetlaoztoc*, the following conclusions were reached:

**Table 8.5.** Nahua soil types in Tepetlaoztoc ranked according to their productivity for maize

| NAHUA SOIL TYPE | ENGLISH NOMENCLATURE | SOIL CHARACTERISTICS | PRODUCTIVITY RANK | ESTIMATED MAIZE YIELD kg/ha |
|---|---|---|---|---|
| Atoctli | Alluvium | Transported and deposed river sediments. Moderately deep, fine-textured soils, with high organic matter and nutrient contents. High moisture retention capacity. Soils considered humid. Located on flat highlands and at valley bottoms. | 1st class | 1,400 |
| Tezoquitl | Clayey black soil | Moderately deep, massive clayey soils, with high moisture retention capacity. High CEC but not easily workable. Named black soils locally. Located on footslopes and at valley bottoms. Soils considered humid. | 2nd class | 1,000 |
| Tlacoztli | Yellow soil | Silty loam, medium-textured soil, with high moisture retention capacity and high basic mineral content. Located on footslopes. | 3rd class | 1,000 |
| Xalalli | Sandy soil | Volcanic ash, fine-textured soil, with moderate moisture retention capacity and medium nutrient content. Located on footslopes. | 3rd class | 600 |
| Tlaltelli | Stony soil | Stony shallow soil, with moderate organic matter content. Moderate to low retention capacity. Located on flatlands or slightly sloping lands. | 3rd class | 600 |
| Tepetlalli | Tepetate (hardpan) | Compacted, shallow mineral soil, with low nutrient content and low moisture retention capacity. Difficult to work unless it is cracked. Located on sloping lands and easily erodible. | 3rd class | 600 |
| Tlaixtli | Sloping soil | Shallow, fine-textured hillslope soil. Low moisture retention capacity and low nutrient content. | 3rd class | 600 |
| Tetlalli | Stony soil | Stony, very shallow soil, with very low moisture retention capacity and nutrient content. Located on steep lands. | 3rd class | 600 |

**Source:** Williams (1990)

(1) There was enough maize excedent for redistribution at local level in normal climatic conditions, but nearly half of the households could not produce enough maize to fulfil their basic consumption requirements when the conditions were subnormal.

(2) Twenty five percent of the households would produce more than 50% of the maize needed to fulfil their basic consumption requirements even during subnormal climatic conditions, but 20% of the households depended drastically on climatic factors to balance the production-consumption ratio.

(3) There was a sharp division between poor and rich householders according to maize production, when considering only the agricultural activity, but social stratification implied also labor division between urban and rural activities. Other factors contributed also to balance production and consumption including (a) intensive production in multicropping systems such as homegardens; (b) the existence of well-structured regional markets of staple goods, able to satisfy the needs of more than 15 million people living in rural and urban areas just before the Spanish conquest; (c) the assessment and veneration of rainfall as main environmental factor affecting the performance of maize, linking cosmovision and cognition of soil–maize–water relations (Williams, 1990).

## 8.6. CONCLUSION

In addition to the complex symbolic representation of land as a supra-natural and non-human being, soil and land resource characteristics, properties, qualities and dynamics were assessed in sophisticated ways, taking advantage of potentials and overcoming constraints in relation to agricultural activities. These knowledge-based systems are reflected in 16th century documents and codices, which provide extensive soil information, especially from the Nahua of central Middle America. Nevertheless, these sources reflect only partially the complex and extensive knowledge that evolved during thousands of years. So far, systematic ethnopedologic research focused mainly on central and southeastern Middle America because of the richness and abundance of ethnohistorical documents, leaving aside sources and evidence from other regions and peoples of this vast civilization core. Furthermore, reconstruction of pre-Hispanic Middle American ethnopedologies still raises more questions than answers.

The 16th century Nahua ethnopedologic information reflects complex soil nomenclature and classification. Nahua named and classified soils mainly according to texture, structure, consistence, organic matter and chemical composition, soil fertility and color. Soil–relief position and soil–water-holding capacity were used for assessing soil productivity according to crops, crop varieties and landraces. The maintenance and restoration of soil fertility were key-factors in the Nahua soil knowledge and land management. Linked with land symbolic perception, practical soil knowledge was applied to replenish the life cycle centered on the perpetuation of maize cropping.

The 16th century Nahua practical soil knowledge complexity is reflected in pictographic, ideographic and textual representations. The Nahua soil classification was incorporated as a convention in their written tradition. Glyphs were used as conventions to label soil and land resources. Ethnohistorical evidence shows three main ways of applying the Nahua soil classification system.

(1) Soil–plant relationships were widely assessed. Nahua ethnobotanical and medical documents reveal several ways of using and applying soil descriptors in relation to medicinal plants: (a) soil knowledge was used to label plant life forms; (b) soil knowledge was applied to characterize plant ecophysiology or habitat; (c) soil resources were used for medicinal purposes; and (d) phonetic morphemes used to label soils were also used to characterize plant physiognomy.

(2) Other documentary sources providing extensive soil information are the Nahua toponymic documents. Soil descriptors were commonly used to recognize and label landscapes surrounding villages, according to natural characteristics or biophysical qualities. Pictorial and/or textual information of soil reflects pre-Columbian Middle American cultural landscapes and offers information of how soil knowledge was related to other biophysical or cultural factors to characterize landscapes, villages and landholdings. Place names give accurate information about land–water–relief relationships as qualities to assess land productivity. Furthermore, soil fertility was a main quality to label some place names.

(3) Probably the most accurate application of soil knowledge was for tributary purposes. Conventional uses of soil pictorial descriptors are given in plot-level Nahua tributary codices from the 16th century. Cadastral maps at village level provide information on social and natural factors, similar to the cadastral systems developed in China, India and Egypt long before the Christian era. Aztec bureaucracies combined agricultural land productivity assessment with mathematical measurement of each landholding to impose taxation at household level in Post-Classic central Middle America. Soil glyphs much probably represent information on soil classes, soil intergrades and soil mixtures at each landholding. This information was cross-checked with social characteristics such as the number of members per household, the name of the owner of each landholding and the ownership of highly productive homegardens per household.

Information provided by one of these 16th century tributary codices was used to elaborate a model able to estimate maize production and consumption at household level and the production surplus for distribution via market or taxation. Maize surplus was linked to highly fluctuating climatic conditions, which reflect an unstable rain-dependent agricultural system. The level of production caused sharp social division between poor and rich householders, submitted to a complex market and taxation system at village and regional levels.

# CHAPTER NINE

## SOIL AND LAND MANAGEMENT SYSTEMS IN PRE-COLUMBIAN MIDDLE AMERICA

### 9.1. INTRODUCTION

This chapter describes land management techniques aimed at improving soil fertility and land productivity for maize cultivation in Middle America. Special attention is given to fragile lands, such as sloping and inundated fields in semi-dry temperate highlands and humid tropical lowlands. Agricultural terraces on hilly landscapes, drained fields such as *chinampas* on flooded highlands, and raised-bed fields on tropical low-lying wetlands are analyzed, specifically in relation to soil, water and relief management.

According to Wolf and Palerm (1955) agricultural intensification in Middle America developed as a cause and consequence of social and economic factors under centralized urban societies, having complex social stratification and labor division. Agricultural technological changes were presumably adjusted to the specific environmental conditions of this complex area (Butzer, 1972; Denevan, 1992b; Doolitle, 1984, 1996), which has a large proportion of fragile lands where soil, relief and water availability were major constraints for agricultural activities (Wilken, 1987; Denevan, 1989 and 1995). Table 9.1 shows a classification of fragile lands in Middle America according to climate, relief, main stress factors and geographical distribution within six major regions. In this context, agricultural landscapes were modified according to ecological and cultural factors and towards the intensification of the *milpa* system (Warman, 1989; Palerm, 1990; Bonfil, 1987b; Whitmore and Turner II, 2001).

Middle American environmental knowledge-based systems and organized human labor constituted main sources of agricultural technological change at local and regional levels, shaping complex cultural landscapes despite the lack of animal force and transportation technologies (Harrison and Turner, 1978; Crosby, 1991; Butzer, 1992b; Denevan, 1992b; Whitmore and Turner II, 2001). Local-level cultural landscape modifications enriched Middle American environmental systems, but also caused main ecological impacts during 4,000 years of independent development (Denevan, 1992b). Although there is evidence suggesting severe environmental degradation and cultural collapse as response to ecological overexploitation, due to demographic pressures on landscapes in the Mayan and Teotihuacán cases (Sanders, 1973; Hammond, 1978; Ezcurra, 1990), the discussion of this issue overemphasized the lack of a 'principle of permanence' in the natural resource management systems (Cook, 1949; Simpson, 1952; Coe, 1984; Abrams and Rue, 1988). Alternative evidence, based on better understanding of the production systems, suggests that neither the pristine myth of Middle American nature nor the catastrophist Malthusian view of environmental-cultural collapse, permits a comprehensive evolutionary prospect of the complex social and ecological realities of Middle America (Denevan, 1992b; Withmore and Turner, 1992 and 2001; Crosby, 1994a; Endfield and O'Hara, 1999a and b).

Alternative evidence refutes the idea of Middle America as a virginal natural area or conformed by "ecologist" societies, but recognizes it as a territory with sophisticated natural resource management and ecological imbalances as well. Many locations in central Middle America show strong evidence of anthropogenic accelerated soil erosion spanning at least 3,600 years (Whitmore and Turner, 1992 and 2001; Butzer and Butzer, 1993; O'Hara et al., 1993 and 1994; Metcalfe et al., 1994; Frederick, 1995). Agricultural activities had positive and negative environmental impacts on fragile landscapes over long time periods.

**Table 9.1.** Fragile lands in Middle America

| Category | Stress factor | Geographical distribution |
|---|---|---|
| **Moderately to steeply sloping arid and semi-arid highlands** | | |
| Dry highlands | • Slope<br>• Frost<br>• Aridity | Portions of Northern, Western, Central and Oaxaca regions |
| Semi-dry highlands | • Slope (vulnerability to erosion because of intensive rainfall events)<br>• Frost | Central and Oaxaca regions; portions of Western region |
| **Flat to gently sloping arid and semi-arid highlands** | | |
| Dry flat highlands | • Aridity<br>• Salinization<br>• Flooding<br>• Desertification | Northern region and portions of Central and Oaxaca regions |
| Semi-dry flat highlands | • Excessive temporary flooding<br>• Salinization<br>• Siltation | Central and Oaxaca regions; portions of Southeastern region |
| **Moderately to steeply sloping tropical highlands** | | |
| Montane tropical forest | • Slope (vulnerability to erosion because of high rainfall)<br>• Soil fertility (extremely variable; readily depleted once forest is removed)<br>• Pests | Gulf, Oaxaca and Southeastern regions; portions of Western region |
| **Flat to gently sloping tropical lowlands** | | |
| Tropical lowland forest | • Soil fertility (low initially; readily depleted once forest is removed)<br>• Pests (weeds, animals, insects, diseases; can cause field abandonment even on good soils) | Southeastern region; portions of Gulf and Oaxaca regions |
| Tropical savanna (well drained) | • Temporary flooding<br>• Soil fertility<br>• Soil structure | Gulf and Southeastern regions |
| Wetlands | • Excessive flooding (height and/or duration) | Gulf and Southeastern regions |

**Modified from:** Denevan (1989)

Fragile lands are potentially subject to significant deterioration under agricultural, sylvicultural and pastoral systems (Denevan, 1989). Their environmental fragility is relative and culturally dependent. Potential deterioration is related to specific types of land-use systems and to specific intensity and frequency levels of usage. Fragility of managed, unstable and dynamic environments depends on technology and knowledge availability (social fragility), often more critical than the environmental fragility. Some of the fragile lands are also marginal lands for certain agricultural purposes because of environmental constraints and/or low productivity or accessibility. Nevertheless, technological measures could overcome these constraints when modifying their structure and dynamics and when adopting knowledge-based cultural techniques, converting some constraints into potentials (Denevan, 1989).

In Middle America, soils and landscapes were locally but massively modified to overcome natural constraints and ameliorate the productivity of resources, in marginal lands, such as excessively dry lands, lands subjected to permanent or temporary flooding and sloping lands. Adaptation of these fragile lands for long-term production needed (1) intensive labor, (2) risk minimizing strategies, which may lower productivity, (3) knowledge systems, and (4) local specific modifications (Denevan, 1989). Some of these modifications were successful, allowing medium to high food production, as in the case of the *chinampas*.

## 9.2. MIDDLE AMERICAN AGRICULTURAL TERRACES

### 9.2.1. Comparative advantages of sloping areas for agriculture

There is sufficient evidence that Middle American first agricultural communities were established more on sloping lands than on flat lands, including dry and semi-dry highlands and tropical humid lowlands, contrary to the common perception that sloping lands are marginal to agricultural activities (Sanders, 1957 and 1985; West, 1970; Donkin, 1979). Sloping agriculture evolved before the development of more complex moisture conservation techniques, especially in dry and semi-dry highlands where frost-free hills were selected for cultivation.

There were several reasons to prefer sloping lands rather than flat lands for agriculture on the basis of Middle American landscape characteristics and agricultural technologies. Slopes were considered less risky for crop failure because of: (a) lower incidence of frost compared with flat lands; (b) good air drainage; (c) well drained soils for shallow-rooted crops; and (d) frequent downslope movement of sediments, which were trapped benefiting topsoils with the constant addition of organic matter. Moreover, sloping lands were preferred for cultivation, because (e) soil chemical weathering at shallow depth ensures renewal of nutrients; (f) wooded hills provide organic matter and ashes as fertilizers after slash-and-burn; (g) soil enriched by wood ash is usually well aerated, friable and easy to work; and (h) sloping agricultural lands are less prone to pests and diseases due to biological competition within their surroundings (Posner, 1982).

However, some extensive highland and lowland areas had natural disadvantages for subsistence agriculture. Poorly drained soils in depressions and lake basins, temporarily or permanently waterlogged and prone to siltation, and salinization were among the main disadvantages for cropping. Compacted soils, such as *tepetate* (for a definition of these soils, see tables 8.2 and 8.3), or savanna-like soils were not easily workable and were prone to frost and hail or inundation, besides being easily colonized by grasses after several burnings (Spencer and Hale, 1961; Williams, 1972; Donkin, 1979; Wilken, 1979; Posner, 1982). Two Spanish chroniclers refer to Middle American sloping agriculture as the one preferred by the inhabitants. "The Indians liked hills better than plains" wrote Francisco Cervantes de Zalazar (1554), while Diego Durán (1967) subscribed that "The season for sowing began in [the eighteenth] month – on slopes and hills... This feast [in honor of *Tlaloc* and *Matlacueye*] was designed to encourage sowing on the hills. This was done early because, as they say, moisture begins on the hills, rainstorms being more common there before they appear on the flat lands".

Farmers often managed distinct and contrasting landscapes and habitats, combining intensive and extensive agricultural methods and adapting them to overcome their chief disadvantages. Agricultural techniques, evolved during thousands of years, were applied to increase the extent of suitable land by reclaiming marginal lands (steep, dry, wet, and/or with low soil fertility) and to increase the production and the frequency of cultivation by improving or maintaining soil fertility. Locals developed complex techniques, applying deep ecological understanding of their surrounding landscapes. The combination of terracing slopes, irrigating dry and semi-dry lands and draining wetlands achieved the needs for food supply in densely populated areas (García-Oliva, 1992). The most advanced techniques, capable of producing a regular surplus of staple goods, included extended irrigation and terracing and comparatively small areas of swamp farming (Armillas, 1949; Wolf and Palerm, 1955; Armillas et al., 1956; Palerm and Wolf, 1961; Sanders, 1965; Sanders and Price, 1968; Sanders et al., 1979; Denevan, 1980a and b; Turner, 1983, 1993; Neely et al., 1990). These agricultural systems are mainly located in the Basin of Mexico, Teotihuacán, Puebla-Tlaxcala, Lake Pátzcuaro (Figure 9.1), and other lacustrine intermontane basins. Oaxaca, Chiapas and Guatemala highlands and the Yucatán Peninsula in the southeastern region have extended irrigation, terracing and swamp farming. Similar farming systems are more scattered in the western and northern regions of Middle America (see figure 7.2).

### 9.2.2. Origin and types of terraces

Pre-Hispanic agricultural terracing is difficult to date. However, some records show its appearance from 900 to 200 BC in the Teotihuacán Valley and the Basin of Mexico (Armillas, 1949; Palerm and Wolf, 1957; Hopkins, 1968; Sanders, 1976;), from 500 BC to 100 AD in Oaxaca and Chiapas (Hopkins, 1968; O'Brien, 1980; Redmond, 1983; Woodbury and Neely, 1967) and from 500 to 600 AD in the Yucatán Peninsula (Turner, 1974, 1993; Matheny, 1982; Dunning 1992 and 1993; Coultas et al., 1993). According to Donkin (1979), archaeological evidence suggests that several independent centers of origin of the most elementary agricultural terraces, followed by the diffusion of more advanced forms in association with stone-working and earth-moving shifts and canal irrigation, arose during the Late Pre-Classic Period. This historical trend

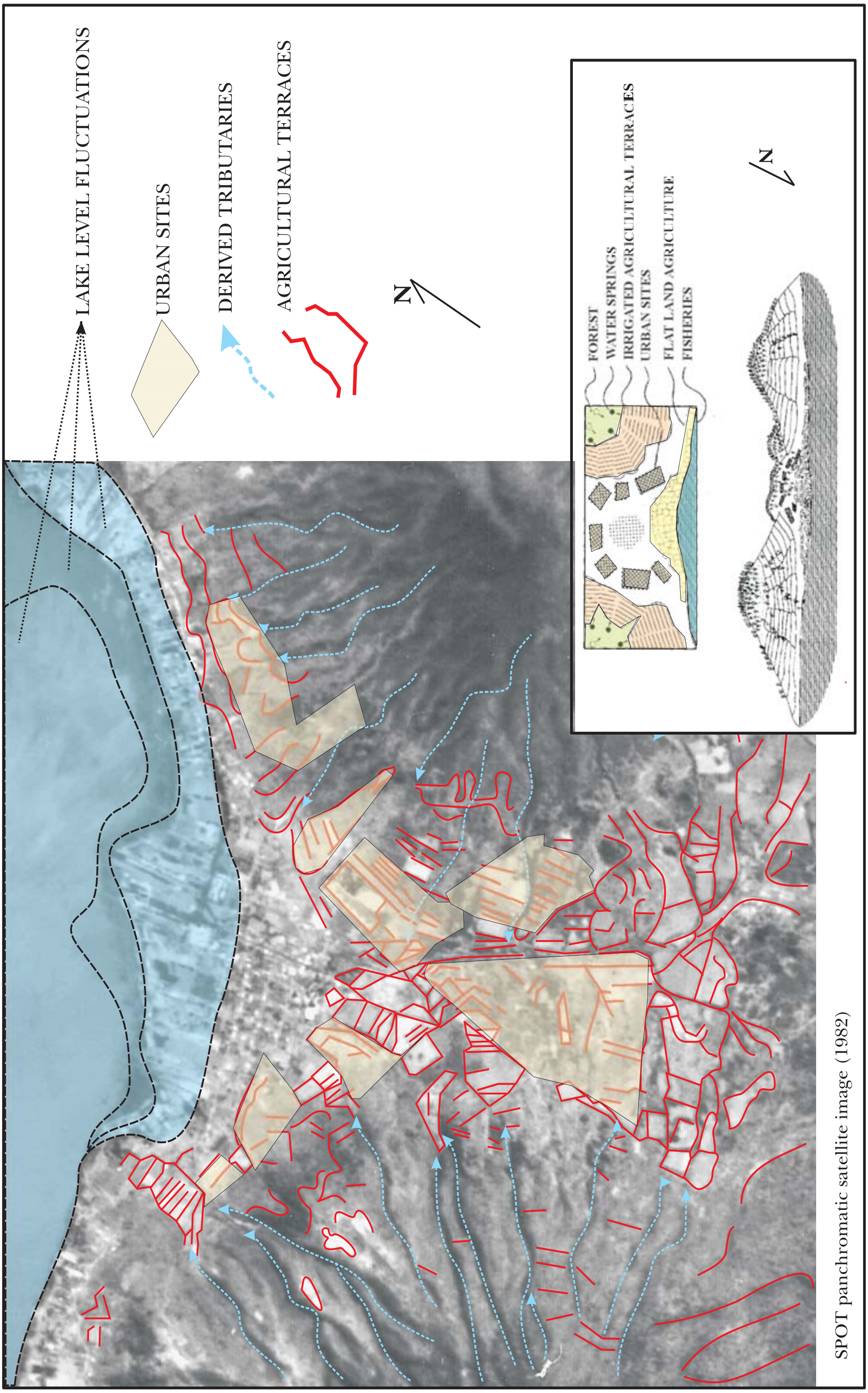



**Figure 9.1.** Agricultural terraces in the pre-Hispanic capital of the Purhépecha: Tzintzuntzan, Michoacán, Mexico

is similar to that of plant domestication (Hernández Xolocotzim., 1993) and irrigation (Doolitle, 1990a and 1996). Locally adapted cropping systems, landscape modifications and irrigation techniques follow similar patterns, suggesting that terracing and irrigation emerged as a co-evolutive, conscious local agricultural adaptation favoring plant domestication.

The majority of agricultural terraces apparently was designed to overcome slope disadvantages for long-period farming in areas with pronounced dry season, thin soils and inadequate soil moisture (Raikes and Wheeler, 1967; Kirkby, 1973; Donkin, 1979; Matheny, 1982; Denevan, 1995). This accounts for more than 80% of Middle America (Challenger, 1998). The key factor of terrace building was the maintenance and improvement of soil fertility. Terraces reduce the kinetic energy of flowing water and its erosivity and transport capacity by decreasing the slope gradient and length. The effectiveness of terraces depends on their design, maintenance, outlet, interval, and other types of conservation measures used together with the terraces, such as mechanical, biological and agronomic multifunctional techniques (Beach and Dunning, 1995). Table 9.2 shows different types of agricultural terraces developed all along Middle America.

Two main measures led to agricultural terraces: slope management (mechanical measures, see table 9.2) and field-surface management (biological and agronomic measures) (Wilken, 1987). Agricultural terracing involved the construction of stone or earth walls or ridges on slopes, providing more level surfaces, managing natural and human-induced soil erosion-deposition, controlling and managing upstream water streams and accumulating soil. Controlling topography, water, vegetation and soils permitted microclimate control of cropping systems (Wilken, 1972, 1979 and 1987).

### 9.2.3. Management of terraces

Agronomic and biological measures were applied to enhance agricultural production on terraces, using field-surface management at parcel level. Ethnohistorical and ethnographic evidence reveals complex land, soil and water management on terraces (Rojas and Sanders, 1985), although there is no evidence of specific field-surface measures applied in each one of the agricultural terrace types and subtypes (Denevan, 1980a and 1995). Sahagún (1963: 41-42) wrote that, in the 16th century, "The good farmer...is...dedicated to separate things;...he works the soil, stirs the soil anew, prepares the soil; he weeds, breaks up the clods, hoes, levels the soil, makes furrows, makes separate furrows, breaks up the soil... he stirs the soil anew during the summer; he takes up the stones; he digs furrows; he makes holes; he plants, hills, waters, sprinkles; he sows beans, provides holes for them, fills in the holes; he hills the maize plants...".

Farmers not just took advantage of the natural runoff water to fertilize soils and enhance soil moisture, but caused up-slope erosion to benefit down-slope parcels (Bocco, 1991). Terraces, in this sense, were built to manage rather than control soil erosion, and to benefit from soil erosion (Donkin, 1979). Figure 9.2 shows a farmer managing runoff water to moisten his land. Stonewalls behind which soil was placed or accumulated bound most agricultural terraces, forward and backward. The purpose was to deepen the soils. Cross channel terraces were filled in succession by material washed down from adjacent slopes and the clearing of vegetation, and loose stones may have deliberately accelerated the process. Contour terraces were filled by the downward movement of soil under cultivation and/or by the introduction of soil from elsewhere (Donkin, 1979). Such soils should be considered as anthropogenic (Sandor and Eash, 1991; Sandor and Furbee, 1996; Dunning, 1993).

Micro-level soil measures were conducted to take advantage of soil variability at parcel level (Wilken, 1987; Williams, 1982). Table 8.2 (see chapther Eight) shows a soil productivity ranking according to the pre-Hispanic Nahua farmer's perception. Certain soils were ameliorated by adding organic matter or manure (*Tlalauiyic*), or wood ash (*Quauhtlalli*), or by mulching with grass or straw (*Tlaxotlalli*). Figure 9.3 shows a 16th century pictorial representation of a farmer manuring the land, possibly with human excrements. Several ethnohistorical documents refer to human excrements (Armillas, 1961), green manure (Sahagún, 1963), bat manure or *guano* (Alzáte y Ramirez, 1963) and domestic refuse (Denevan, 1980a) as widely used fertilizers (Donkin, 1979). It is also well known that Nahua farmers rotated house sites on their fields to benefit from the fertilizing effecto of house and human refuse.

**Table 9.2.** Slope management in Middle America: Terraces

| TYPE | MAIN CHARACTERISTICS | GEOGRAPHICAL DISTRIBUTION |
|---|---|---|
| **Check-dam terraces**<br>• Weirs<br>• Cross-channel terraces<br>• Channel-bottom terraces<br>• Trincheras | • Irrigated by flood water<br>• Stone walls built across ravines to trap silt (lameo), settle water or spread water | Northern region<br>Oaxaca region<br>Yucatan Peninsula in Southeastern region |
| **Semi-terraces**<br>• Metepantli<br>• Bancales | • Maguey (*Agave spp.*) hedges<br>• Hillside check dams (bordos)<br>• Low embankments paralleled immediately down slope by drains, forming a zanja/bordo combination<br>• Zanja – small field reservoir to catch seepage and ponded runoff that tops the bordos<br>• Uniquely adapted to the physical and agricultural conditions of Central Middle America | Central Middle America |
| **Sloping-field terraces**<br>• Great variety of types and subtypes | • Rainfed and irrigated systems<br>• Frequently having channel irrigation systems<br>• Cropping surfaces are less steep than the natural slope but are not flat | Central and Southeastern regions<br>Basin of Mexico<br>Teotihuacán Valley<br>Puebla-Tlaxcala<br>Yucatan Peninsula<br>Highland Guatemala<br>Western Guatemala |
| **Bench terraces**<br>• Great number of types and subtypes<br>• Tablones | • Flat floored with vertical back walls, linear contoured<br>• Stone walls<br>• Irrigated and non-irrigated systems<br>• Small ridges (bordos) along riser edges<br>• Ditches<br>• The steeper the slope, the narrower the bench or bed<br>• Terraces are not leveled to an acceptable degree by natural forces; direct labor investments were necessary for almost all phases of construction<br>• Earth cut and filled | Central and Southeastern regions<br>Yucatan Peninsula<br>Highland Guatemala<br>Western Guatemala |

**Sources:** Donkin (1979), Denevan (1980b), Beach and Dunning (1995)

**Figure 9.2.** Managing runoff agriculture according to a 16th century pictorial representation. **Source:** Sahagún (1963)

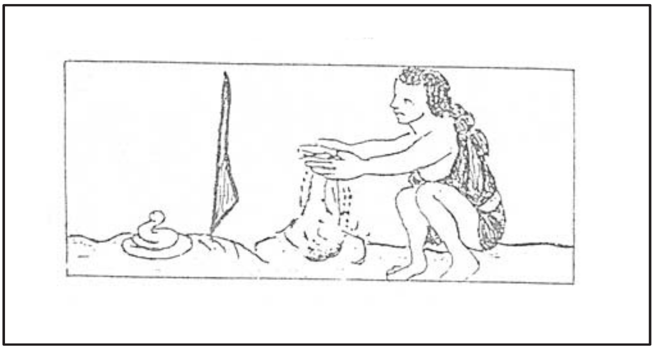


**Figure 9.3.** Pictorial representation from 16th century showing a farmer manuring the land, possibly with human excrements. **Source:** Sagahún (1963)

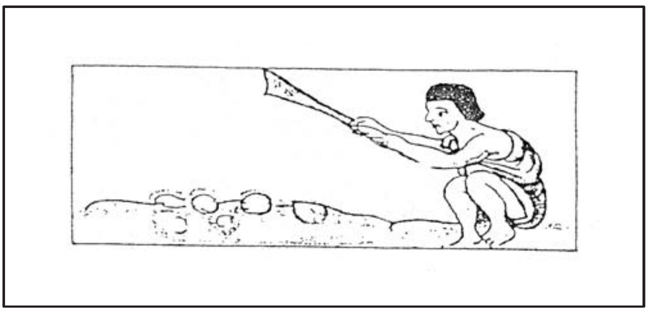


**Figure 9.4.** 16th century pictorial representation of a farmer breaking down a compacted soil with a stick. **Source:** Sagahún (1963)

Human refuse was systematically collected in Tenochtitlán, the Aztec capital, and transferred by boat to tanneries and produce gardens (Armillas, 1961) The soil type *Callalli*, which refers to house (*Calli*) and soil (*tlalli*), was considered fertile. Sahagún (1963: pp.251-252) refers to this type of soil as follows: "This land upon which a house has rested, and also the surrounding houses. It is fertile; it germinates".

Other soils, such as *Tlaluitectli* and *Ttepetatl,* not easily workable because of compaction, were modified by breaking down the top soil with a stick and adding wood soil (*Quauhtlalli tlaneliqui*) or sand (*Xallali*) to ameliorate structure, texture, consistence and moisture holding capacity. Soil mixtures and intergrades were well recognized in the Nahua classification and soil management. Figure 9.4 shows a Nahua farmer breaking down, with a stick, a compacted soil, much probably a *Tepetatl* soil.

Pre-Hispanic farmers shaped soil micro-topography using digging sticks, shovels and hoes, and molding a variety of mounds, ridges, pits, and beds, to modify the edaphic and microclimatic conditions on the terrain surfaces and in root zones for particular crop-plants and crop-trees. Sahagún (1963: 128) recognized the wide use of maize mounds or hilling (*Tlalteles* in Nahua), writing that "...when the seed had sprouted and formed shoots [*the farmer*] hoed the ground; he built up mounds; he broke the clods of earth, and went stirring up the dust".

Micro-topography management was carefully adjusted to relief, as in the case of interlaced gently sloping lava flows with thin but fertile soils. Terraced volcanic landscape in central Middle America was extensively managed and covered by thousands of small-scale terraces, many of which are still used in a fashionable way. Stony lands (*pedregales* in Spanish) of volcanic origin were also carefully managed for maize-bean-squash cropping. Stony lands were considered having fertile soils. Surface and subsurface stones and boulders (basaltic pumice-like gravel or rocks) were kept in the field and considered beneficial for planting with a digging stick, because they stabilized soil daily temperature and preserved moisture during the dry season (Zizumbo and Colunga, 1993). To conserve soil moisture, stones were also well accommodated and covered with humid topsoil surrounding the crop bases. According to Sahagún (1963; see table 7.8), *Teltalli,* a stony and dry deep-down soil, hard when dry but well moist during the rainy season, was considered fertile and productive, especially for *Teocintle*, the maize-father.

Attention was given to individual plants and multicropping was generally established (Armillas, 1949; Serra-Puche and McClung, 1986; Romero-Frizzi, 1990; Serra, 1990; Hernández-Xolocotzim, 1993). Middle American farmers made micro-topographic adjustments to the field surface to favor particular crops in particular environments. Rearranging planting surfaces varied from simple mounding around individual plants or plant clusters to carefully constructing elaborated planting beds (Wilken, 1987). Sahagún (1963: 283) refers to the former in the following way: "At this time each [*maize*] is hilled, the hollow is filled in, the crown is covered, the earth is well heaped up". Middle American agriculturists replenished soil nutrients in a closed-cycle system in varied ways (Gliessman et al., 1981; Chacón and Gliessman, 1982; Altieri, 1983).

Multicropping using legumes such as beans (*Phaseolus spp.*), protecting and favoring nitrogen fixation trees such as *Prosopis, Acacia* and *Leucaena* at the edges of the parcels (Donkin, 1979), or tolerating and manipulating weedy legumes at parcel level (Chacón and Gleissman, 1982), were some of the biological and agronomic strategies used to replenish the soil nutrients consumed during the crop cycle. This was followed by organic matter application, straw maintenance at parcel level and land fallow (Rojas and Sanders, 1985).

Terracing agriculture was well established in Middle America long before the Christian Era and the Spanish conquest. Agricultural terracing and irrigation were developed as an indigenous adaptation to ecological, social and economic needs, with intensive labor investment at plot, village and regional levels in highly centralized imperial states. Labor investment included not only the implementation of these agricultural technologies and strategies, but also the maintenance of such investment in fragile lands.

The role of Middle American terracing agriculture is still under debate among specialists. Did high population densities around main urban centers in Middle America cause terrace building to overcome land degradation? Did terracing strategies satisfy the food demand under these conditions? Did terracing respond to drought periods or to long-standing agricultural evolution? Did terracing cause extensive soil erosion or was it a soil and water conservation strategy promoted by centralized bureaucracies and/or local farmers? What was the ecological impact when terrace maintenance was neglected after the demographic collapse during the 16$^{th}$ century? Why are agricultural terraces still maintained by small farmers in contemporary Middle America? Are they sustainable ways to produce food to meet current demands? Are they land-use systems able to be reorganized according to future demands?

### 9.2.4. Terraces in the Mayan country

Turner (1974, 1993) studied Mayan agricultural terraces in the southern portion of the Yucatán Peninsula, in southeastern Middle America. His findings revealed the importance of terrace farming and modified the conventional view that considered shifting cultivation as the most important and even only agricultural system in Latin American tropical lands (Dahlin, 1985; Denevan, 1992b, 1995). Hundreds of thousands of old terraces, distributed over some 10,000 square kilometers were found on karstic slopes with 4$^{o}$ to 47$^{o}$ gradient in the Mayan tropical lowlands and highlands (Turner, 1974; Donkin, 1979; Olson, 1982; Dahlin, 1985; Dunning, 1992 and 1993; Wingard, 1992; Fedick, 1994).

Mayan terraces are dated between 500 AD and 600 AD during the Post-Classic Period (Dahlin, 1985). They were irrigated to produce maize, beans and squash, or *milpa* system (Turner, 1974; Ewell and Merrill-Sands, 1987). Production in 75% of the terraces was enough to partially feed 1.5 million people, assuming that the remaining 25% was under reparation every year. Calculations suggest that the Mayan terraces could feed some 150 persons per square kilometer in areas having a density of 500 persons per square kilometer (Jiménez Osornio and Gómez Pompa, 1987; Culbert and Rice, 1990). The remaining 350 people/km$^2$ were fed from shifting cultivation and raised-field agriculture. The building and maintenance of terraces required intensive labor, which might have been a strategy of the Mayan elite to control thousands or millions of farmers (Willey and Shimkin, 1973; Demarest, 1993). Agroforestry, drained fields, shifting cultivation and terracing constituted main activities of the Mayan subsistence strategy (Puleston, 1968; Barrera et al., 1977; Harrison and Turner, 1978; Wiseman, 1978; Denevan, 1980a, 1980b and 1980c; Flannery, 1982; Matheny, 1982; Gómez Pompa, 1987, 1991, 1993; Gómez Pompa et al., 1993; Siemens, 1989; Gómez Pompa and Krauss, 1990; Kass and Somarriba, 1999; Whitmore and Turner, 2001).

## 9.3. *CHINAMPA*: THE MIDDLE AMERICAN POLDER

### 9.3.1. Origin and characteristics

*Chinampa* (in Nahuatl, *chinamitl*=reed fence and *apam*=flatland) is a drained field for agricultural production (Wilken, 1969). It is one of the most impressive, aesthetic and efficient solutions to overcome natural disadvantages for cropping in semi-arid and temperate sub-humid highlands of Middle America (Armillas, 1949; Denevan, 1980a). Flat lacustrine highlands in central and southern Middle America had severe biophysical constraints for agricultural purposes due to: (a) frequent hail and frost occurrence, (b) excessive seasonal or permanent flooding, (c) poor soil drainage, (d) soil compaction, (e) high siltation risk, (f) soil salinization, and (g) weed invasion in agricultural fields after repeated burning (Table 9.1). Most population concentrated on slopes surrounding marshes and lakes since the Pre-Classic period, or established on islands, for strategic and subsistence purposes, with few flat land areas suitable for agriculture (Donkin, 1979). This was the case of almost all inter-mountainous lakes in the Middle American central region, and Chiapas and Guatemala highlands in southeastern Middle America (Challenger, 1998). Notable examples are the basins of Tlaxcala-Puebla, Teotihuacán, Tenochtitlán, Toluca, Cuitzeo, Pátzcuaro and Chapala in central Middle America (Coe and Flannery, 1964). These areas concentrated about 13 to 14 million people at the beginning of the $16^{th}$ century (Cook and Borah, 1960).

The *chinampa* system is similar to other drained fields reclaimed to gain land from marshes and permanently flooded areas, such as the *waru-waru* system in the Andean Lake Titicaca (Moriarty, 1986; Denevan and Padock, 1987; Erickson, 1988 and 1993), the *fen* system in England (Wagret, 1968; Wilken, 1969) and the *polder* system in the Netherlands (Schilling, 1993; Wagret, 1968). Nevertheless, the peculiar construction, management and maintenance of *chinampa* are considered unique of Middle America, with its most sophisticated elaboration in the Basin of Mexico (West and Armillas, 1950; Sanders, 1957 and 1976; Coe, 1964; Parsons, 1976; Rojas, 1983a and b).

In spite of dating difficulties because of its natural characteristics and the environmental history of its surroundings, archaeological evidence of the *chinampa* system goes back to the Pre-Classic Period, after 500 BC (Donkin, 1979), and extends to the Post-Classic Period (1400-1600 AD) (Armillas, 1971; Coe, 1974; Parsons, 1976). After a long-standing permanence of at least 1,500 years, this efficient agricultural system vanished at the beginning of the second half of the $20^{th}$ century. There are still some active remnants of this indigenous agro-hydraulic technique in the surroundings of Mexico City (Rojas, 1983a; Chapin, 1988). The *chinampa* system is probably the most studied indigenous agricultural system of Middle America (Rojas, 1983b). Soil and water conservation and management techniques have been analyzed from archaeological, ethnohistorical and ethnographic evidence mainly in the Basin of Mexico, the ancient territory dominated by the Aztec. Parsons (1976) describes the political significance of the *chinampa* agricultural production for the Aztec elite of Tenochtitlán and its economic relevance for farmers, workers and bureaucracies.

The $16^{th}$ century *chinampa* system includes the following mechanical, agronomic, biological and socio-economic factors:

(1) The construction and maintenance of small, elongated and narrow rectangular agricultural parcels on inundated areas, raised by digging and transferring dung from the bottom of the lake to build anthropogenic soils according to a well-organized pattern of agricultural islands (Armillas, 1971).

(2) The integration of various production activities, including fishing, hunting, gathering, extracting and cropping, in an intensive way and on relatively small land-water fractions of land, recreating closed nutrient cycle flows (Gómez Pompa and Venegas, 1976).

(3) The formation of anthropogenic soils from organic muck, rich in decomposed aquatic plants and animals, algae and silt, transferred periodically from lake and marsh sediments to the drained field surfaces, making continuous cultivation possible (Denevan, 1995).

(4) The setting of special planting areas as nursery beds or seed beds in a spatial and temporal multicropping strategy, organized in efficient and complex ways to enhance land productivity in space-scarce systems (Wilken, 1987).

(5) The intensive use of labor and energy for nurturing, transplanting, fertilizing, hand irrigating, mulching, soil fertility restoration and water management, to sustain a multi-use land productivity strategy (Rojas, 1983).

(6) The reduction of transportation costs using long-distance aquatic communication to supply commercial or tributary goods to urban and peripheral settlements (Parsons, 1976).

(7) The capability of this multifunctional subsistence strategy to provide ample and constant surplus demanded by densely populated areas with strong social stratification (Calnek, 1972, 1975 and 1976).

(8) The sustained performance of the drained-field agricultural system lasting for more than 1,500 years.

Sixteenth century Spanish chroniclers gave an account of the sophistication of the *chinampa* system on the margins of the lakes that surrounded Tenochtitlán. Sahagún (1963) wrote, when referring to the ability of Middle American farmers: "… if it was a land with available water, [*the farmer*] worked his land to be irrigated. If it was a swampy land and the farmer lived in these marshes, he cultivated and yielded maize for tamales, transplanted and cropped chili-pepper and fertilized the land". Torquemada (1969), referring to farmers cultivating near the fresh-water lakes of central Middle America, wrote: "Indians cultivate without much effort and yield maize and vegetables because all are drained fields [*camellones*], named by them as Chinampas, that are furrows made over the water [*and*] fenced by canals, they don't need to irrigate".

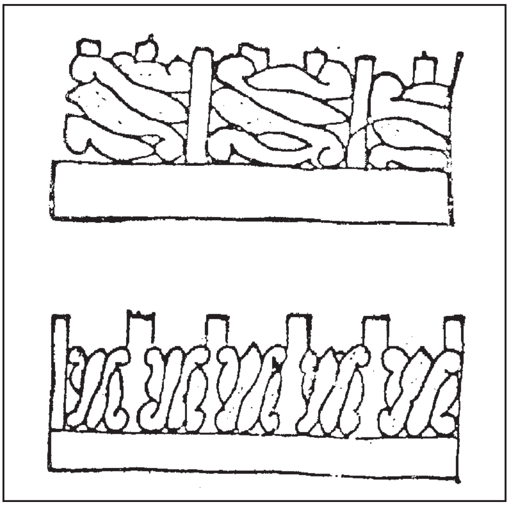
Ponce ([1586] 1968) described the ways *chinampas* were constructed and their spatial pattern at the end of the 16th century as follows: "named chinampas [...] made over the water, putting together and piling up strips of cut grass from the firm land and mud from the lake, and making narrow plots. Leaving a canal between plots or between each chinampa, which stand one vara or less [0.80m or less] above water level, producing tall maize plants, because they grew and fed from the humidity of the lake, even without rainfall. And they nurtured maize seeds on seedbeds, and they were transplanted in a very particular way on those lands". The information provided by these chroniclers and from other sources, including contemporary information, permits the assessment of the pre-Hispanic *chinampa* system.

### 9.3.2. Construction, maintenance and management

The construction of a chinampa involved several steps requiring great amount of labor and use of energy, according to archaeological, ethnohistorical and ethnographic evidence. Choosing a proper place to construct the *chinampa* by using a wooden stick to measure the desirable depth of water and establishing its size by posting wooden poles at each of its four corners, were the first steps to establish its foundations. Subsequently, poles were used to build up a fence of interlaced branches and ditch reed, where several layers of aquatic vegetation, grass strips, mud from the lake bottom, topsoil from older *chinampas* and basaltic rock were piled up over a mat of interlaced branches placed over its foundations. Piling up was done until the interlaced platform reached around 30 to 60 cm above the water level. Figure 9.5 shows a 16th century representation of a *chinampa* fence.

Several soil and water parameters were assessed during the construction of the raised field to secure good performance of a long-standing agricultural plot. The size of the *chinampa* was small (from 100 to 500 $m^2$) and the shape would be narrow and rectangular to allow permanent moisture in the overall sub-surface of this micro-island. The height above the water level should allow splash irrigation of the total surface of the platform. Maintaining soil moisture at sub-surface level permited the decomposition of organic matter and provides water for deep-rooted crops and trees. Splash irrigation mitigates the possibility of salinization of the topsoil and provides moisture to short-rooted crops. Running fresh-water thorugh the four surrounding canals also prevented salinization in the soil subsurface.

**Figure 9.5.** Pictorial representation of chinampa fences according to the Aubin Codex (1576)



The piled-up intermixed layers of different natural materials resembled a soil profile, allowing subsurface water percolation through basaltic rock layers to help decomposition of aquatic and terrestrial vegetation. Muck consistence was improved with fertile lake sediments, giving a soft structure to the soil. Water-tolerant trees, such as willow or ahuejote (*Salix bondplandiana*), were planted along the edges of the raised field to prevent soil erosion and strengthen the chinampa foundations. Trees also worked as windbreaks, provided shade to delicate crops, offered wood for construction of new *chinampas* and fuel wood, and regulating diurnal temperature changes.

According to West and Armillas (1986), the porosity of the created soil and the narrowness of the raised field allowed water penetrating from the surrounding canals exactly at the root level. Splash irrigation made possible sustained cropping, even during dry seasons. Four years after the construction of a chinampa, the raised bed was considered to be a "true soil". According to Santamaría (1912), an agronomist advising Porfirio Díaz, the dictator of the 19th century pre-revolutionary Mexico, local farmers considered that decomposition of organic matter during a period of four years was enough to form a suitable soil.

Nutrient cycling was the key-factor to sustain soil productivity. This was obtained by improving soil workability, restoring topsoil fertility, protecting the soil from inundation as well as desiccation, and controlling soil salinization. Although these measures were integral part of agronomic and biological practices, they are analyzed hereafter individually for better comprehension.

Two main maintenance measures were of considerable importance:

(1) The *chinampa* soil surface was carefully leveled to maintain the proper height of the water table in relation to the field surface (30-60 cm). Sub-irrigation from the groundwater allowed crop development under conditions of moisture deficit, for instance when the onset of the rainy season was delayed or when normally wet summer months were exceptionally dry (Crossley, 1999, 2000). *Chinampa* soils were incredibly high in hydrophilic organic matter, which made them remain wet for long periods and contributed to reducing the amount and frequency of splash irrigation. Sub-irrigation from the groundwater was more important for supplying moisture to the willow trees, thereby reducing the competition for the moisture supplied from the surface (Crossley, 2000). Topsoil removed when leveling was used for building new chinampas. Santamaría (1912) wrote: "Topsoil is removed from old chinampas, which are highly raised due to soil-crop management over years and made it inappropriate for cropping". Ponce (1586) recorded similar measures during the 16th century, saying: "as these gardens are raised and leveled [*rebajar* in Spanish] less than a vara (80 cm) above the water, even without rainfall they bear vigorous maize, sustained by the moisture provided by the lagoon".

(2) Water canals (*apantli* in Nahuatl) were managed to balance drain discharge, avoiding excessive water table variations, supply water for surface irrigation and carry away surface runoff from heavy rains. Drains also supplied field dressing in the form of deposits rich in organic matter and minerals. In fact, canal-water management was part of a complex hydraulic engineering of dikes and aqueducts (Palerm, 1955; Rojas, 1983a; Ezcurra, 1990). Dikes were constructed to divide salty and fresh waters coming from an interconnected lake system. Some dikes required

prolonged labor investment, measuring 15 km long (Palerm, 1955). Long aqueducts were constructed to supply fresh water from springs and rivers for human consumption, chinampa irrigation, and topsoil washing to prevent salinization (Palerm, 1955).

Mucking contributed to *chinampa* fertility. Rich semi-liquid mud (*zoquitl*), containing suspended organic sediments and algae, was constantly dredged up with a long-handled scoop (*zoquimaitl*= *zoquitl*, mud or sludge; *maitl*= tool, instrument) from surrounding canals to improve topsoil fertility and soil texture (West and Armillas, 1950). This practice is still applied in the *chinampa* system of Xochimilco, in the southern Basin of Mexico (Calderón, 1983). According to Wilken (1987), *chinampa* farmers still rate muck deposits according to color, possibly odor and, to at large extent, texture. Calderón (1983) recognized complex cognition, labeling and management of *chinampa* soils at the end of the 20th century in the Xochimilco area. Wilken (1987) reported the use of sand to modify the soil texture, lower salt contents and adjust field levels. Typically, a *chinampa* topsoil has a texture of organic clay loam, that gets sticky when wet and forms massive clods when dry, and therefore inhibits soil workability (Wilken, 1987:89). Adding sand partially corrects these undesirable properties. Turning, breaking and leveling the *chinampa* topsoil, and creating micro-topography by building mounds or hills and ridges between furrows according to specific crop-plants, were other labor-intensive mechanical measures reported by the 16th century chroniclers (Rojas, 1983b).

Soil salinization (*tequizquitlalli*: salty soil in Nahuatl) was a major problem in agricultural lands enriched with volcanic and lacustrine sediments, as is the case of the chinampas, to diminish evaporation and increase land productivity. Several mechanical measures were applied to lower salt levels, including constant splash irrigation, muck incorporation, sand application and manual removal of salt crusts, which all required intensive labor (Wilken, 1987).

At this point, it is necessary to reconsider the common assumption made by some specialists (Williams and Ortíz Solorio, 1981; Ortíz Solorio, 1990, among others), which emphasizes the lack of knowledge of soil as a 3-D body by Middle American farmers. Anthropogenic soils, such as the *chinampa* soils, were built by applying the repertory of wisdom evolved through thousands of years of engagement with the soil. Figure 9.6 shows the complex structure of a *chinampa* field and reveals evidence of high labor investment, applying long-standing environmental wisdom. Anthropogenic soil formation and processes were well understood by *chinampa* farmers, although it is difficult to assess the pre-Hispanic views of the soil as three-dimensional body. Assuming that farmers lacked this understanding hampered the analysis of contemporary local soil cognition and retarded the research on anthropogenic soils in Middle America (Crossley, 2000).

### 9.3.3. Biological and agronomic practices: a multistory strategy

Several agronomic and biological measures were applied to intensify and diversify cropping, whilst maintaining and restoring soil fertility in the *chinampa* system. They were driven by two key-factors: (a) management of space scarcity with high manual labor investment, and (b) multistory strategy consisting in a relatively closed nutrient cycling (Wilken, 1989). A wide array of techniques was applied in an intensive fashion during the whole year, taking advantage of permanent irrigation, high soil fertility and land productivity. Estimated maize yield ranged from 3 to 4 tons per hectare. Some of the most important measures are analyzed hereafter, with emphasis on intensive crop care, space and time management, and multiple land-use strategy.

(1) Intensive crop care

Micro-topography was adjusted to each crop variety according to nutrient needs during the whole plant cycle (West and Armillas, 1950; Wilken, 1989). Seedbeds (*tlachtli* or *cintlimilli* in Nahuatl), mounds or hills, ridges and furrows were carefully adapted to the root system and soil moisture requirements. Treatments were applied to each maize plant, according to different phenological stages. Root-cutting (*Xhomani* in Nahuatl: to disturb) was carefully done during the crop cycle to control the plant height, reduce leave production and induce cob production (Rojas, 1982). A vigorous long-cycle and highly productive maize variety, "*Chalqueño-chinampero*", was adapted to take advantage of specific soil qualities. This variety is still widely used in irrigated and humid lands of Central Mexico (Wellhausen et al., 1951).

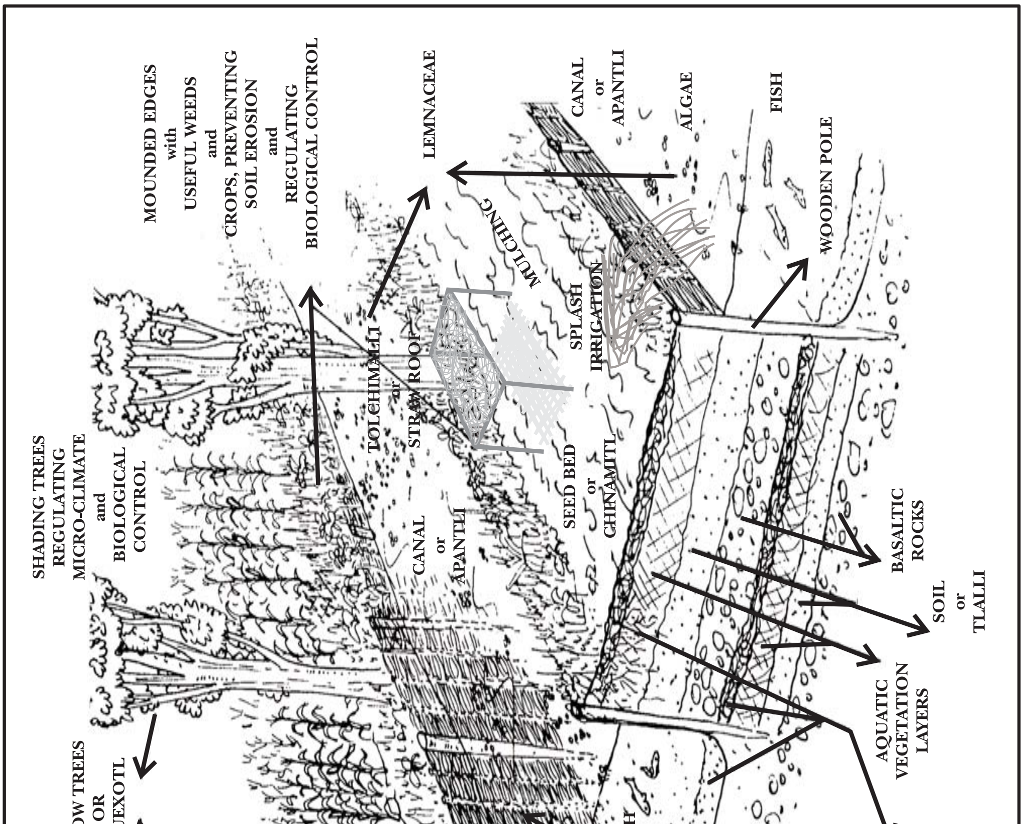



**Figure 9.6.** The chinampa system. **Sources:** Coe (1964); Vera (1991); Challenger (1998)

(2) Space and time management

Spatial arrangements were done to enhance multistory productivity at vertical and horizontal levels. Cropping was strategically scheduled to combine short-term annual crops (tomato, chili pepper, etc), long-term annual crops (maize, amaranths, etc), and perennial tree-crops (capulín, tejocote, etc). This complex spatial arrangement allowed to: (a) intensify multi-cropping production on scarce space; (b) minimize non-planted space; (c) minimize duration of each cropping; and (d) maintain food cropping during the cold and dry season. *Chinampa* became the only agricultural system in Middle American highlands that produced staple goods all along the year.

An example of vertical space arrangement is the *milpa* system (maize-beans-squash) and tree plantation along *chinampa* edges. Both measures aim to take advantage of insolation, or reduce it, control micro-climatic diurnal and nocturnal changes, and enhance the nitrogen balance by planting nitrogen-fixing crops, such as beans, with nitrogen-consuming crops such as maize. Nitrogen-fixing crops and useful 'weeds' (*Chenopodium spp.*) were tolerated on the four edges of the *chinampa* to procure soil nitrogen replenishment and prevent soil erosion. Horizontal space management was carefully established and the multi-cropping strategy was adjusted via intercropping and crop rotation of staple goods, flowers, spices, and useful weeds. In this sense, the chinampa agriculture is considered a horticultural system (Denevan, 1980). Land fallow was considered an ultimate measure to restore fertility (Sanders, 1957, 1983) and a non-prestigious strategy among farmers and bureaucracy (West and Armillas, 1950). Table 9.3 shows the main crop-plants and crop-trees cultivated in the *chinampa*, according to 16$^{th}$ century registers. Plant nurturing on seed beds was sophisticated and used until the 20$^{th}$ century to minimize non-planted space and minimize cropping time per crop (Coe, 1984; Wilken, 1989). Figure 9.7 shows a 16$^{th}$ century pictorial representation of *chinampa* seedbeds.

A wide array of agronomic and biological techniques was used for soil fertility restoration, maintenance and enhancement, according to soil-crop requirements. Composting, mulching and manuring were intensively applied according to micro-local and temporal circumstances. Compost was prepared from maize straw, pre-dried aquatic vegetation, dried grass (*atlapacatl* in Nahuatl) and dried weeds and leaves. Organic mulch was prepared by mixing compost with manure and human excrements and applied according to crop-plant requirements (Alzate, 1993; Santamaría, 1993; Rojas, 1983b). Preparation and application of mulch required intensive manual labor.

Manure (*tlazoltlalli*: decomposed earth in Nahuatl) was carefully applied in different amounts according to each crop. Specialized uses of manure are recorded in 16$^{th}$ and 17$^{th}$ century documents and ethnographic evidence confirmed its use until the 20$^{th}$ century (Alzate, 1993; Sanders, 1957; Sagahún, 1963; Williams, 1980c; Wilken, 1989; Zizumbo and Colunga, 1993). Apparently, great volumes of bat manure from the 'tropical or hot land' were transported to *chinampas* and applied specifically to tomato and chili pepper cultivars (Alzate, 1791; Rojas, 1983a). Turkey manure (*totocuicalt* in Nahuatl) and human excrement were extensively used. Human excrement was systematically collected in Tenochtitlan, the Aztec capital, and transferred by boat to tanneries and later on to the *chinampas* (Armillas, 1961). Ethnographic registers reveal a complex farmers' classification of manure according to hot and cold properties and its application to specific crops (Sanders, 1957; Wilken, 1989).

### (3) Multiple land-use strategy

The *chinampa* can be conceived as a multiple land-use system, initially aimed to meet subsistence needs and later on managed to produce surplus for tribute payment and market trading. In addition to agriculture that comprised the cultivation of 30 to 50 different crops (Rojas, 1983b), hunting, fishing and gathering were complementary activities carried out during the year . Hunting of migratory birds, such as duck (*Anas spp.*), goose (*Anser albifrons*), heron (*Ardea herodias*), pelican (*Pelecanus spp.*), crane (*Grus canadensis*) and cormorant (*Phalacrocorax spp.*), was important (Ezcurra, 1990). Animal protein was also provided from fishing in lakes and canals, which was controlled by the Aztec bureaucracy (Rojas, 1983b).

**Table 9.3** Crops commonly found in chinampas according to 16th century documents

| Common name | Scientific name |
|---|---|
| Ahuejote | *Salix bomplandiana* H.B.K. |
| Alegria or huahtli | *Amaranthus leucocarpus* S. Wats |
| Beans | *Phaseolus vulgaris* L. |
| (*Several*) | *Phaseolus coccineus* L. |
| Capulin | *Prunus capuli* C. |
| Chayote | *Sechium edule* (Jacq.) Sw. |
| Chia | *Salvia hispanica* L. |
| (*Several*) | *Hyptis suaveolens* Pot. |
| Chilacayote | *Cucurbita ficifolia* Couche |
| Chili pepper | *Capsicum annum* L. |
| (several) | *Capsicum frutescens* L. |
| Dahlia | *Dahlia coccinea* Cav. |
| (*several*) | *Dahlia pinnata* Cav. |
| | *Dahlia lehmannii* Hieron |
| Epazote | *Chenopodium ambrosioides* L. |
| Flor de muerto ó Cempoalxochitl | *Tagetes patula* L. |
| Green tomato | *Physalis ixocarpa* Brot. |
| Higo | *Ficus carica* |
| Maguey | *Agave atrovirens* Karw. |
| (*several*) | *Agave latissima* Jacobi |
| | *Agave pisaga* Trel. |
| Maize chinampero | *Zea mays* L. |
| Nopal | *Opuntia spp.* |
| Quelites | *Amaranthus spp.* |
| (*several*) | *Chenopodium spp.* |
| | *Porophyllum spp.* |
| | *Rumex spp.* |
| Romerito | *Suaeda torreyana* Wats. |
| Romero | *Rosmarinus officinalis* L. |
| Squash | *Cucurbita pepo* L. |
| (*several*) | *Cucurbita mixta* Pang. |
| | *Cucurbita moschata* Duch. |
| Tejocote | *Crataegus pubescens* (H.B.K.) Stead. |
| Tomato | *Lycopersicon esculentum* Mill. |
| Uahuzontli or Quelite | *Chenopodium nuttaliae* Saff. |
| Mazorca | *Zea mays* L. |

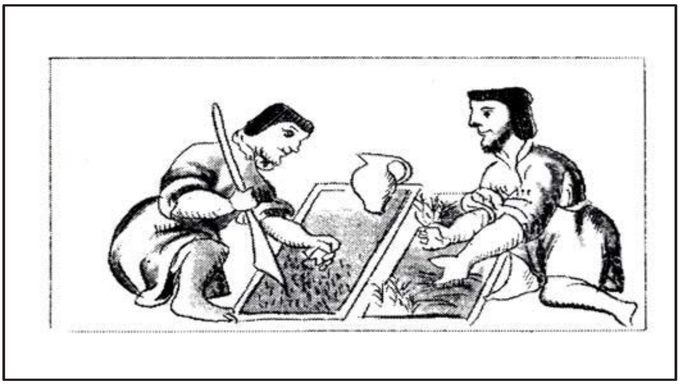
**Source:** Rojas (1983a)

An endemic fish (*Chirostoma spp.*) supplied important amount of food to Tenochtitlan. Different subspecies of this white fish (i*ztamichin* in Nahuatl) were captured according to their specific life cycles to maintain populations, covering animal protein consumption throughout the year and compensating for the lack of meat from mammals (Ezcurra, 1990). Gathering provided animal protein as well.

Edible aquatic animals, such as frog (*Rana spp.*), turtle (*Kinosternon spp.*), an endemic batracian called axolotl (*Ambystoma lacustris*) and other crustaceans, and insects gathered in the *chinampas* and surroundings were commonly consumed, providing high amounts of protein (Jiménez Osornio and Gómez-Pompa, 1987; Ramos-Elorduy and Pino, 1989). Algae (*tecuicatl* in Nahuatl), recollected from salty-water lakes, were widely eaten. A green-bluish algae (*Spirulina spp.*), rich in protein, vitamin and carbohydrate, was extensively extracted from the lakes and canals and prepared for human consumption (Challenger, 1998).

*Chinampas*, as an intensive multipurpose land-use system, became an essential food supplier in the densely populated Basin of Mexico during the last 200 years of the Aztec domination (Armillas, 1971). Tenochtitlan, the Aztec capital located on an island in Lake Texcoco, benefited from the strategic proximity of the *chinampas*

**Figure 9.7.** Planting seedbeds according to 16th century pictorial representation. **Source:** Sahagún (1963)



(Calnek, 1976). The Aztec government closely controlled production by constructing hydraulic infrastructure, which led to the expansion of the *chinampa* system in the southern Basin of Mexico, and by enhancing its efficiency via public labor, labor organization, landholding policies, taxation, tribute and marketing (Parsons, 1976). The permanence of the *chinampas* after the Spanish conquest proved their strategic value as a sustainable production system until the middle of the 20th century (West and Armillas, 1950; Jiménez Osornioland Gómez-Pompa, 1987).

### 9.3.4. The role of the *chinampas* at the eve of the Spanish conquest

Armillas (1971), Calnek (1976) and Parsons (1976) provide archaeological, paleoecological, ethnohistorical and ethnographic evidence of the ways *chinampas* became a strategic food supplier during the Aztec rule in central Middle America. According to Armillas (1971), the largest expansion of *chinampas* in the southern Basin of Mexico took place between 1400 and 1600 AD, coinciding with specific environmental conditions favorable to the conversion of marshes and swamps into agricultural fields. Parsons (1976) estimates that the *chinampa* system covered 95 to 120 $km^2$ at the beginning of the 16th century.

The expansion of the *chinampa* system also coincided with the emergence of the Aztec empire, its control over extensive areas of Middle America and a rapid population growth in central Middle America (Parsons, 1976). About 150,000 to 200,000 inhabitants were living in Tenochtitlan at the beginning of the 16th century, being part of the 1 to 1.2 million people distributed over the 7,000 square kilometers of the Mexico Basin (Calnek, 1976). Tenochtitlan, a 12 $km^2$ island with an estimated population density of 16,000 inhabitants per square kilometer, had severe limitations to produce enough food to fulfill the local demand.

According to Calnek (1972), Aztec bureaucracy implemented several strategies to reach the food requirements: (1) establishment of tributary systems in the dominated provinces (Barlow, 1949), (2) establishment of a complex marketing network, and (3) imposition of landholding taxation to sustain the Aztec elite living in Tenochtitlan. Two landholding policies were also established: (1) land expropriation on conquered territories within and outside the Basin of Mexico, and (2) expansion of new agricultural lands, especially in the southern portion of the basin by means of *chinampas*. The spatial organization of the *chinampa* system by the Aztec government overlapped with the spontaneous initiatives of individual producers (Armillas, 1971). Ethnohistorical evidence confirms that production activities within the *chinampa* system were supervised and controlled by Aztec bureaucracy, using tenant laborers and small-holding owners from different villages (*calpulli* in Nahuatl) (Calnek, 1976).

Parsons (1976) proposes a food production model of the *chinampa* system in the Post-Classic Period, taking into account an average crop yield of 3 ton/hectare/year, a labor need of 0.75 individual/hectare/year, a food requirement of 200 kg per inhabitant/year, and the food consumption by the population working in the *chinampas*. According to Parsons' model (1976), the *chinampa* system produced agricultural surplus to fulfill the basic food requirements of half to two thirds of the population living in Tenochtitlan, in addition to the subsistence needs of the *chinampa* producers. The Aztec bureaucracy controlled the *chinampa* food surplus by imposing a tribute on small-scale owners and a landholding taxation on tenant laborers, and by controlling the market.

The model highlights the strategic importance of the *chinampa* system to sustaining the largest city of the world at the beginning of the 16th century and the ways Aztecs extracted food surplus from Middle American farmers at the eve of the Spanish conquest (Coe, 1984; Rojas, 1988). This knowledge-based and labor-intensive multipurpose land-use system lasted in a sustainable way during 500 years after the decay of the Aztec empire. Sanders' (1957) ethnographic accounts about land and water management practices during the first half of the 20th century, in the same area where pre-Hispanic *chinampas* flourished, revealed a complex subsistence strategy rooted in local environmental knowledge and high labor investment, centered on maize production and based on agricultural terracing, home gardening and *chinampas*.

## 9.4. Drained-field agricultural systems in tropical lowland

### 9.4.1. Origin and forms of drained fields

Drained agricultural fields in flooded areas of the Middle American tropics have received less research attention than terracing and *chinampa* agricultural systems (Denevan, 1970; 1982 and 1992b), because of several reasons:

(1) tropical drained-field agricultural systems became lost after the Spanish conquest and land-uses in areas where this type of agriculture evolved have been strongly modified during the last 50 years as part of the colonization of the tropical lands. As a consequence, drained field features and relics were partially or totally destroyed (Denevan, 1995);

(2) the natural dynamics of tropical areas subjected to periodic flooding and intensive nutrient cycling limit the possibility to carry out archaeologic, pedologic and archaeobotanic surveys. In addition, such areas are frequently isolated and thus difficult to access for ground recognition (Siemens, 1982 and 1989);

(3) some relict patterns of these agricultural systems resemble natural swamp vegetation patterns, resulting from hydrological landscape evolution, which makes differentiation from airborne surveys difficult (Siemens, 2000); and

(4) the general opinion considering shifting cultivation as the principal agricultural system in tropical areas has limited for some time a comprehensive understanding of the wide array of agricultural techniques used to intensify crop production in different Middle American societies, such as the Olmecs, Totonacs and Mayas (Denevan, 1992b).

Recent advances in understanding the remnants of such agricultural systems are revealing their importance and sophistication. Nevertheless, information gathered at field level still raises more questions than answers about their role in sustaining densely populated areas, such as the Mayan lowlands (Siemens and Puleston, 1972; Matheny, 1976; Wiseman, 1978; Turner and Harrison, 1981; Siemens, 1989 and 2000; Denevan, 1995; Faust, 1998) and the coastal lowlands of the Gulf of Mexico (Schmidt, 1977; Siemens, 1989; Zolá and Marchal, 1986; Heimo and Siemens, 2000; Whitmore and Turner, 2001). Figure 7.2 shows the drained-field agriculture distribution in pre-Hispanic Middle America.

A raised field is a land tract prepared by transfer and elevation of soil above the natural terrain surface to improve cultivation conditions (Denevan, 1980a and b). Denevan (1980a and b) points out that the primary aim was to improve the drainage of seasonally flooded tropical savannas, highland basins and waterlogged areas. Raised fields were also used as garden islands in shallow lakes of Middle and South America. Other functions included soil aeration, concentration of organic matter in the topsoil, temperature modification, erosion control, and moisture retention or irrigation. Raised fields were intensive agricultural systems, where fallow periods were usually of shorter duration than cropping periods (Denevan, 1982). Most of these agricultural systems were built on wetlands, such as floodplains, lake margins and swamp land surrounded by *Tierra Firme*.

By far the most important forms of Middle American tropical raised fields were the large platforms or ridged fields, with accompanying ditches and canals, whereby water and soil were carefully managed to improve crop growing conditions in otherwise marginal habitats (poor drainage, poor soils). Raised fields and ditches elevated the crops, removed excess of flooding water, retained water during the dry season, enhanced the crop rooting systems and extended the growing season. Water management aimed to: (1) facilitate drainage during flooding, and (2) inhibit drainage during the dry season. Areas with raised fields are usually subjected to a prolonged dry season, followed by a long wet season (500–2000 mm). Common soils are Gleysols, Calcimorphic soils and Lithosols, where savanna and swamp vegetation constitutes the main natural formations (Siemens, 1989).

Although there is no sufficient evidence about the periods when these agricultural systems arose, extended and consolidated as intensive crop production systems, they seemingly evolved over a long period of time in the Yucatán Peninsula. Puleston (1971) obtained a radiocarbon date of 1110 (± 230) BC for raised fields in the Petén of Belize, corresponding to the Pre-Classic period. Hammond (1978) obtained a radiocarbon date of 1400 BC on the same raised fields of Belize, corresponding also to the Pre-Classic period. Faust (1998) identified extended raised fields in the vicinity of Edzná, Campeche, Mexico, that supported an important Maya population until the late Classic period (650-900 AD). The same author (Faust, 1998) points out that only in conditions of population pressure are raised fields preferable to swidden agriculture, since the labor costs are higher unless the fallow duration is reduced. Hundreds of square kilometers with ancient raised fields have been recognized since Puleston's discovery in tropical flooded lands of Middle America (Denevan, 1970; Puleston, 1971, 1977a and b). An ethnohistorical research of Mayan raised fields provided by Pohl (1981) suggests a widespread distribution in low-lying (*bajos*) and inundated areas close to highly populated Mayan cities of the Classic and Post-Classic periods, highlighting their importance as food suppliers until the Spanish conquest.

### 9.4.2. Construction, maintenance and management of raised fields

The construction and maintenance of raised fields required huge investment of time and resources, but populations supported by raised-field agriculture were substantial. According to Denevan (1982), the labor days invested in constructing raised fields in the southern Yucatán Peninsula equal a work force of 100,000 men working 150 days/year to reclaim 35,000 ha of raised fields over 10 years. Thus, such an enormous labor investment should be rather considered as spread over hundreds of years. This also raises the question of the social organization needed to carry out such labor demanding works. The complexity and sophistication of raised-field systems required specialization, planning and coordination, thus a centralized society and a bureaucratic state controlled by the Maya elite, similar to the *chinampa* system in central Middle America (Matheny and Garr, 1983; Parsons, 1991). This "top-down perspective" is challenged by a "bottom-up perspective" on the basis of archaeologic, ethnohistoric and current ethnographic evidence, which shows that raised fields were and are still developed and managed by local households and community organizations in the Andean region (Erickson, 1995) and in Middle America (Siemens, personal communication), and that their construction required less labor force than previously estimated (Erickson, 1995). This means that intensive agricultural systems were periodically constructed under emerging centralized states and locally persisted after the collapse of the controlling bureaucracies.

Similar to the highland *chinampa* system, tropical lowland raised-field agriculture involved complex soil and water management (Marcus, 1982), and required the development of anthropogenic soils in temporarily inundated areas, making infertile soils fertile, as is the case of the Mayan karstic areas (Siemens, 1978 and 1983). High labor inputs substituted complex tools for landscape engineering, although techniques for extracting, collecting and retrieving water were highly developed in the Classic Mayan tropical lowlands, indicating advanced engineering skills (Turner, 1974, 1983; Turner and Harrison, 1981; Denevan, 1982; Whitmore and Turner, 2001).

Lowland people in tropical Middle America considered flooded lands beneficial for agriculture. In pre–Hispanic Mayan representations, aquatic vegetation as symbol of land productivity, the Mayan deity *Itzam Na* represented by a crocodile symbolizing land and water, and a growing maize plant as symbol of abundance, are all associated with flooded lands (Puleston, 1977b; Siemens, 1989). However, so far no representations of soil and land resources, similar to the Aztec soil glyphs of pre-Hispanic central Middle America, have been found. Not much is known about Mayan pre-Hispanic soil knowledge. Contemporary Mayan ethnopedology is discussed in chapter Ten, reflecting links to prehistoric knowledge and management systems of soil and land resources. Table 9.4 shows a 16th century Mayan

**Table 9.4.** 16th Century Mayan soil and environmental nomenclature

| Mayan soil (Luum) terms | English meaning |
|---|---|
| Cu luum | Good soil |
| Ek luum | Good black soil |
| Yukucnac luum | Wet or moist soil |
| Puz luum | Dry soil without stones |
| Buy luum | Sterile soil |
| Xib luum | Sterile or depleted soil |
| Noth luum | Bad soil |
| Nothocnac luum | Depleted, impoverished soil |
| Tzekel luum | Poor soil for planting; very rocky soil |
| Cheh luum | Rocky soil |
| **Maya environmental terms** | **English meaning** |
| (1) Coastal formations<br>• Brackish lowland areas | |
| Ukum | Lagoon |
| Chiib | Salt spring |
| U chuchil taab | Salt pan |
| • Upland areas | |
| Pay | Beach |
| Nicab | Headland |
| Ecab | Headland |
| (2) Inland formations<br>• Flooded areas or water sources | |
| Chi haa | Bank or edge of a water body |
| Akal | Swamp |
| Akalche | Wooded swamp |
| Acaan | Calm lake |
| Acan haa | Puddle, pond |
| Chen | Cistern, well |
| Emelbil chen | Walk-in well |
| Actun chel | Cave with water |
| Conot | *Cenote* or waterhole |
| Pek | Artificial reservoir or pond |
| Yakalil cay | Fish reservoir or pond |
| Yoc haa | River |
| • Open grasslands or plain | |
| Chakan | Open grassland |
| Pik chakan | Savanna |

**Source:** Marcus (1982)

soil, hydrology and relief nomenclature from the Motul and San Francisco Maya-Spanish dictionaries (Martínez Hernández, 1929; Michelon, 1976). Mayan soil names relate to fertility, stoniness, moisture content and color.

So far, there is little evidence from archaeological research about the ways Maya built anthropogenic soils on raised fields. Transferring organic matter from the aquatic system to the crop system was an essential component of raised field formation. Recycling plant biomass from a marsh or swamp was a key strategy to build highly fertile anthropogenic soils (Denevan, 1982; Siemens, 1989). Olson (1974) and Puleston (1977a, 1977b and 1978) studied the stratigraphy of anthropogenic soils and found that raised fields were constructed and periodically reconstructed with layers of marly limestone (*sascab* in Maya), covered with aquatic sediments extracted from the surrounding canals (Siemens, 1989).

Liming was an important measure to improve soil fertility in the Mayan lowlands. Limestone in tropical karstic landscapes dissolves fast under moist and warm conditions (Matheny and Garr1983). Maintaining optimal soil reaction levels was critical to Maya farmers, especially for maize whose optimal pH range is 6.0 to 7.0 (Allaway, 1975). Freidel and Scarborough (1982) found ancient Mayan canals in Belize lined with a limestone gravel fill and banked with a layer of *sascab*, a local powdery form of limestone rock. Water flowing in these canals gradually dissolved the limestone, making the canal water more alkaline and transferring lime to the drained fields, thus maintaining the soil reaction balanced for intensive maize growth. Fedick (1995 and 2000) found rock constructions in cross-channel alignments in the northern Mayan lowlands, functioning as check-dams to slow the rush of rainwater runoff into cultivated areas and trap sediments. The same author (1995) presents chemical analysis of the abundant periphyton found in natural depressions, which could have been an excellent natural fertilizer for wetland soils.

According to Faust (1998: 139), ancient Maya had ways of estimating soil reaction from the types of weed growing on the soil, which are still widely used by contemporary Maya framers. Maya identify soil types and assess the potential of the sites from the vegetation and past yields, recognizing stages of plant succession after the abandonment of cornfields or *milpas* (Gómez-Pompa, 1991). Increasing weed growth is perceived by Maya farmers as an indication of increasing soil acidity (Flores and Ucan-Ek, 1983).

### 9.4.3. A descriptive model of the raised-field system

After 20 years of intensive research in the tropical lowlands of the Gulf of Mexico and the Yucatán Peninsula, Siemens (1989) proposed a descriptive model of the Middle American raised-field agricultural system (Figure 9.8). Raised fields in flooded tropical lowlands were constructed the same way as Middle American highland *chinampas*, according to Palerm and Wolf (1957). These authors support the idea that "the abundance of swamps and lakes on the lowlands and the apparent Mayan predilection for these environments suggest the possibility of a cropping system on flooding lands by means of measures similar to those employed in highland *chinampas*".

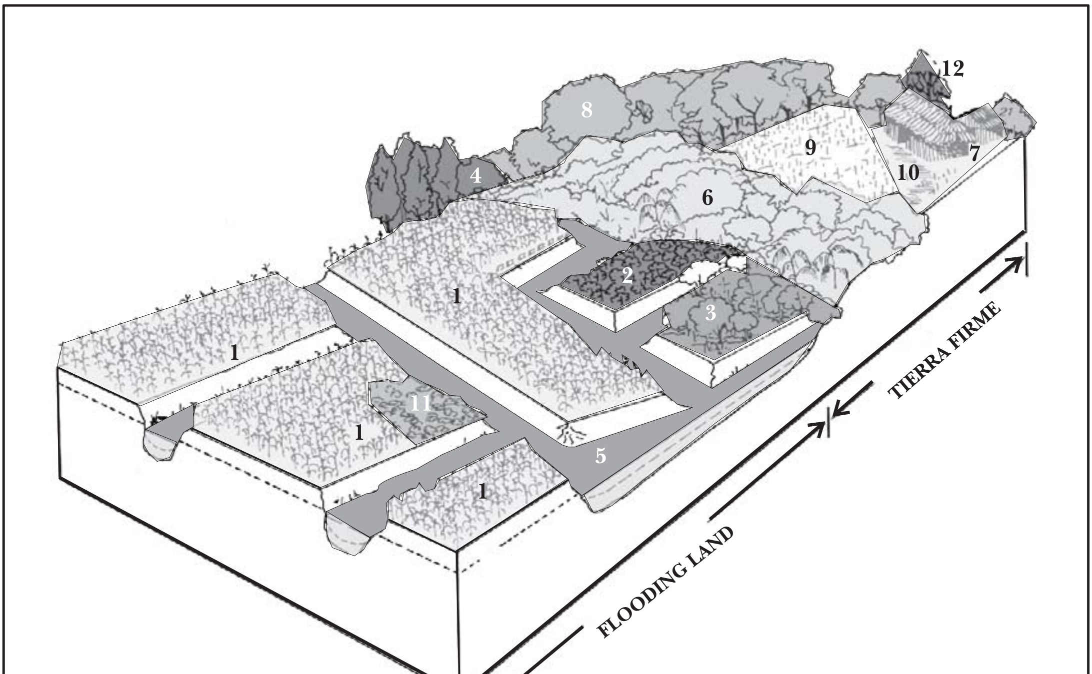



**Figure 9.8.** Model of Middle American raised-field agricultural system. (1) Platform or *camellón*; *milpa* cultivars. (2) Drained field; cotton and root crops cultivars. (3) Drained field; cacao cultivars. (4) Tree edges. (5) Canal; fisheries. (6) Forested strip composed of useful trees and palms. (7) Household. (8) Homegarden. (9) Swidden Maya *milpa*. (10) Backyard garden. (11) Root crop cultivars. (12) *Ramón* trees (*Brosimum alicastrum*). **After:** Siemens (1989)

Relics of the raised-field systems present several major features. A set of platforms or *camellones*, that vary in size and orientation but present a well defined rectilinear pattern, occurs frequently on the upper and dryer borders of non-forested lowlands, outside the principal flooding area. These platforms are surrounded by a network of canals, which connect rivers or lakes with the upper and dryer borders of the lowlands. Adjacent archaeological sites are commonly present; some of them present a complex and dense building distribution, thus suggesting densely populated areas whose livelihood was supported by intensive cropping on the raised fields (Siemens, 1989).

A closer view of raised fields allows differentiating other relevant features or subsystems. First of all, a main division is made between *tierra firme* and flooding land on the typical karstic landscape of the Mayan cultural area. Sediments in flooded areas consist of a combination of earth debris from dissolved limestone and high amounts of plant and animal organic residues. Platforms or *camellones* were constructed on this subsoil, interlacing marly limestone (*sascab*), aquatic plant residues and mud extracted from the bottom of the surrounding canals. The fertile anthropogenic topsoil allowed, in many cases, continuous cropping. The height of the platforms above the water level in the canal was 0.5-1 m to avoid waterlogging of the topsoil during the flooding season and maintain soil moisture during the dry season, similarly to the management of the *chinampas.* Drained fields near the boundary between flooded land and *tierra firme* were probably a result of canalization rather than platform construction.

As in the highland *chinampa* system, raised fields and drained fields were stabilized with the aid of wooden poles and tree edges. The presence of wooden poles on the banks of the platforms can also be considered as an anti-erosive and biological control measure (Gliessman, 1988). Radiocarbon dates of wooden poles suggest that this agricultural system was in use since the late Pre-Classic until the Post-Classic Period (Puleston, 1971; Hammond, 1978; Siemens 1989).

According to pollen analysis (Puleston, 1977a; Dahlin, 1979), maize and cotton were the main crops, together with root crops, such as *yuca* or cassava (*Manihot esculenta*), *camote* or sweet potato (*Ipomea batatas*) and *jicama* (*Pachyrrhizus erosus*). Cacau (*Theobroma cacao*) was probably widely cultivated. Canal fishing was an important source of protein. Canals were managed to control flooding during the wet season and retain water during the dry season by means of ditching.

Aquatic plants, periphyton and algae were probably used as organic fertilizers combined with mud for mulching. Sub-irrigation and splash irrigation using canal water were also probably implemented, especially during the dry season. A forested strip composed of useful trees and palms was established or tolerated as a boundary between flooding land and *tierra firme.* The typical swidden Maya *milpa* was established on the upper *tierra firme,* close to the village households. Homegardens and backyard gardens surrounded the houses. These agroforestry systems were dominated by tree species, such as *ramón* (*Brosimum alicastrum*), hogplum (*Spondias spp.*), avocado (*Persea americana*), anona (*Anona reticulata*), *chicozapote* (*Manilkara zapota*), *guayaba* (*Psidium guayava*), and other fruit-bearing trees and useful shrubs and herbs.

Raised fields varied in shape, pattern and size according to environmental conditions and the time period in which they were constructed. Thus, the descriptive model presented above represents a generalization of the systems distributed all along the coast of the Gulf of Mexico and in the Yucatán Peninsula. Siemens (1989) suggests a conceptualization of this model to understand the logic of the cropping cycle along the year. Raised fields were more intensively used than the *tierra firme* swidden *milpas.* The combination of dry season cropping on raised fields and wet season cropping on swidden *milpas* produced amounts of food greater than needed for household and village subsistence. Food surplus was transferred to the densely populated areas in the Middle American tropical lowlands.

## 9.5. The mayan agro-ecological system

Middle American tropical lowlands have a variety of ecosystems, which were adopted and adapted by farmers through long periods of experimentation and innovation using diverse agricultural methods (Harrison and Turner, 1978). During the Post-Classic period, the vast majority of the land was already occupied and managed in many distinct ways leaving conspicuous traces on the landscape. These heavily humanized landscapes reflect the complexity and sophistication of natural resources management since ancient times.

One of the most striking evidence is the presence of anthropogenic soils near settlement sites (McCann, 1999). Raised fields, terraces, mounds, sunken fields, orchards and homegardens are intensive cropping systems, which reflect the direct human influence on the biophysical environment and the soilscape. What seems clear now, even without written or pictorial references that could enrich the present knowledge of what is physically recognizable on the 'anthrosoilscape', is that ancient peoples of the lowlands possessed sophisticated soil knowledge (Marcus, 1982; Dunning, 1992 and 1993; Gómez-Pompa, 1991; Beach and Dunning, 1995). Moreover, this knowledge system was applied under densely populated conditions, allowing agricultural surplus production to meet the food demand in tropical lowlands. Faust (1998) points out that "It is clear that Maya science and technology sustained sophisticated regional states, with population densities estimated by some archaeologists at 180 persons per square kilometer in the central southern lowlands, which include large areas of swamp". According to Culbert and Rice (1990), this figure would place the Mayan lowlands in the same density range as Java and China –that is among the most densely populated regions of the pre-industrial world.

How was this possible? Recent archaeologic, ethnohistoric and ethnographic evidence suggests, for example, the development of an intensive agroforestry system by the ancient Maya people, who adopted and adapted a variety of ecosystems constructing different humanized landscapes (Gómez Pompa, 1991). Land-use decision making and conservation practices were complex and sophisticated, resulting from the ample environmental knowledge system possessed by common Maya farmers. Some of these practices are still in use by present-day Mayan and *Mestizo* populations in former Mayan cultural areas.

This new evidence challenges conventional assumptions, which claim that Maya destroyed the forest, suggesting that Classic Maya collapse resulted from soil loss produced by shifting cultivation and deforestation, and by the siltation of lakes (Morley, 1956; Olson, 1982; Rice at al., 1985; Rue, 1987; Wingard, 1992; Hodell et al., 1995). Even if that was the case in some areas (Olson, 1982; Rice et al., 1985; Lopinot and Woods, 1993), it is important to recognize that the relationship between population and soil erosion is not necessarily positive and linear. In the Maya case, population decrease and disruption of the social organization due to warfare could have caused the neglect of erosion-control devices, such as terraces, check-dams and canals, leading ultimately to the tremendous pulse of erosion that is recorded in the sediments of the Petén lakes in Guatemala. As McCann points out (1999) "The physical landscape at any given place and time is made up of the accumulated residue of past events, but linking the "residue" to particular past events can be very difficult, and interpretations of landscape history can be radically divergent. When dealing with human history, there is always the danger of reading too much *into* the landscape when attempting to read *from* it". The Maya, no doubt, experienced soil erosion and deforestation as their population grew, but they learned some lessons from the collapse and from other changes in their economic, ecological and meteorological environment (Faust, 1998).

Although there is no clarity about the factors causing the Mayan collapse, there is enough evidence to discard the hypothesis of poor management of soils and deforestation (Gómez-Pompa, 1991). Figure 9.9 shows main land-use systems managed by ancient Maya farmers: some of them are considered as extensive agricultural systems as is the case of swidden cultivation or the Mayan *milpa*, but most are considered as intensive cropping and agroforestry systems where anthropogenic soils were built up.

### 9.5.1. Swidden agriculture: the Mayan *milpa*

Swidden agriculture or the Mayan *milpa* played a substantial role in food supply, as in other tropical lands of the Americas. Swidden or slash-and-burn agriculture consisted of the alternation of short periods of cultivation with long periods of grass, shrub or forest fallow which permits soil recovery and reduction of pest competition (Denevan, 1995). This system is sustainable under a modified forest cover as long as the fallow is sufficient, although productivity per area is relatively low. According to new evidence, swidden agriculture became less important for food supply in the Mayan cultural area when population increased and socio-political organization became state-centralized (Faust, 1998). New demands required intensive production systems, because swidden agriculture alone could not support the new demographic and social realities. Besides, there is an argument suggesting that long-fallow shifting cultivation was not common when forest clearing was done by stone axes, which are very insufficient compared to metal axes not available in the Americas until 1492 (Denevan, 1992b).

Despite of this, conquerors, priests and colonialists have extensively documented the 16th century Mayan *milpa*, suggesting its importance as food supplier (Terán and Rasmussen, 1994).

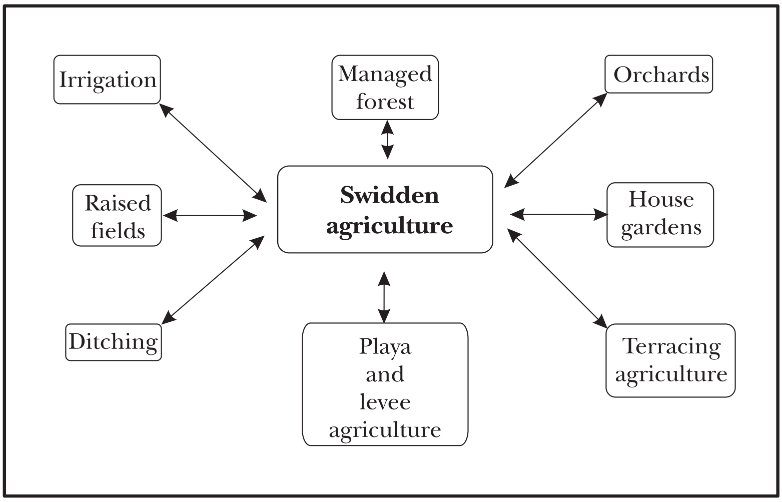



**Figure 9.9.** Mayan agroforestry model

The Mayan *milpa* is a mosaic of plots in different stages of recovery after a period of agricultural production, enlarging the availability of useful plant and animal species. Woody species are deliberately associated with crops, either in space or time, so that the *milpa* is in fact an agroforestry and multicropping system (Nair, 1993; Kass and Somarriba, 1999). Selection and protection of useful trees, planting of trees before fallow, including shade leguminous nitrogen-fixing trees, coppicing of selected species in slash and leaving stumps ready to take advantage of fallow when areas were abandoned after two to three years of cultivation, were main agroforestry practices (Gómez-Pompa, 1991). Burning was essential to the replenishment of soil fertility. Besides of adding accumulated organic matter as fine ash, which rain washed into the soil, burning increased soil alkalinity when a substantial amount of burned limestone was converted into quick lime, later washed into the soil. As pointed out above, maintaining optimal alkalinity levels for intensive cropping was critical in the Mayan *milpa*. Faust (1998) suggests that, alongside declining availability of lime for agriculture, rainfall would have been a critical factor for population density in ancient Mayan areas.

The Mayan *milpa*, centered on maize production, was adapted to a patchy and difficult environment (thin soils, irregular rainfall pattern, and lack of surface water). *Milpa* management practices were based on detailed local empirical knowledge of the dynamics of forest regeneration, soil fertility replenishment, and particular land and relief conditions (Ewell and Merrill-Sands, 1987). Besides, swidden practices were embedded in an evolving tradition of Mayan cosmology. The orientation of the fields, the way they were laid out in squares, and the association with the sun and the winds, all are congruent with the cosmological system of the ancient Maya civilization and, indeed, represent a technological analogy of ritual symbolism (Faust, 1998). Despite disputed views of the role played by the Mayan *milpa* during pre-Hispanic history, there is no doubt of its importance as household and village food supplier and as part of the Mayan agroforestry strategy, evolved over thousands of years, as shown in figure 9.9.

### 9.5.2. Managed forests, orchards and homegardens

Mayan sylviculture consisted of a series of activities of protection, cultivation, selection and introduction of trees in the *milpa*, fallow, plantations, forest, homegardens, living fences, *cenotes* or sunken holes and urban centers (Gómez Pompa, 1991; 1992). Ancient Maya managed their forest ecosystems (Barrera et al., 1977) from which they derived basic goods (Gómez Pompa et al,, 1987; Puleston, 1968; Peters, 1983). Forests contain many useful native trees, scrubs and herbs. Conservation of forest patches, selection and introduction of useful trees were done in special ways reflected in Maya forest nomenclature (*tolché*: forested belt surrounding the *milpa*; *pet kot*: circular wall of stones protecting forested sites). Managed forests present high biological diversity, with an important number of useful trees, suggesting that they supported dense human populations without known detrimental impact on forest ecosystems. No evidence is available that mass extinction of species occurred in the past or that Mayan managed forest diversity and richness were diminished by human activities, despite intensive use (Gómez-Pompa, 1987, 1990 and 1991). The fact that remnants of managed forests are still dominated today by many species that are protected, used and managed by present-day Maya farmers, is an evidence of their anthropogenic origin.

Orchards and homegardens were the most important agroforestry systems of Maya farmers (Barrera, 1980; Alcorn, 1987) and are still extensively managed in present Mayan cultural areas (Caballero, 1992). As in other tropical regions, these agro-ecosystems played a fundamental role for household and village subsistence among indigenous and traditional small-farmers, providing goods for human nutrition, health and religious needs. Trees are the most important components of the gardens, having complex structure and resembling the structure of the nearby tropical rain forest (Barrera, 1980). Trees provided shade, food, firewood and medicines. Their individual ordering within the homegardens was according to factors such as soil moisture and light variability (Caballero, 1992). Anthropogenic soils were developed in these agro-ecosystems using human wastes and organic disposals (McCann, 1999). Special elevated seedling beds (*kaanché*) were and are still constructed with organic soil (Vargas-Rivero, 1983). In Mayan orchards or traditional plantations, cacau was planted under the shade of legume trees. According to Gómez Pompa (1990: 50), cacau plantations represent the most highly sophisticated arboricultural system of ancient Maya. Plant domestication, toleration and cultivation were activities playing an exchange role between swidden agriculture and managed forest, homegardens and orchards, enriching each of these agroforestry systems.

### 9.6. Conclusion

Complex soil, water and relief management in the Middle American Post-Classic period was applied to intensify agricultural systems in densely populated areas surrounded by fragile lands, such as sloping or inundated fields in semi-dry temperate highlands and humid tropical lowlands. Agricultural landscapes were modified according to diverse ecological and socio-cultural factors to improve the *milpa* productivity. Outstanding technified soil and land resources knowledge was applied to build anthropogenic soils, converting infertile areas into highly fertile croplands.

Agricultural terraces were constructed to take advantage of frost-free planting surfaces, well drained soils, and natural and/or human-induced movements of sediments, either in semi-dry temperate highlands or humid tropical lowlands with long dry season. A wide array of terracing techniques was implemented to enhance soil fertility and intensify land productivity by means of upstream irrigation. Techniques were adjusted to local ecologies, inducing the offspring of crop plant diversification. Narrative documents from the $16^{th}$ century describe the ways terracing techniques and soil and water conservation measures were implemented. Soil and water knowledge-based systems, high labor investments and hydraulic engineering were adopted and adapted to replenish soil fertility.

The most sophisticated intensive agricultural system of Middle America was without doubts, the *chinampa* system of drained-field agriculture. Land was reclaimed or gained from marshes and permanently inundated areas in central Middle American highlands. In a broad sense, the *chinampa* system can be considered as an agroforestry strategy to intensify food production on relatively small plots, where organic anthropogenic soils were constructed and maintained by means of mechanical, biologic and agronomic measures. A sophisticated technique was developed to build organic matter-enriched anthropogenic soils. Documents from the $16^{th}$ and $17^{th}$ centuries draw attention on the construction and maintenance of *chinampas* and more specifically on the techniques applied to maintain soil moisture and soil fertility. These measures allowed crop production throughout the whole year. While the structure and functioning of the *chinampa* are well documented, the formation of anthropogenic soils still needs comprehensive research.

The strategic importance of the *chinampa* system during the Post-Classic period in the Basin of Mexico lies in its capability to fulfill major food demands and maintain two thirds of the inhabitants of Tenochtitlan, the Aztec capital considered the largest urban center of the world at the eve of the Spanish conquest. Farmers' soil knowledge was critical for such an agro-ecological enterprise. *Chinampa* production, only slightly diminished at the beginning of the second half of the $20^{th}$ century, was sustained for thousands of years without massive use of external inputs.

Similar to the *chinampa* system, an intensive agricultural system developed in the Middle American tropical flooding lands. Raised fields or *camellones* were constructed on marshes, swamps and lake margins in the coastal areas of the Gulf of Mexico and in the Yucatán Peninsula. Although less studied and more difficult to analyze due to ecological constraints and recent land-use changes, raised-field agriculture was a strategic production system able to fulfill the basic food requirements of the densely populated Mayan areas during the Post-Classic period. Remnants of raised-field anthropogenic soils suggest a good understanding of the soil resources in karstic landscapes, where liming and mulching were crucial to maintain soil fertility and sustain *milpa* production. Mayan subsistence strategy involved the management of diverse agro-ecological systems, from the most extensive such as shifting cultivation to the most intensive such as terraces and raised fields. This multi-system strategy was supported by agro-sylvicultural land-uses.

The presence of anthropogenic soils on agricultural terraces, *chinampas* and raised fields reveals that Middle American farmers were well aware about soil processes and dynamics and had a comprehensive understanding of the soil resource as a 3-D "living being", despite contrary assumptions in the literature. In fact, Middle American farmers perceived soil and land resources as 4-D non-human beings, when considering them as sacred supra-natural deities capable to behave and change according to circumstances. Kosmos, Corpus and Praxis of soil and land in Middle America were complex, sophisticated and usually efficient.

Although pre-Hispanic Middle American ethnopedologies still need more comprehensive and systematic understanding, the exploratory explanation presented in chapters Seven, Eight and Nine shows their complexity and sophistication when analyzing archaeological, ethnohistorical, ethnobotanical and ethnographic information. Centered on a common cosmovision and maize domestication as cultural matrix, Middle American ethnopedologies share commonalities about the ways soil and land were perceived, symbolized, ritualized, cognized and managed to fulfill sacred and concrete needs and aspirations. Moreover, pre-Columbian ethnopedologies show multiple ways of knowing and managing soil and land resources according to local and regional ecological, agronomic and cultural contexts, and resemble the complexity of the Middle American civilization core. The understanding of these knowledge-based systems offers an historical background to analyze the permanence and/or changes occurred in contemporary Middle American ethnopedologies after 500 years of European contact, a topic which is discussed in Chapter Ten.

# CHAPTER TEN

## LAND, PEOPLES AND CULTURES IN CONTEMPORARY MIDDLE AMERICA: HISTORICAL BACKGROUND AND CURRENT REALITIES

### 10.1. INTRODUCTION

Chapters Seven, Eight and Nine analyze pre-Hispanic Middle American ethnopedologies by exploring archaeological findings and ethnohistorical and ethnobotanical documents mainly from the 16th century. The contextualization of Middle America as (a) a civilization core, (b) a center of origin of plant domestication, and, (c) a complex biophysical and socio-cultural setting where maize and Middle Americans co-evolved during millennia, is the main objective of the last three chapters. The long co-evolution led to the development of soil and land knowledge systems supporting the intensification of the agricultural production and framed within a common cosmovision. These knowledge systems were analyzed applying the perception, cognition and management (K-C-P) model proposed in chapters Four and Five. This theoretical model proposes that a comprehensive understanding of the ways soil and land resources were and are managed among non-Western societies requires the full integration of the subjective and objective cognitive domains that operate as a whole during the production process. The integration of these domains allows the understanding of how and why soil and land were perceived as living and sacred beings, known as discrete natural objects, and managed as critical production resources. This heuristic interpretation had the objective to provide the historical background of contemporary Middle American ethnopedologies.

Chapters Ten, Eleven, Twelve and Thirteen analyze contemporary Middle American rural realities and ethnopedologies; thus they most be seen as a unit. Chapter Ten provides an overview of the major historical trends that reshaped the pre-Hispanic Middle American landscapes, peoples and livelihoods since the conquest period until the eve of the 21st century. These changes transformed pre-Hispanic soil and land resources knowledge systems in many different ways. Permanence, change, innovation, enrichment and loss of local soil and land knowledge systems constitute major processes that should be framed to fully understand contemporary local ethnopedologies. These processes show that indigenous and *Mestizo* farmers and communities were never isolated and played active and contrasted roles with other social actors involved in rural activities during last 500 years. An explanation of when, how and why these processes occurred is the main objective of Chapter Ten.

Chapter Eleven presents contemporary soil and land resources knowledge systems of several rural communities living in five different agro-ecological zones of Middle America. Analysis includes ethnopedological information from Middle American indigenous peoples and *Mestizo* small farmers, which offspring as a biological and cultural hybrid since the Middle American-European contact. It contrasts ethnopedological information from Mexico, Belize and Guatemala, covering 13 ethnic groups, but excluding the Purhépecha ethnopedological experience, as it will be discussed in chapters Twenty, Twenty One and Twenty Two.

Chapter Twelve presents the Maya ethnopedology within the K-C-P model. Contemporary soil and land perception, knowledge and management among Maya farmers have been best studied in Middle America. The very well documented Maya experience allows explaining how and why they still maintain efficient agro-ecological knowledge systems, highly symbolized and ritualized in syncretic ways, and sophisticated in their practical uses.

A discussion about the similarities and differences of the varied Middle American ethnopedological information is provided in Chapter Thirteen. This discussion allows highlighting the richness and constraints of local ethnopedologies as part of longstanding adapted agro-ecological systems. The chapter concludes that it is possible to establish a general framework of perception, knowledge and management of soil and land resources in Middle America that co-evolved since ancient times as practically all local ethnopedologies were linked to the *milpa* production and shared a common cosmovision. Finally, it also provides a general framework for the ethnopedological case study carried out at local level in the sub-humid temperate highlands of Mexico, among the Purhépecha of Pichátaro in the state of Michoacán.

## 10.2. MIDDLE AMERICA TODAY

Contemporary Middle America constitutes a cultural geographic unit where diversity rahter than uniformity of peoples, places, cultures and traditions dominate. This geographic unit includes seven countries of North and Central America: Mexico, Belize, Guatemala, El Salvador, Honduras and Nicaragua (Figure 10.1). The total area of this cultural region comprises 2.5 million square kilometers, a surface equal to Luxembourg, Belgium, the Netherlands, Germany, France, United Kingdom, Ireland, Portugal, Spain and Italy together, although Mexico alone accounts for 83% of it. Total population during the 1990s is estimated at 127 million inhabitants, 80% of which corresponded to the Mexican population (Table 10.1).

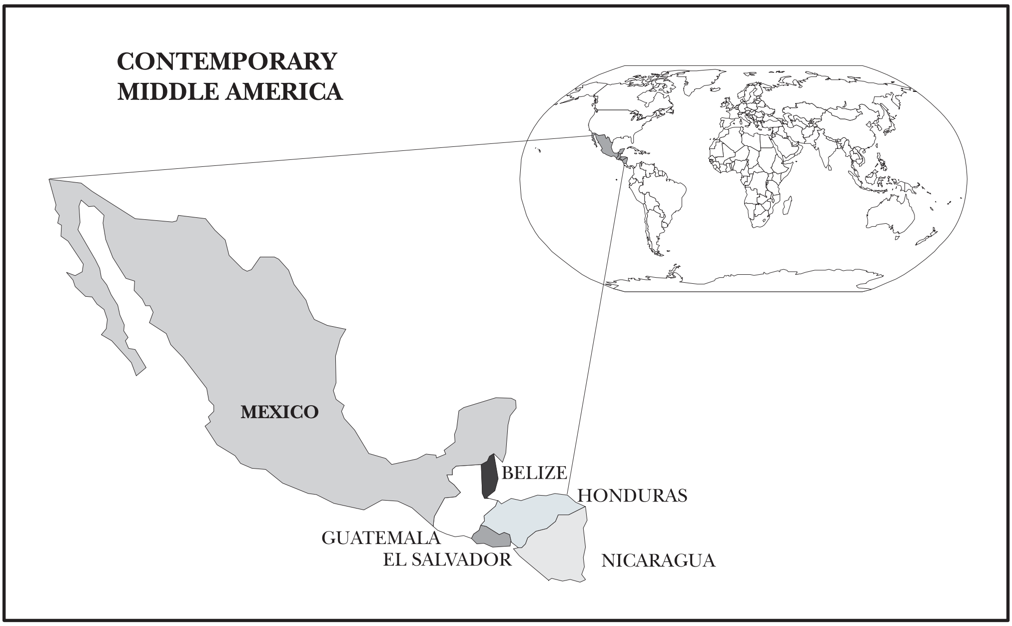



**Figure 10.1.** Contemporary Middle America

Great transformations occurred in Middle America over the last 500 years, that drastically reshaped its lands, peoples and cultures. The independent evolution of this civilization core was sharply truncated since the very moment of its conquest, by the offspring of the inter-oceanic exchange of peoples, knowledge and products that widened the global relations controlled by Europe (Crosby, 1992). Since that moment, the landscapes and livelihoods of the original population were influenced by the new inhabitants, their culture and power. Nevertheless, the encounter of the two civilizations gave shape to a long and slow process of hybridization in all spheres of life of both, the dominant and the dominated societies. The hybridization or *mestizaje* evolved in complex and diverse ways by the exchange of experiences coming not only from Europe but also from Africa

**Table 10.1.** Socio-economic and environmental information of Middle American countries

| COUNTRY | COUNTRY AREA (thousands of $km^2$) | POPULATION (thousands) (1995)[1] | POPULATION DENSITY[1] per $km^2$ (1995) | % POPULATION GROWTH per YR [5,6] | % RURAL POP.[3] | % AGRICULTURE in GDP[12] | % INDIGENOUS POP.[1,2] | NUMBER OF LANGUAGES[1] | % POP. EXTREME POVERTY[4,7] | % ANNUAL DEFORESTATION[8] | % SOIL DEGRADATION[11] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **MEXICO**[9,10] | 1,972 | 100,349 | 49 | 1.8 | 25 | 5% | 11[2] | 295 | 40[7] | 0.9 | 4,3 |
| **GUATEMALA**[10] | 109 | 10,998 | 98 | 2.7 | 58 | 20% | 44[1] | 53 | 53[7] | 2 | 4,3 |
| **BELIZE** | 23 | 214 | 9 | 2.4 | 53 | 21% | 11[1] | 8 | | 0.3 | 0,2 |
| **EL SALVADOR** | 21 | 5,870 | 278 | 1.6 | 55 | 13% | 5[1] | 5 | 48 | 3.3 | 3 |
| **HONDURAS** | 112 | 5,459 | 51 | 2.4 | 55 | 22% | 7[1] | 9 | 50 | 2.1 | 3,2 |
| **NICARAGUA** | 130 | 4,206 | 37 | 2 | 37 | 34% | 5[1] | 7 | 55 | 2.5 | 2 |
| **TOTAL** | 2,367 | 127,096 | 54 | 2.1 | 47 | 19% | 14 | 377 | 49 | 1.8 | |

**Sources:**

(1) Grimes, B. F. 1996. Ethnologue. Summer Institute of Linguistics. Dallas, Texas, USA.
(2) Durning, A.T. 1992. Guardians of the land: indigenous peoples and the health of the earth. Worldwatch paper no. 12, Worldwatch Institute, USA.
(3) Toledo, V. M. 1994. La apropiación campesina de la naturaleza: un análisis etnoecológico. PhD Thesis, UNAM, Mexico.
(4) Poverty % of people living on less than US$ 1 per person per day, 1981-1995. The World Bank. 1997. World Development Report. Oxford University Press, UK.
(5) SPSS 7.5, World95m.sav. Population growth rates.
(6) UNDP. Human Development Report 1997, Oxford University Press, UK.
(7) HPI Index (Human Poverty Index): concentrates on deprivation in three essential elements of human life: (a) longevity (people not expected to survive age 40), (b) percentage of adults who are illiterate, and (c) the deprivation in a decent living standard in terms of overall economic provisioning (% of people without access to safe water, % of people without access to health services, and % of moderately and severely underweight children under 5). Human Development Report 1997, UNDP, Oxford University Press, UK.
(8) The World Bank. 1997. World Development Report, Forest and Water Resources (Table 10, Annual Deforestation, 1980-90), Oxford University, UK.
(9) Megabiodiverse countries. McNeely, A. 1988. Conserving the World's biological diversity, IUCN.
(10) Countries with high genetic diversity of crop varieties. Reid, W. V. and K. R. Miller. 1989. Keeping options alive: the scientific basis for conserving biodiversity. WRI, USA.
(11) ISRIC/UNEP. 1991. World map of the status of human-induced soil degradation. The Netherlands. Ranking values are (0) Stable, (1) Low, (2) Medium, (3) High, and (4) Very High. Ranking values shown per country cover more than 80% of their extent and are arranged per decreasing importance.
(12) CIA, World facts book. 1997, Washington, D.C.

and Asia. Adaptation, integration, exclusion, permanence and secession have played substantial roles in the reshaping of all the Middle American regions since that moment until today. Despite these transformations, two main social phenomena were maintained in Middle America: (1) the Middle American indigenous and *Mestizo* populations attached to the land, and (2) their agrarian tradition based on the *milpa* cultivation. Both constitute main aspects that allowed the long permanence and enrichment of local knowledge systems about soil and land resources until the eve of the 21st century.

### 10.2.1. Middle America as a complex cultural, economic and geographical mosaic

Contemporary Middle America constitutes a cultural geographic unit where diversity rather than uniformity of peoples, places, cultures and traditions dominate. This complex unity is tied to its geographical continuity and its common history evolved since pre-Columbian times, despite differences from one country to another and from region to region within the same country. The nature of this cultural heterogeneity resides not only in its diverse physical environment and its historical transformations, but also in:

(1) the variety of number, density, and technological level of the pre-Columbian indigenous population and *Mestizo* small-farmers;
(2) the cultural baggage, motives for conquest, and colonial methods and polices of the European groups that entered the area in the early period of settlement;
(3) the role played as the first experimental area of the 'New World' in which tools, plants, animals, and political and economic institutions were introduced for the eventual conquest and settlement of the whole American continent;
(4) the impact of isolation and localism, and
(5) the differentiated effect of modernization and neocolonialism within rural and urban areas (Augelli, 1989).

There are important economic commonalities and differences within the seven countries (Table 10.1). Today, agricultural activities play a major role in the six Central American economies. Commercial plantation crops, such as banana, sugar cane, coffee and citrus fruits constitute main export produces. Meat and wood are important export commodities as well. Agriculture and cattle ranching account for 25% of the GDP and employ around 60% of the labor force in each country. Corporate commercial plantations and family agricultural activities constitute the bases of the Central American national economies. Despite the importance of the agrarian activities in the national economies, more than 50% of the Central American population under extreme poverty lives in rural areas. Agricultural business does not benefit the majority of the Central American framers because of coexistence of two rural economies built up since colonial times: the commercial enterprises owned by transnational corporations and the subsistence small-farming economies (Vellinga, 2000).

Mexican economy sharply contrasts with the Central American economies. Agricultural and cattle ranching activities account for only 5% of the GDP and employ 24% of the Mexican labor force, or some 10 million rural producers, equivalent to 63% of the total population of the six Central American countries. Main agricultural export commodities are coffee, cotton and beef, but the majority of the Mexican rural population still lives from maize-based subsistence agriculture and small-cattle ranching enterprises. More than 10,000 villages and communities, each one with 2,500 or fewer inhabitants, constituted the rural nuclei directly involved in agricultural activities during the 1980s (Toledo and Barrera-Bassols, 1984). Today, more than 30 million people of rural areas are considered to live in extreme poverty; many of them are indigenous families (INI, 1993).

Two major agricultural systems coexist in contemporary Middle America, presenting sharp social, technological and economical contrasts:

(1) the commercial enterprises producing export commodities, such as coffee, banana and other tropical fruits, legumes, flowers and beef, and

(2) the rainfed agricultural production to satisfy basic staple needs, mainly at local and regional levels, relying on *Mestizo* small-farmers and indigenous communities (Conway and Barbier, 1990).

Social polarization has become more acute in the rural sector of these countries due to new external demand of certain agricultural commodities and the increase of production costs of the staple products traditionally consumed by local people. Inequalities in the accessibility to capital, technology, land and markets appear to be major effects of the structural adjustment policies introduced in each country and promoted by the globalization of agricultural commodities since the late 1980s (de Janvry et al., 1989). Rural polarization affected the great majority of farmers who lost their capacity to rely on agrarian activities, while it benefited a few big landowners and transnational enterprises that took advantage of the new commercial circumstances, integrating their activities to the new agricultural demands. Increasing import of staple goods as maize, is another major effect of the social polarization in rural Middle America. A shift of the traditional role of the Middle American countries from net agricultural exporters to net agricultural importers is taking place, thus reducing their precarious food self-sufficiency and deepening the rural crisis that these countries are facing today (UNDEP, 1997).

The great majority of Middle American small-farmers still relies on rainfed agriculture as their main subsistence strategy. Many of them maintain multicropping systems based on maize-beans-squash or the Middle American *milpa*. Maize continues as the major staple food within the seven countries, but the combination of agriculture with off-farm activities is increasingly dominating the rural economies. Immigration to cities, other rural areas and the USA increased drastically since at least 20 years ago, when the subsistence capacity of indigenous and *Mestizo* small-farmers households was severely affected (de Janvry and García-Barrios, 1988). Today, 10% of the indigenous population of Mexico lives in the largest urban areas of the country and the USA. Although there are no official estimates of the indigenous population working in the USA, the economic remitences sent by immigrants (via bank) from the USA to the most indigenous States of the country give an idea of the magnitude of this social phenomenon. These transfers were greater than two billion dollars in 1991 (INI/World Bank, 1998; CONABIO, 1998). Non-Mexican Middle American farmers temporarily immigrate to Mexico and then to the USA in similar proportions.

### 10.2.2. Cultural commonalities and contrasts

Middle American countries share main cultural features, although internally they show contrasting cultural patterns due to differential historical trends. The great majority of contemporary Middle American population is *Mestizo*. *Mestizo* means a person of mixed blood, usually the offspring of European and Amerindian. The term has also acquired a cultural connotation. *Mestizo* culture implies assimilation with the European pattern, as distinguished from the indigenous. A person whose way of life is European may be racially a pure Amerindian but culturally a *Mestizo*. Similarly, a non-Indian person who lives like an indigenous person may be culturally classified as an Indian (Augelli, 1989). More than 60% of the population is considered biologically as *Mestizo*, but an important percentage of this population, especially in rural areas, still maintains cultural elements from the pre-Hispanic times.

Indigenous population constitutes the main cultural minority of Middle America, ranging from 10 to 50% of the total population according to each country, except for El Salvador, which has only 2% of indigenous population (Table 10.1). Indigenous population, considering only language as cultural element, is estimated at 15 million inhabitants or 42% of the total indigenous population in Latin America . Mexico ranks in second place as the Latin American country with the highest indigenous population, while Guatemala ranks in second place as the most indigenous country of Latin America with some 50% of the total population (INI, 1993). A total of 369 languages are spoken in contemporary Middle America, including Spanish and English. These correspond to 30% of all languages spoken in Latin America and 7.5% of the indigenous languages spoken worldwide (Grimes, 1996). Mexico ranks as the 5$^{th}$ country with the highest number of indigenous languages in the world, representing 78% of the languages spoken in Middle America (Chapter Three).

Black-African population constitutes the second cultural minority, corresponding to 5% of the total Middle American population. Africans arrived to this region during the colonial period as slaves and were forced to work in tropical plantations; this is why their current distribution is confined to the tropical lowlands, mainly in Central America. About 9 million Africans arrived to the American continent during the colonial period (Augelli, 1989). In Mexico, Africans mixed with Indians and Europeans since the beginning of the 16th century. This has resluted in a *Mulato* population, meaning a mixed-blood persons, usually of African, Amerindian or European descent.

Contemporary Middle Americans are fervently religious. Pre-Columbian Middle American cosmovision was deeply rooted in a polytheist religion but forcedly converted to the monotheist Catholicism just after the arrival of the first Spanish conquerors and priests. Today, some 90% of the contemporary Middle American population is Catholic. Middle American Catholicism is considered as a popular and syncretic religion. Complex and mixed Catholic and Middle American religious beliefs and rituals coexist until today in the indigenous territories and within ample *Mestizo* sectors, from rural to urban areas. Popular Catholicism merges with pre-Columbian Middle American beliefs and rituals performed during the year, mixing the Catholic and the ancient religious calendars. Often, Catholic images have corresponding ancient Middle American deities as a forced resolution to reach a spiritual agreement between the Christian priests and the 'converted' indigenous population, since the 16th century. Moreover, popular Catholicism built up a strong and parallel social institution, which still regulates local livelihoods besides the constitutional regulation held by the states of Middle American countries. Religious organization is rooted in the cyclic performance of ceremonies (*fiestas*), embodied by customary rules (*usos y costumbres*) and obligations (*sistema de cargos*), intimately linked with local agricultural calendars, thus supporting local social and cultural cohesion. Popular religious organization plays a strong political role among local inhabitants, within localities, and between localities and governmental institutions. This religious organization has been strongly influenced by the liberation theology, supported by many Catholic priests in Latin America and linked with indigenous and other social movements in rural and urban areas (Masferrer, 1991).

### 10.2.3. Common environmental problems in the rural areas

Soil erosion and deforestation constitute major environmental problems in contemporary Middle America. Human-induced soil degradation in rural areas is severe (WRI, 1993). According to the GLASOD study (1991), 63% of the land is degraded and 61% is considered as moderately, severely and extremely degraded. Major types of land degradation are: (1) water erosion (74%); (2) chemical degradation (11%); (3) physical degradation (8%); and (4) wind erosion (7%). Major causes of land degradation are: (1) agriculture (45%); (2) deforestation (22%); (3) overexploitation (13%); and (4) overgrazing (15%) (Oldeman, et al., 1991). Severe water, chemical and physical degradation of the soil is found in Mexico and Central America, where 25% of the vegetated land is moderately or extremely degraded, 10% of it (25.5 million hectares) falling in the serious and extreme categories.

Most of the soil degradation results from water erosion along the mountainous Pacific coast of Central America, but there is also serious physical and chemical deterioration in central and southern Mexico, Honduras and Nicaragua. Most of this degradation was caused by deforestation and overgrazing, some by poor agricultural practices (WRI, 1993). Deforestation rate is 1.8% per year, the second highest in the tropics. Deforestation increased by 50% during the 1981-1990 period, when more than 1.4 million hectares of forest disappeared (FAO, 1991). In Mexico, 700,000 hectares have been deforested, representing 50% of the areas deforested in Middle America during the same period (CONABIO, 1998). Pressure on land increased during the 1990s as a consequence of the deepening of the rural crisis (massive emigration included), leading to more deforestation and land degradation, especially in the areas inhabited by *Mestizo* small-farmers and indigenous peoples. Off-farm activities rapidly increased, including wood-made handicrafts and clandestine logging, for short-term economic revenues by the locals and new commodities to international markets. Natural resources depletion constitutes one of the major consequences of the structural adjustment and deregulation policies in the region (Vellinga, 2000).

Contemporary Middle American countries are experiencing new challenges and opportunities as part of globalization in the Third World. There is a need to reconsider the vast richness of the region, as a way to widen the limited opportunities needed to overcome these enormous challenges. The historical experience of resistance, adaptation and innovation by Middle American rural peoples could create possible opportunities. A recount of the major demographic, technological and cultural trends experienced between the 16th and 20th centuries helps explain how Middle America persisted as a complex cultural unit and why it could overcome the new challenges when taking into account its own history. This recount refers to natural resource management in areas inhabited by historical producers. A full historical review could give a comprehensive recount of how limitations were overcome and why some specific local environmental knowledge systems persisted while others vanished.

## 10.3. Major historical trends that shaped contemporary middle america

### 10.3.1. The 16th century experience

#### (1) The demographic collapse

Two contrasting demographic phenomena took place in Middle America during the last 500 years: (1) a demographic collapse during the second half of the 16th century, and (2) an explosive demographic growth over the last 70 years of the 20th century. This shows the capability of Middle American population to meet challenges and benefit from opportunities. One of the first challenges faced by indigenous peoples of Middle America was the dramatic population reduction after the Spanish conquest.

About forty million people were living in Middle America at the eve of the Spanish conquest (Cook and Borah, 1977; Palerm and Wolf, 1972; Gerhard, 1986; Denevan, 1992a; Whitmore and Turner, 1992), with 35 millions on the present territory of Mexico and 5 millions in the countries of Central America (Augelli, 1989). The greatest demographic collapse in recent humankind history took place in this civilization core during the 60 years following the Spanish conquest. More than 90% of Middle American population died as a consequence of bloody rivalries, illness and slavery imposed by less than 2000 invaders, but most of all because of diseases imported from the 'Old World" (Crosby, 1972, 1976, and 1986; Butzer, 1992a; Barrera-Bassols, 1995). The microbial unification of the world devastated a population that evolved in isolation during more than 40,000 years and did not have the biological capacity to fight against exotic micro-organisms (Crosby, 1991). Less than three million Middle Americans had survived by the end of the 16th century, showing the biological effects of the encounter between the 'New' and the 'Old' worlds (Gerhard, 1991). Several factors are considered to have directly contributed to this demographic phenomenon:

(a) the virulence of the new diseases caused extremely high mortality rates, even in areas where the diseases were considered confined;
(b) smallpox, measles, flu and tuberculosis caused virulent disease outbreaks that mostly affected men and women in the range of 15-40 years, thus diminishing the population in age of biological productivity and causing famine, specially among children and elderly people;
(c) diseases attacked massively and in a compound way, thus increasing their destructive consequences;
(d) fugitives with epidemic diseases infected communities that were living in complete quarantine, producing a fatalistic attitude about inevitable dead and accelerating the pandemic, and
(e) these exotic diseases were more virulent in the tropical areas of Middle America.

Despite the population collapse of the 16th century, Middle Americans maintained a demographic majority during the colonial period, with some regional differences. The Spanish settled mainly in the central highlands of Middle America, which resemble the original landscapes of the colonizers (Gibson, 1967). Black Africans and Moors were forced to live in the tropical lowlands (Butzer, 1992a and b), while Middle Americans were confined to the most isolated areas around the mines, on land granted by the colonizers or in settlements of New Spain. During the 17th and 18th centuries, population of the new Spanish colony maintained stable. After independence from Spain, demographic evolution was more or less the same in all countries until the end of the 19th century. A new spectacular demographic expansion was going to occur during the second half of the 20th century.

## (2) Species introduction

**Rural production and livelihoods** of Middle America experienced substantial polarization during the 16th century. Its integration as a Spanish colony permitted the introduction, adaptation and selective adoption of new natural resources, knowledge and technology, thus reshaping the rural landscape. The incorporation of exotic land-use systems into the indigenous agricultural activities expanded natural resource management in syncretic ways, but land was increasingly granted to Spaniards and indigenous people were resettled (Crosby, 1991; Butzer, 1992a). Indigenous depopulation, dispossession and domination were the engines that benefited colonialists all along the Colonial period and during the first 100 years after the Independence of Middle American countries (Prem, 1992; Chevalier, 1973).

Several significant processes paralleled the demographic collapse of the original population of Middle America during the first phase of the Spanish domination were:

(a) introduction of new biota;
(b) land tenure re-ordering;
(c) agricultural technological adoption and adaptation, and
(d) land-use changes.

These processes drastically transformed landscapes and livelihoods, reflecting the union of cultures and reconfiguring the history of this civilization core by hybridization (Whitmore and Turner, 1992). Moreover, these processes also opened the way for biological, technological, economic and cultural transfers on a large scale between the two worlds, thus increasingly integrating the world system.

There is evidence that the pre-Columbian Middle American landscape of the early 16th century was a humanized landscape almost everywhere, as discussed in Chapter Seven. Populations were large; forest composition had been modified, grasslands created, wildlife disrupted; and erosion was severe in places (Denevan, 1992b; Whitmore and Turner, 1992 and 2001; Butzer, 1992b). Pre-Columbian Middle Americans were agriculturalists who developed technologies and management practices to crop a wide range of ecological conditions, giving rise of a multiplicity of cultivated landscapes (Whitmore and Turner, 2001). Specialization of agriculture was emphasized by the absence of big mammals to domesticate and by the endemic coevolution of people and plants in ecological and cultural isolation due to the geography of the American continent. The introduction of Old World biota and technologies, part of what Crosby (1972) calls the Columbian Exchange, had great impact on the landscape because of the new land-uses associated with them and the expansion of these uses into areas extensively utilized by Middle Americans. As a result, few or any cultivated lands remained untouched during the first century after the conquest (Butzer, 1992a).

Two main processes affecting land-use systems took place during the first 100 years of this historical period. On the one hand, the conquerors reapportionated land and labor under conditions of rapid depopulation, reconstituted agriculture and adapted cattle ranching through the introduction of European technology and exotic biota. On the other, the conquered people retained where possible and appropriated, their knowledge, crops, livestock and cropping techniques. These forces were, however, borrowed extensively by both conquerors and conquered "…if differentially, from one another, and the reconfigured landscapes that resulted were not so much one culture's cultivated landscape replacing another's but their union on "hybrid" landscapes" as Whitmore and Turner (1992: p. 416) point out.

Pre-Columbian Middle American peoples and landscapes were dramatically impacted by the introduction of range livestock, previously unknown (Simpson, 1952; Butzer, 1992b; Barrera-Bassols, 1995). The introduction of range livestock (cattle, horse, mule, donkey, sheep and goat) to the Gulf Coast of Middle America had several consequences:

(a) an explosive increase of the ungulates during the first century after arrival, in contrast to the demographic collapse of Middle Americans (Denevan, 1992b; Barrera-Bassols, 1995);
(b) the dissemination of smallpox, measles, mumps, diphtheria, and influenza bacteria by domestic animals and Europeans, causing massive devastation of the original inhabitants. Without demographic collapse, it seems improbable that the Spanish would have been able to control the populous Middle America (Butzer, 1992a);
(c) the irruption of cattle into the Middle American *milpa*, provoking extensive land-use changes and social conflicts for land, food and water resources (Butzer and Butzer, 1993), and
(d) the inclusion of meat and milk into the Middle American diet and the integration of livestock into the agricultural systems, providing fertilizer and plow force (Butzer, 1992b; Jordan, 1993; Barrera-Bassols, 1995).

The introduction of a small number of cattle, sheep and goat to continental America, three years after the arrival of the Spanish to the coast of the Gulf of Mexico, initiated a rapid growth of ungulates that took only one hundred years to reach its population peak. By 1620, more than 1.5 million cattle and 8 million sheep and goat were grazing over 150,000 square kilometers of central New Spain (Simpson, 1952; Butzer, 1993; Barrera-Bassols, 1995). The same occurred in the southern portion of Middle America (Jordan, 1993). Livestock increase and spatial expansion were because of the biological capacity of the ungulates to adapt to varied climatic conditions, the vast amount of food supply over depopulated rural landscapes, and the lack of competition with other big mammals.

Transhumance cattle grazing, together with some 90% population loss within a century, led to a widespread abandonment of agricultural landscapes. Range livestock became the most important agrarian activity, an opportunistic economic enterprise and a way to alienate indigenous land holdings (Chevalier, 1973). The new colonists acquired immense tracks of land through cattle ranching, especially in the tropical lowlands where a medieval type of agrarian enterprise gained importance, that is the *hacienda ganadera* (Simpson, 1952; Cook and Borah, 1979; Barrera-Bassols, 1995). Sheep and goat raising was more important in the mountains; as it was more integrated to the indigenous livelihoods, it went beyond the former limits of the agricultural lands as a transhumance activity (Melville, 1994).

The arrival of range livestock to Middle America had other consequences on landscapes and rural livelihoods until today. The introduction of fodder species, mainly from Africa, alienated landscape ecologies when Africanizing the autochthonous biota, sometimes occurring as plagues (Rzedowsky and Calderón, 1990). Deforestation and soil erosion expanded, mainly in mountainous landscapes due to sheep and goat overgrazing of winter pastures (Cook, 1949; Melville, 1994). Social conflicts for territory, land and water resources, and food supply, developed during the following three hundred years between the diminished Middle American agriculturalists and the new rural landlords (*hacendados*) (Chevalier, 1973; Romero-Frizzi, 1990; Rodríguez and Scharrer, 1990; von Wobeser, 1990).

Middle American agricultural systems benefited from the introduction of exotic plants (Crosby, 1986, 1991 and 1994a). The autochthonous rural population, well experienced in plant domestication, rapidly but selectively assimilated the integration of Mediterranean, African and Asiatic plants. Fruit trees, plantation crops, such as sugar cane, coffee and banana, winter crops, such as wheat, oats and barley, rice, broad beans, a number of condiments including onion and garlic, and vegetables were rapidly adapted to the different agro-ecological zones of Middle America. Some of them were integrated to the *milpa* system or adopted for monocropping. Fruit trees were integrated into the Middle American homegarden, enriching its multiple-use strategy. Commercial plantations were expanded, causing important land-use changes, for inter-Atlantic commerce.

Wheat was the most important and well-adapted crop introduced into the rainfed *milpa* system. Wheat and other winter crops enriched the *milpa* system, allowing agricultural activities over the whole climatic cycle and intensifying agricultural land-uses (Whitmore and Turner, 1992). Wheat was also produced as large-scale monocropping in the *haciendas* of the central and northern semi-arid flatlands of New Spain, near the mines and the new cities that demanded great amounts of food supply (Romero-Frizzi, 1990). The introduction of poultry (pigs, Castillian chicken, goat and sheep) in household backyards and homegardens provided milk, cheese, eggs and meat as well as organic fertilizers that benefited the new horticultural systems (Butzer, 1992a).

Maize kept its first place of importance during the 400 years after the Spanish conquest, despite the introduction of exotic crops and their rapid adaptation to new agro-ecological conditions. At the end of the Colonial period, maize was the basic staple food for 80% of the population (Romero-Frizzi, 1990). Nevertheless, maize production was confined to marginal agricultural lands, and cyclic droughts, plagues and early winter hazards constantly decimated its production (Florescano, 1976). Also, land-use changes occurred during the first century of the colonial period and reordered labor allocation, affecting mostly the maize agricultural lands (Whitmore and Turner, 1992).

### (3) Technological adoption

The arrival of the new biota from the Old World was accompanied with new technology and agronomic knowledge. The introduction of the plow and draft animals of the *milpa* system was revolutionary, intensifying production and increasing productivity. New irrigation systems were constructed in the semi-arid bottomlands, allowing winter (dry season) cultivation, especially for wheat cropping. In some cases, the reworking of Middle American irrigation systems permitted efficient agricultural production, while the application of European irrigation technology was extremely efficient in other cases. New technology helped overcome water scarcity or desiccating water bodies, as is the case of the Tenochtitlan Lake system. Treadmills, gristmills and ovens simplified rural activities, but the introduction of the wheel and draft animals was the most important technological advance, reducing distances and labor force for transportation.

The Iberian land classification according to land productivity, mentioned in several colonial documents, was apparently less sophisticated than the Nahua soil and land classification system (Williams and Ortíz-Solorio, 1981). Three land classes were recognized for agricultural purposes: The first and the most productive land class was suitable for trans-Atlantic commercial agriculture (*Tierra de pan de llevar*); the second most productive agricultural land class was used for internal commercial production (*Tierra de pan de comer*), the third and less productive land class was used for subsistence production (*Tierra de pan de sembrar*) (Romero-Frizzi, 1990).

### (4) Land granting

Land granting (*Merced*) contributed to shaping new Colonial landscape (Prem, 1992). Land granting favoured prominent citizens, who had rendered service to the conquest, the new Colonial government and Spain. Officials, officers, religious institutions and the economic elite received land, thus rapidly accumulating large holdings (Prem, 1992). Spanish land granting, as a policy of prestige, led to absentee land ownership and inefficient management of *haciendas*. Meanwhile, the indigenous resettlement (*congregación*), consisting of the regrouping of surviving families from several villages into new urban nuclei, led to a significant abandonment of indigenous lands. Moreover, the steady migration of Indians to mines, new cities and Spanish *haciendas* reduced the work force of traditional communities (Simpson, 1952).

Depopulation, resettlement and emigration of Middle American populations accelerated the expansion of Spanish land holdings and the consolidation of large estates. A dual rural economy emerged as the product of social polarization. Spanish *hacienda* became a market-oriented production system aimed to fulfil the new Spanish towns demands, whilst the indigenous communities reorganized the subsistence agricultural systems aiming to fulfil their own needs.

Tropical plantations, historically characterized by agglomerated, village-type settlements of workers near the large house of the absentee landowner, undertook a different economic role. Plantation production was and still is almost exclusively oriented towards cash-cropping export. Usually a monocropping system, plantation imported more capital, technology and managerial skills, giving rise to absentee ownership and the export of profits. While the utilization of the land is more efficient than on the *hacienda*, the plantation holds considerable idle land in reserve for expansion of the production, crop rotation, grazing, and other uses. Plantation requires seasonal labor, which historically was imported from Africa. Authored primarily by North-Europeans and later by Anglo-Americans (with the exception of the sugar cane plantations), plantations were later owned by transnational corporations, mainly in Central America, and still constitute important agribusiness. Similar to the *hacienda*, tropical plantation expansion benefited from indigenous depopulation, dispossession and domination, and still does (Augelli, 1989).

#### (5) Land-use changes

Main land-use changes during this historical period took place in several agroecological zones of Middle America:

(a) the tropical lowlands and hilly lands (*Tierra caliente*) were virtually abandoned, allowing major regeneration of the tropical forests. The few remaining indigenous populations, armed with new steel-cutting tools, moved towards laborsaving swidden cultivation. Spanish colonialists were granted enormous haciendas, specializing in cattle ranching, and tropical plantations of sugar cane, cotton or sisal;

(b) the temperate highlands (*Tierra templada*) where largely abandoned, leading to a disproportional redistribution of major tracks of land to Spanish settlers. Wheat cultivation and livestock production developed on large *haciendas* drawing on indigenous labor, and

(c) the semi-arid lands (*Tierra semi-arida*), scarcely populated before the conquest, were distributed to Spanish settlers, who acquired enormous *haciendas* specializing in irrigated wheat production, and transhumant cattle ranching and sheep grazing (Simpson, 1952; Chevalier, 1973; Wolf, 1982; Rojas, 1988 and 1990a; Rojas and Sanders, 1985; Butzer, 1992a and b; Challenger, 1998).

The colonial rural landscapes of Middle America were a product of agricultural systems lost, added, modified through exchange, and redistributed across the terrain (Whitmore and Turner, 1992 and 2001). These contrasted landscapes did not experience great modifications until the mid-19$^{th}$ century and some of them persisted as palimpsests until the eve of the 20$^{th}$ century. The appropriation of immense land tracks by absentee *hacendados* and plantation owners, the substantial reduction of *Mestizo* ranches and indigenous territories, and the use of indigenous people as forced labor on the *haciendas*, constitute the main social engines that create rebellions and structured agrarian movements at the end of the 19$^{th}$ century.

### 10.3.2. The 20$^{th}$ century experience

#### (1) The explosive demographic growth trend

The recovery to pre-Columbian Middle American population size did not occur until the 1930s and, from that moment on, the region experienced an explosive demographic growth, reconfiguring landscapes and livelihoods as never before in its long history. On the eve of the 20$^{th}$ century, the population size of Middle America was 3.5 times the one estimated at the beginning of the 16$^{th}$ century. Today, the mean annual rate of natural population increase for all countries is 1.7% (Table 10.1), doubling the initial population every 25 years during the last 75 years. In spite of the general population growth, the size of the indigenous population at the moment of the Spanish conquest was not recovered. National census during the 1990s accounted for 15 million indigenous inhabitants, representing 12% of the total population and only 38% of the autochthonous population estimated at the beginning of the 16th century (Psacharopoulos and Patrinos, 1994). Unofficial estimates give a proportion of 30 to 40% of total population of contemporary Middle America (Stavenhagen, 1992), but the current dimension of the indigenous population is yet unknown.

Although the rate of population increase is slowing down, it is still too high for the area's limited resources and economic development, constituting one of its major challenges for the near future. Several causes induced demographic growth, with substantial differences between and within countries (Augelli, 1989):

(a) agrarian movements struggling for land access gave the opportunity to the original owners to recover their ancient territories and rural lands, now possessed as social properties or private small landholdings;
(b) agrarian reforms encouraged agricultural production for export in areas with high land productivity and established subsidiary policies for small farmers to ensure staple good production for national food security needs, in areas with low and medium land productivity;
(c) the increase of members per rural household unit helped maintain non-paid labor force to overcome the lack of capital accessibility under production pressure, especially in the subsistence agricultural economies. The reduction of child mortality and the expansion of life expectancy helped endure this process, and
(d) economic development via industrialization was subsidized by rural production, promoting mass migration from rural to urban areas and causing Middle America to be one of the most rapidly urbanizing regions of the world. The subsequent socio-economic mobility widened the urban middle classes at the expense of reducing the production efficiency of the rural classes.

### (2) Land granting

During the 20th century, agrarian movements increased in all Middle American countries, although the struggle for land took diverse patterns and trends in each country. Socio-political differences had contrasting effects as a consequence of particular tensions between internal forces and external interests under the new integration of the world system after the First World War. In Mexico, for example, the agrarian movement in the first decades of the 20th century evolved as a national revolution that, at the end, gave a renewed possibility to rural populations to gradually recover some 50% of the Mexican territory, now possessed under social property regimes. Indigenous rebellions or national agrarian movements in the six Central American countries persisted until the 1980–1990s, when social movements gained momentum and partially succeeded in their struggle for land. That was the case of indigenous upheavals in Guatemala and the rural-urban movements in Nicaragua, Honduras and El Salvador (Psacharopoulos and Patrinos, 1994; Acosta, 1999; Plant, 1999). In any case, social instability has been a major factor in modern Middle America and will be in the near future.

### (3) Rural modernization

Rural Middle American landscapes and livelihoods were substantially modified during this period, under the social circumstances discussed above. These modifications resulted from several important processes known as rural modernization. Modern agricultural technologies, based on high external inputs according to the Green Revolution, were introduced after the 1950s, promoting on increase of land productivity until the 1970s.

Agricultural systems based on high external inputs were established in areas where mechanization was possible. The tropical lowlands and the flat temperate and semi-arid highlands were privileged because of their agro-ecological characteristics and the extensive tracks of land owned as private property in many cases. Irrigation, chemical fertilizers, plaguicides, pesticides, herbicides and mechanization heavily technified tropical plantations and seasonal monocropping (WRI, 1990). High-yielding varieties were introduced and staple crops were substituted for commercial cash crops in vast areas of high land productivity (Challenger, 1998).

Increased agricultural productivity allowed export of produces, benefiting national economies. Banana, sugar cane and coffee plantations dominate the tropical lands, while cereals and vegetables cover the temperate and semi-arid highlands (Augelli, 1989).

Rainfed agriculture partially benefited from the Green Revolution and was subsidized by national governments until the 1980s. The adoption of high-yielding varieties and the use of chemical fertilizers, plaguicides, pesticides and herbicides, with partial mechanization of the agricultural activities, led to an important increase in land productivity for staple crop farming. In the tropical and temperate mountains and hilly landscapes, where the majority of *Mestizo* small farmers and indigenous communities established *milpa* production much before the colonial period, agriculture was modernized thanks to these new technological advances. Social property systems as the indigenous community and *ejido*, dominate in these landscapes with an average of 5 hectares per household (Appendini, 1994). Increase of land productivity, integration of subsidized markets and prices guaranteed by the state led to the substitution of staple crop imports and secured national food self-sufficiency until the 1970s (Pretty, 1995). The majority of Mexican farmers exposed to rural modernization rapidly adapted their farming practices, hybridizing their agricultural systems like in the 16th century.

### (4) Land-use changes

Land-use changes for commercial or subsistence purposes reshaped the agrarian mosaic of Middle America, without real benefits for the rural majority of the region. Several farming systems emerged during the 20th century as a consequence of modern development, although most of them maintain the same land-use since the colonial period. In fact, rural modernization in Middle America was addressed to increase the productivity of pre-existing farming systems, resulting in hybrid techno-landscapes.

### (a) Cattle ranching

Cattle ranching in the tropical lowlands (*Tierra caliente*) and in the semi-arid highlands (*Tierra semi-arida*) grew considerably during this period, resembling to the growth of ungulates during the first 100 years after the conquest (Barrera-Bassols, 1995). The opening of great extensions of pastureland, via colonization-deforestation, to sustain livestock with low productivity levels in the tropical lowlands was promoted by the 'hamburger connection' (Myers, 1980; Rifkin, 1992). Increased meat demand from the USA and the urban middle classes led to the conversion of complex tropical ecosystems into grasslands. A population of 44 million cattle was registered during the 1980s, corresponding to 50% of the Middle American population at that moment. Cattle annual growth rates were similar to human population growth rates during that decade.

The introduction of zebu (*Bos indicus*), a cattle adapted to tropical conditions, together with high-yielding grass varieties and artificial insemination, modernized cattle ranching. Low production costs, increased meat demand for export and internal consumption, and subsidies for areas not densely populated were the main factors promoting this land-use specialization. A similar process took place in the semi-arid and scarcely populated highlands of Mexico, where cattle ranching grew on the ex-*hacienda* estates.

### (b) Tropical plantations

Plantations on tropical land (*Tierra caliente*) were substantially modified by technological innovation. The adoption of high-yielding varieties, the massive use of chemicals to improve land productivity and reduce pests, diseases and plagues, the new irrigation schemes and the use of cheap labor force modernized the colonial-type plantations. Banana, coffee, sugar cane and citrus are the most important export commodities.

Multinational corporations, especially in the Central American countries, popularly named as the 'Banana Republics' (*Repúblicas bananeras*), now own extensive tropical plantations. International demand for tropical commodities permits maintaining social production structures similar to the ones originated during the 16th century. Coffee plantations in Mexico are different from the extensive commercial plantations in Central America. In the mountains of central and southern Mexico, shaded coffee was incorporated into traditional agriculture by indigenous communities and *Mestizo* small farmers, which produced some 75% of the national production during the 1990s (Challenger, 1998; Moguel and Toledo, 1999). Approximately 200,000 small farmers, possessing traditional coffee plots with an average size of less than 5 hectares, produce the essential of this export commodity. More than 1.5 million people are economically involved in traditional coffee production. Mexico ranks fourth in terms of production volume and first for organic coffee export, accounting for one-fifth of the total volume produced worldwide (Moguel and Toledo, 1999).

### (c) Commercial monocropping of cereals for export

Commercial cereals are produced in the temperate and semi-arid highlands (*Tierra templada y Tierra semi-árida*) and in some areas of the tropical lowlands. Highly technified, these agricultural systems were the major target of the Green Revolution. High-yielding varieties (HYV) of maize, wheat, sorghum, rice, cotton and oleaginous crops were introduced after extensive research done at CIMMYT (International Maize and Wheat Improvement Centre) in Mexico. Other international institutions, such as IRRI (International Rice Research Institution), in the Philippines and CIAT (International Centre of Tropical Agriculture) in Colombia, forming part of IARC (International Agricultural Research Centres), played a central role as well (Mooney, 1983).

Genetic plant research conducted by these institutions was based on the improvement of traditional varieties found in the major centers of plant domestication of the world. Maize and wheat HYVs were hybridized from the cultural heritage of the small farmers of Middle America, producing a great transformation of cereal production in the world (Wellhausen, 1976; Hewitt de Alcántara, 1978, 1992; Wolf, 1987; Conway and Barbier, 1990; Barkin, 1990). The construction of irrigation systems on highly productive flat lands, the adoption of the Green Revolution technological package, and the integration of international and national markets contributed to increase agricultural production from the 1950s until the 1970s (Barkin, 1990; Challenger, 1998). These new agricultural systems were introduced in areas of social and private property regimes, but the latter dominated and rapidly absorbed the former ones via land granting. Ninety percent of the irrigated lands in Middle America belong to this type of agriculture. Many of them are now owned by multinational corporations, which produce cereals as fodder for the cattle ranch business, cotton for the textile industry and other commodities for industrial purposes. Thus the staple crop production for human consumption was substantially reduced.

### (d) Rainfed maize agricultural systems

Rainfed agriculture, practiced by *Mestizo* small farmers and indigenous communities, was also strongly influenced by rural modernization. Partial adoption of the Green Revolution's technological package led to a rapid land productivity increase during the 1950-1970s, but this adoption affected crop diversity of the *milpa* because of the massive use of herbicides and the introduction of HYV varieties. Historically, these agricultural systems were the core of a subsistence strategy based on the multiple use of crop diversity, well adapted to the local agroecological heterogeneity. The reduction in complexity of these systems primarily affected the household diet.

The agricultural hybridization of the traditional *milpa* had probably more negative impacts than the ones occurred during the 16th century, due to the adoption of techniques not suitable for cultivating marginal lands. The increasing dependence on external inputs caused economic and socio-cultural changes at various levels. Production efficiency was reduced, undercapitalizing local economies and generating severe environmental problems under population pressure. Nonetheless, these agricultural systems were the engine that accelerated development via industrialization-urbanization in Middle America until the 1970s. Initial efficiency was based on low production costs thanks to non-paid labor force, the producers' capacity of innovation, large internal demand, subsidy policies and prices guaranteed by the state.

Rainfed agriculture for subsistence is practiced in a scattered mosaic on all rural landscapes of Middle America and presents a variety of agro-ecological adaptations and technological levels, most often on low productivity lands. A diversity of swidden agricultural systems occurs on tropical lowlands and hilly lands, but rainfed agriculture is mainly practiced in the sloping temperate and semi-arid highlands. All of them rely on the integration of *milpa* production, monocropping and small-scale cattle ranching.

### 10.3.3. Rural crisis in modern Middle America: the case of Mexico

Two contrasting rural Middle Americas evolved during the second half of the 20th century as a consequence of differential modernization: (1) the highly technified and capitalized commercial agriculture, including commercial cattle ranching with various technological levels, and (2) the impoverished and undercapitalized rainfed agriculture. The contrast became sharper by the end of the 1970s, when Green Revolution slowed down, national food self-sufficiency got lost and staple crop import increased under high rates of population growth. From the early 1980s until today, this contrastive agricultural model was severely affected by the economic crisis with external debt and increasing social instability in Middle America.

Today, globalization affects the vast majority of rural and urban populations of Middle America (Castells, 1996a). The decrease of labor opportunities and the reduction of agricultural activities, especially those supporting the regional food self-sufficiency, are worsening the current social polarization. All that goes together with rapid environmental degradation, mass migration, social insecurity, inter-cultural tensions, political instability and the offspring of new agrarian movements led by indigenous peoples in defense of multiculturality, territory, language and self-determination (Assies, 1999). The case of Mexico illustrates these new circumstances and reflects the challenges and opportunities that Middle America is facing today.

#### (1) Deterioration and loss of natural resources

Yearly, 1-1.5 million hectares of forest are cleared, leading to a loss of 95% of the tropical forests by 1991 (Challenger, 1998). Mexico holds the third highest annual rate of deforestation in Latin America and the highest in Middle America. Currently, temperate forests are decreasing by 1% per year and tropical forests by 2.5% per year (Mas and Vega, 1996). Since 1985, deforestation has increased by about 100,000 hectares per year. Seventy five percent of the Mexican forest is on communal lands (*ejidos*), belonging in particular to indigenous communities. Between 1980 and 1990, deforestation on communal lands ranged from 24% to 31%, with highest rates in the communities of lowest income (de Janvry et al., 1997). Land overexploitation and inadequate soil management have caused erosion in more than 85% of the national territory (UNEP, 1997). About 60% of the total Mexican land is under severe erosion (CONAZA, 1993) and another 16% is completely denuded (ICSA, 1996). Approximately 30% of the irrigated land is affected by salinization. Main land degradation processes are the loss of topsoil through wind and water erosion, biological erosion, nutrient loss, salinization and sodification (UNEP, 1997). Associated with the former, 50% of the groundwater is overexploited, and rivers and lakes are polluted by industrial and urban uses (Barry, 1992).

Global climate change by drying and warming could reduce crop yields up to 1/3 (Liverman and O'Brien, 1991). Models indicate that, with Mexican customs of burning wood for fuel and slash-and-burn agriculture, there may be a doubling of $CO^2$ emissions in the country by year 2025 and an increase in the overall temperature by 2 to 5 °C (Liverman, 1992; Liverman and O'Brien, 1991). Drylands at higher elevations may become significantly warmer and more arid. Degraded drylands may themselves perpetuate the greenhouse effect, as they are important stores of carbon.

#### (2) Agricultural crisis

Development based on industrialization and urban growth at the expense of agricultural production gave shape to two rural Mexico's. The privileged one specializes in cattle ranching and large-scale production of export goods with high external inputs. Its modernization is based on technological intensification, transnationalization of production and hyper-concentration of land and capital. In contrast, the peasant and subordinated rural Mexico produces rainfed maize with low outputs and poor credit. This process has led to the atomization of the production units and increasing poverty among a large segment of the small-scale farmers (Gordillo, 1993; Pretty, 1995).

More than 50% of the arable land is cultivated with maize. At the beginning of the 1990s, there were 2.4 million maize producers, representing 78% of the Mexican farmers and 12.5 million family members (SARH, 1991). Seventy percent of the farmers and some 15 million family members control 50% of the arable land and 50% of the irrigated areas, forming a rural sector organized in 28,056 *ejidos* and indigenous communities. This sector produces 73% of the national maize output, but only 9% of this sector holds farmlands larger than 20 ha, while 64% holds farmlands of less than 5 ha. On average, communal farmers cultivate 4 ha of maize, where they obtain yields of 1.7 ton/ha under rainfed conditions and 2.1 ton/ha under irrigation (Barkin, 1998).

The national agrarian crisis is reflected by a decreasing contribution of the primary production sector to the Gross National Product: 16% in 1970, 7% in 1990 and 5% in 1999. During the period 1970-1999, the country has changed from exporter to net importer of the main basic goods, including maize and milk (Mestries, 1991; Gordillo, 1993; Barkin, 1998). From 1993 to 1999, maize imports from USA increased by 773% and import costs increased from 67 to 600 million US dollars. During the 1984-89 period, the real value of the maize production declined by some 30% and the average real agricultural wages decreased by about 25% (McKinley and Alarcón, 1995). Therefore, at the beginning of the 1990s, rural wageworkers and campesinos were among the poorest people in Mexico. From 1984 to 1999, the proportion of poor people increased from 20 to 40%. Seventy percent of the poor were in rural areas, especially in the states where indigenous population concentrates.

### (3) Economic and social crisis

The social inequality caused in rural Mexico by the development model implemented during the last 20 years has affected large masses of small-scale farmers and indigenous communities, generating rural unemployment, internal urban immigration and international emigration, mainly to the United States of America. Mexico is currently the world's largest emigration country and contributes to nearly half of the total immigration to the USA (Cross and Sando, 1996), which receives more immigrants than any other country.

While the economic crisis deepened in the previous decade due to the enforcement of the prevailing economic model, the growth of the national and international debt led to a substantial reduction in the purchasing power of important urban and rural sectors. As a consequence, people living in conditions of extreme poverty increased to more than 30% of the national population (CONAPO, 1993; Tello, 1993). By the end of the 1990s, 24 million people contributed to only 6% of the GNP. In contrast, 10 Mexican families controlled 60% of the GNP. Economic polarization caused 15 million people to live below the subsistence level, with small-scale farmers and indigenous villages being the most severely affected.

### (4) Cultural crisis in a country with strong social and economic contrasts

The erosion of the relations in the Mexican inter-ethnic mosaic, based on a rural population historically subordinated to the urban and hegemonic *Mestizo* society, became acute due to the widening of the cultural value differences. The urban society modernizes through the marginalization of impoverished peasants, urban and rural indigenous masses and city workers. Respect for cultural differences has diminished in the past 20 years due to ecocide, racism and ethnocide as daily practices of the dominating socio-cultural sector. This sector intends to consolidate the hegemony of its own cultural perceptions, attitudes and beliefs (Bonfil, 1991c and 1993). As a response, the upheaval of indigenous movements became critical since 1994, when an armed rebellion declared war to the Mexican government in the southern state of Chiapas. The neo-Zapatista movement opposes the neoliberal globalization and searches for the constitution of a multicultural nation based on the respect of cultural differences, the establishment of autonomy rights for the indigenous territories and the rights for self-determination of indigenous peoples. These new identitarian projects propose a drastic reform of the Mexican State and challenge the political stability of the country in the near future (Castells, 1996a; Assies, 1999; Franco, 1999).

Linked with these processes, which have determined present national dynamics, are the legal and economic changes introduced by the trade agreements between Mexico, USA and Canada (NAFTA, 1993). Such changes are constitutional modifications to the agrarian and natural resources exploitation laws, which could result in new guidelines for the management of the agricultural sector and nature. This is carried out with high cultural and social (Bonfil, 1993), economic (Calva, 1991) and ecological (Toledo, 1992a, 2000) costs in both rural areas and ethnic territories (de Janvry, et al., 1995).

### 10.4. Conclusion

This chapter analyzed current rural realities of Middle America after 500 years of integration into the world-system, as an introduction to the contemporary Middle American ethnopedological discussion. Its objective is threefold: it contextualizes main commonalities and contrasts of rural landscapes and livelihoods; gives an overview of major historical trends that constantly reshaped the agrarian activities; and discusses the rural imbalances in today's Middle America, with emphasis of the Mexican case. It also places the ecological, social and economic complexity of this cultural region, emphasizing two historical periods that drastically transformed landscapes, peoples and cultures, that is the 16th and 20th centuries.

Without an historical review, it would not possible to fully understand why and how the vast majority of Middle American farmers still rely on maize cropping, base their production strategies on combining ancient and modern technologies, seeds and domestic animals, and possess endured environmental knowledge systems. Also importance is given to how the historical rural producers of this region overcame social and economic challenges and benefited from opportunities. Major cultural legacies of the peoples of Middle America include:

(1) rural landscape hybridization by exchanging, adopting and innovating biota, knowledge and technology;
(2) cultural syncretism as a way to maintain endured worldviews; and
(3) *Mestizaje* as a biological/cultural identity construct.

The contrasting histories of the 16th and 20th centuries reveal that indigenous peoples and *Mestizo* small-farmers were never isolated or static after the conquest period, but always adapting and selectively integrating knowledge, technology and biota. These centuries witnessed contrasting demographic trends, the introduction of new species or HYVs, and the implementation of new technological and knowledge systems. Associated with these, land granting, land-use changes, and the political and economic role assigned to the region into the world-system were the engines that constantly hybridized the rural landscapes and livelihoods of local populations. In short, the comparison highlights three main historical contrasts from demographic, economic and technological perspectives.

Contemporary rural Middle America faces new challenges and opportunities due to globalization. A severe economic and social crisis, together with environmental problems, is drastically reducing the opportunities for the vast majority of the rural populations of the region, which suffer poverty, land degradation and emigration. Still, many remain attached to the land, as the core of their agrarian traditions, and continue basing their local economies on maize production. Local environmental knowledge systems survived by hybridization. Syncretism was, in many cases, an efficient strategy to overcome historical challenges.

There are two potential pathways for the future of these rural strategies now that the pendulum has swung again in the direction of embracing local environmental knowledge. The pessimistic one assumes that globalization will destroy local knowledge. The other one, constituting the core of this thesis, acknowledges the dynamism of local knowledge and the blended nature it often takes, and uses it as a syncretic springboard for the development and maintenance of sustainable land-use systems (WinklerPrins and Barrera-Bassols, 2003). Effort should be especially addressed to the areas and peoples in the most fragile landscapes where rural modernization failed. Critical to this effort are the recognition and analysis of contemporary Middle American ethnopedologies, as soil and land resources became scarce and local soil knowledge systems are threatened to disappear. Chapters Eleven, Twelve and Thirteen describe and discuss some of the most important ethnopedological findings of today's Middle America and reveal their potentialities under the ever changing and unpredictable circumstances of the region, but acknowledging the historical experiences that converted challenges into opportunities.

# CHAPTER ELEVEN

## CONTEMPORARY MIDDLE AMERICAN ETHNOPEDOLOGIES

### 11.1. INTRODUCTION

Chapter Eleven analyzes 13 selected ethnopedological case studies from Mexico and Guatemala. This account covers nine examples of contemporary indigenous soil and land knowledge systems and four examples of Mestizo small-farmers' ethnopedologies. The local ethnopedologies are situated in five agro-ecological zones of Mexico, Belize and Guatemala. They show the richness and potentialities of current perception, knowledge and management systems of soil and land resources under different environmental and cultural settings of today's rural Middle America. Although the discussion is limited to the case studies, the literature analysis includes 55 documents that are directly related to the topic or give valuable ethnopedological information; thus, in most cases, local data are provided by several authors or documents (Barrera-Bassols and Zinck, 1998, 2000, 2003a). The regional account is limited to Mexico and Guatemala due to the accessibility of literature sources difficult to acquire, but ethnopedological information is also available for Costa Rica (Box, 1991; Gonzalez, 1995), Honduras (Ericksen, 1998) and Nicaragua (Nietschmann, 1973). Nonetheless, Mexico accounts for more than 90% of the contemporary ethnopedological studies analyzed and has the highest number of studies in the world (Barrera-Bassols and Zinck, 2003a).

The type of information gathered from the literature sources biases the analysis of local ethnopedologies, which reflect different methodologies, research interests and theoretical assumptions, but also allows a critical analysis of the information and a fertile discussion about the limits and potentialities of this research topic. The analysis will highlight the ethnopedological similarities and contrasts among the case studies and draw main ethnopedological research trends in Middle America during the 20th century.

The ethnopedological information is organized by agro-ecological zone as the main entrance and by ethnic group as a second entrance. The selected case studies cover relevant ethnopedological topics although at different levels of depth. Local soil classification systems, soil fertility management, local knowledge of soil-relief and soil–plant relationships, soil and water conservation strategies, agricultural management of soils, technological adoptions for agricultural soils management, local land-use systems and land evaluation systems, are well covered topics. Local management of soil variability, land management per agro-ecological zone, and the ecological succession management under shifting cultivation as a strategy for soil fertility replenishment are also addressed. Local perceptions of soil and land as symbolic means and as sacred representations are frequently neglected or ignored, reflecting the researchers' lack of awareness about the importance of cultural values and ethics attached to the land, that are venerated by contemporary Middle American farmers.

Section 11.2 presents the agro-ecological zoning of Mexico, Belize and Guatemala and the distribution of indigenous populations and ethnic groups in Mexico. Section 11.3 analyzes four ethnopedological studies from the humid tropical lowlands of Mexico and gives an account of three ethnopedological studies from the humid tropical highlands of Mexico. Section 11.4 is based on two ethnopedological studies from the sub-humid tropical lands of Mexico. Section 11.5 analyzes three ethnopedological findings from the sub-humid temperate highlands of Mexico and Guatemala. Section 11.6 reviews two case studies from the semi-arid temperate highlands of Mexico.

## 11.2. Agroecological zoning and indigenous population distribution

### 11.2.1. Agro-ecological zoning

Mexico and Guatemala present agro-ecological complexity (Chapters Three and Seven; see also Nations et al., 1988; Toledo et al., 1989; Toledo and Ordóñez, 1993; Ramamoorthy et al., 1993; Harcourt et al., 1996; Challenger, 1998). Five broad agro-ecological zones are well defined by climate, vegetation, relief, altitude and latitude (Figure 11.1 and table 11.1). These agro-ecological zones present diverse land-use systems, as in the case of Mexico (see also table 7. 3 in chapter Seven), reflecting the historical management of natural resources hybridized since pre-Hispanic times until today. These agro-ecological zones are: (1) humid tropical lands, (2) humid temperate highlands, (3) sub-humid tropical lands, (4) sub-humid temperate highlands, and (5) arid and semi-arid lands.

### (1) Humid tropical lands

This zone is mainly located in the south and southeast Mexico, Belize, in the Atlantic and Pacific coastal lands, and the eastern and western slopes of the Guatemala Highlands (Figure 11.1 and table 11.1). The humid tropical lands constitute the highest thermal agro-ecological zone of Middle America, with very warm and warm temperature regimes and high rainfall, being one of the most humid zones of Middle America. Evergreen and semi-evergreen tropical forests and savanna are the main vegetation types. This zone can be divided into two main landscapes according to elevation and relief: the humid tropical lowlands and the humid tropical highlands.

(a) the humid tropical lowlands (0-500 m.a.s.l.) correspond to the coastal land of the Gulf of Mexico and the Yucatán Peninsula of Mexico, Belize and Guatemala, and the coastal lands of Guatemala. Coastal plains and a karstic platform are the main relief types, and
(b) the humid tropical highlands (500-1,500 m.a.s.l.) are located at intermediate elevations in the southeastern mountains of Mexico and in the western and eastern highlands of Guatemala. Highly dissected mountain slopes and hilly lands are the main relief types.

Dense evergreen and semi-evergreen tropical forests cover mainly the highlands, while a complex mosaic of forest and savanna covers the lowlands. Climate, relief and soils control the distribution of the vegetation cover. This zone has the highest $\alpha$ biodiversity, represented by more than 5,000 phanerogamic species. It comprises 11% of the Mexican territory, more than 30% of Guatemala and the totality of Belize. Main land-use systems in Mexico are pasture land (20%) and agriculture (15%), while forest covers more than 60% (Toledo and Ordóñez, 1993). Shifting cultivation, agroforestry, tropical plantations and homegardening constitute the main traditional land-use systems. Commercial tropical plantations, extensive cattle ranching and cash crop mono-cropping are the main modern land-use systems (Challenger, 1998).

### (2) Sub-humid tropical lands

This zone is restricted to the Mexican territory, comprising 17.5% of the territory. It is located in the Pacific coastal plains, at intermediate elevations in the eastern mountains of Mexico, in the north of the Yucatan Peninsula, central Veracruz and southern Tamaulipas, and the coastal plains of the Gulf of Mexico (Figure 11.1 and table 11.1). The sub-humid tropical lands present very warm and warm temperature regimes, with intermediate or sub-humid seasonal rainfall regime. The dry period covers five months during the year.

A variety of tropical deciduous forests cover large altitudinal and latitudinal gradients. Tropical deciduous forests have high $\alpha$ biodiversity, high species richness and high plant endemism (40% of all species occurring in the zone). About 6,000 phanerogamic species are present in this agro-ecological zone. The sub-humid

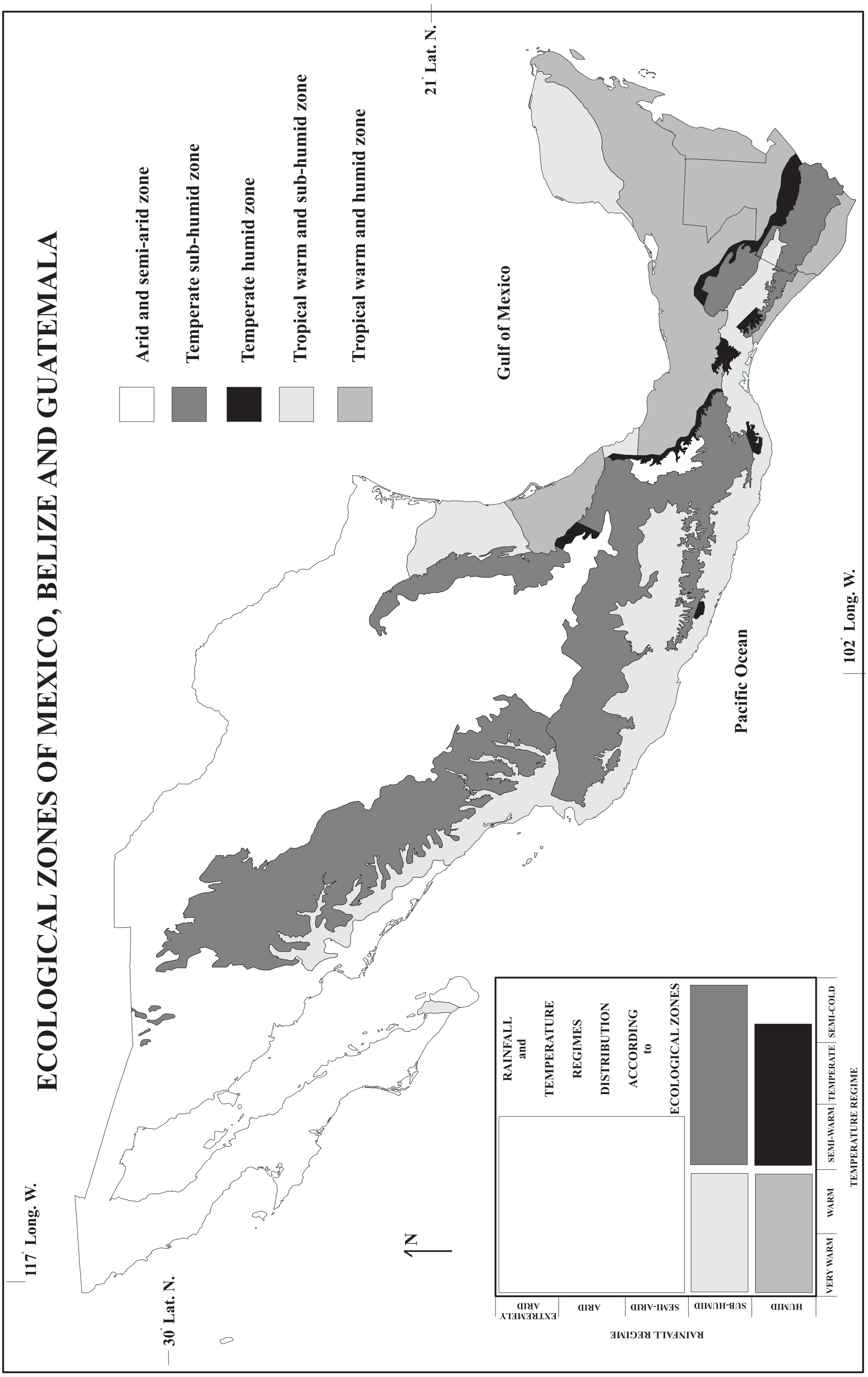



**Figure 11.1.** Ecological zones of Mexico, Belize and Guatemala. **Modified from:** Toledo and Ordóñez (1993) (1993)

**Table 11.1.** Environmental indicators of agro-ecological zones in Mexico, Belize and Guatemala

| AGRO-ECOLOGICAL ZONE | Elevation range (m.a.s.l) | Mean Annual temperature (°C) | Thermic regime | Mean annual rainfall (mm) | Rainfall regime | Vegetation | % of land use in Mexico (1990) | | | Biodiversity characteristics |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Agriculture | Pasture | Forest | |
| **HUMID TROPICAL LANDS** | 0-1,500 | 22-29 | Warm to very warm | 1,500-4,000 | Humid | Evergreen tropical forest and savanna | 14 | 19 | 60 | The zone of Highest α biodiversity; 7,000 plant species |
| **SUB-HUMID TROPICAL LANDS** | 0-2,000 | 20-29 | Warm to very warm | 800-1,200 | Sub-humid | Deciduous tropical forest | 25 | 20 | 45 | High α biodiversity; high plant richness and plant endemism 40%); 6,000 plant species |
| **HUMID TEMPERATE HIGHLANDS** | 1,400-1,600 | 12-23 | Temperate to semi-warm | 2,000-6,000 | Humid | Pine-oak forest; Cloud forest and evergreen tropical forest | 8 | 22 | 60 | Very high plant richness and plant endemism (70%); 3,000 plant species; patchwork-like pattern |
| **SUB-HUMID TEMPERATE HIGHLANDS** | 1,200-3,500 | 10-20 | Semi-warm, Temperate to semi-cold | 800-1,200 | Sub-humid | Fir forest; mixed forest; pine forest and oak forest | 15 | 11 | 65 | Very high plant richness and plant endemism (70%); 7,000 plant species; biological insularity |
| **ARID AND SEMI-ARID LANDS** | 0-1,500 | < 25 | Very warm, Warm to semi-warm | 40-700 | Semi-arid; arid to extremely arid | Xerophytic vegetation; xerophytic scrub and grassland | 15 | 70 | 5 | Second highest plant endemism (60%); 6,000 plant species |

**Sources:** Toledo et al. (1985); Toledo et al. (1989); Toledo y Ordóñez (1993); Rzedowsky (1993); Harcourt., et al (1996); and Challenger (1998) tropical lands of Mexico have been extensively transformed by agricultural activities (25%) and pasture land (20%). Forest has being heavily modified, but still covers 45% of the zone. Shifting cultivation, agroforestry and homegardening are the main traditional land-use systems. Extensive cattle ranching, cash crop cereal monocropping and commercial tropical plantations are modern land-use systems (Challenger, 1998).

### (3) Humid temperate highlands

This ecological zone is located at intermediate elevations in the mountainous ranges of Mexico and Guatemala. It has a patchwork-like distribution pattern, with large climatic variability, but always high rainfall. These local sites constitute a bioclimatic archipelago covered by cloud forest, evergreen tropical forest and pine-oak forest (Figure 11.1 and table 11.1). This zone covers less than 1% of Mexico, but more than 10% of Guatemala. The humid temperate highlands represent the richest floristic zone in Mexico and Guatemala, despite its limited extent. More than 3,000 phanerogamic species are present in this zone, which is considered the principal center of endemic plants. The coexistence of neo-tropical and neo-arctic forests generates high biological richness endemism in a patchwork-like pattern. Forest still covers 60% of this zone but pasture land (20%) is the most important land-use change (Toledo and Ordóñez, 1993). Shaded coffee plantations, shifting cultivation, agroforestry and homegardening are the main traditional land-use systems. Commercial plantations and extensive cattle ranching are the main modern land-use systems.

### (4) Sub-humid temperate highlands

This zone covers the largest portions of the mountains in Mexico and Guatemala (Figure 11.1 and table 11.1). High temperature variability controlled by elevation and intermediate rainfall controlled by slope gradient a nd latitude allow a wide distribution of pine, oak and mixed forests. This zone covers some 18% of the Mexican territory and is also well represented in Guatemala. In both cases, the distribution pattern is patchy. This biological zone has the highest species richness and endemism of flowering plants. Endemism accounts for 70% of the flowering plants. About 7,000 plant species are present in this vast zone.

The main land-use systems in the sub-humid temperate highlands of Mexico are forest cover (60%), agriculture (15%) and pasture land (15%). Forests are highly modified and over-exploited in extensive areas. Rainfed agriculture, homegardening, some cattle ranching, agroforestry, hunting, fishing and plant gathering are the main traditional land-use systems and production activities. Cash crop cereal monocropping irrigated areas, extensive cattle ranching and logging constitute the main modern land-use systems.

### (5) Arid and semi-arid lands

This zone is restricted to central and northern Mexico, comprising more than 50% of the national territory (Figure 11.1 and table 11.1). Temperatures are warm to very warm and rainfall is low to extremely low. This extensive zone can be divided into semi-arid and arid according to the amount of annual rainfall:

(a) the arid zone is dry for 8 to 12 months per year. In general, the annual rainfall is less than 400 mm. Rainfall of 40 mm is typical in the northern Mexican deserts, and
(b) the semi-arid zone is dry for 6 to 8 months per year, with an annual rainfall of 400–700 mm in central Mexico.

Many different types of desert vegetation, xerophytic scrub, natural grassland communities and halophytic vegetation cover the greatest portion of this extensive zone. Its ecological importance resides in its flora diversity (6,000 phanerogamic species) and its high endemism (60% of the flora). Land-use systems are restricted by water availability. Agriculture is practiced in 15% of the area, while 70% is dedicated to extensive cattle ranching. Forest covers only 5% of the zone. Rainfed agriculture and small-scale irrigated agriculture in the semi-arid areas, and floodwater farming, and hunting and gathering in the arid areas are the main traditional land-use systems. Large-scale irrigated agriculture and extensive cattle ranching are the main modern land-use systems.

### 11.2.2 Indigenous population distribution

Mexico, Guatemala and Belize have important indigenous populations (see Chapter Ten). These populations are unevenly distributed according to a patchwork-like pattern. For Guatemala and Belize, there is no information on indigenous population distribution available at regional and district levels. Mexico has more accurate data in the population census and other official estimates at regional, state and municipality levels (INI, 1993; INEGI, 1995; INI, 1997). These data provide information on the spatial distribution of indigenous populations by ethnic group in México, according to language as the only measured cultural factor (INI, 1997). On the basis of this information, 20 different indigenous regions are recognized (Figure 11.2), which can be overlaid with the agro-ecological zones (Figure 11.1) and with demographic and poverty indices at state level. The cartographic combination (Figure 11.2)allows drawing some relevant correlations.

(1) Indigenous populations are unevenly dispersed all over the Mexican territory. Indigenous language-speaking inhabitants (ILSI) live in 95% of the Mexican municipalities. In 60% of these municipalities, ILSI constitute an important part of the total population, ranging from 30% to more than 70%. There are ILSI in some 20% of the Mexican localities (201,138 localities); in 10% of them, ILSI range from 30% to more than 70% of the total population. Eighty percent of ILSI concentrate in 12 Mexican states (38% of the states), mainly located in central, southern and southeastern Mexico. Most of these states are considered rural according to the size of the total population living in localities with less than 2,500 inhabitants.

(2) The number of ILSI varies according to ethnic group. Ten ethnic groups (17%), out of the 58 officially registered concentrate 79% of ILSI. Seventeen ethnic groups (29%) have populations greater than 100,000 ILSI, representing 91% of the ILSI at country level. Eight ethnic groups in Mexico are provided with ethnopedological information.

(3) Three percent of the Mexican localities are officially recognized as indigenous communities (6,300 localities), corresponding to 21% of all localities having social landholding regime. Landholding is divided in private property (*pequeña propiedad*) and social property (*ejido* and indigenous communities). Indigenous communities possess 22 million hectares or 11% of the Mexican territory. About 22% of the land is under social property regime. Nevertheless, many indigenous localities are registered as *ejidos*, private properties or a combination of; thus, the extent of land under indigenous management is considerably larger than the estimate given above.

(4) Main land-uses in indigenous communities at national level are: (a) pasture land or fallow land (45%); (b) forest cover (32%), accounting for 15% of the national forest cover, and (c) agriculture (10%). Eighty percent of the agricultural land are managed as rainfed systems, while the remaining 20% are managed as irrigated systems.

(5) Ninety six percent of ILSI lives in municipalities considered very poor or extremely poor (41%) (less than 1 US dollar per day/inhabitant). Seven of the most indigenous states, according to the population size of ILSI, are considered to be extremely poor.

(6) The majority of the indigenous regions (70%) has access to natural resources belonging to more than one ecological zone and 25 of them (43%) have access to the sub-humid tropical lands and the sub-humid temperate lands, the most suitable for agricultural purposes (Challenger, 1998).

(7) Eighty six percent of ILSI lives in humid or sub-humid areas, with 34% in the humid tropical lands and 22% in the sub-humid tropical lands. The remaining ILSI population lives in the arid and semi-arid lands (8.6%) and in the humid temperate lands (5.2%).

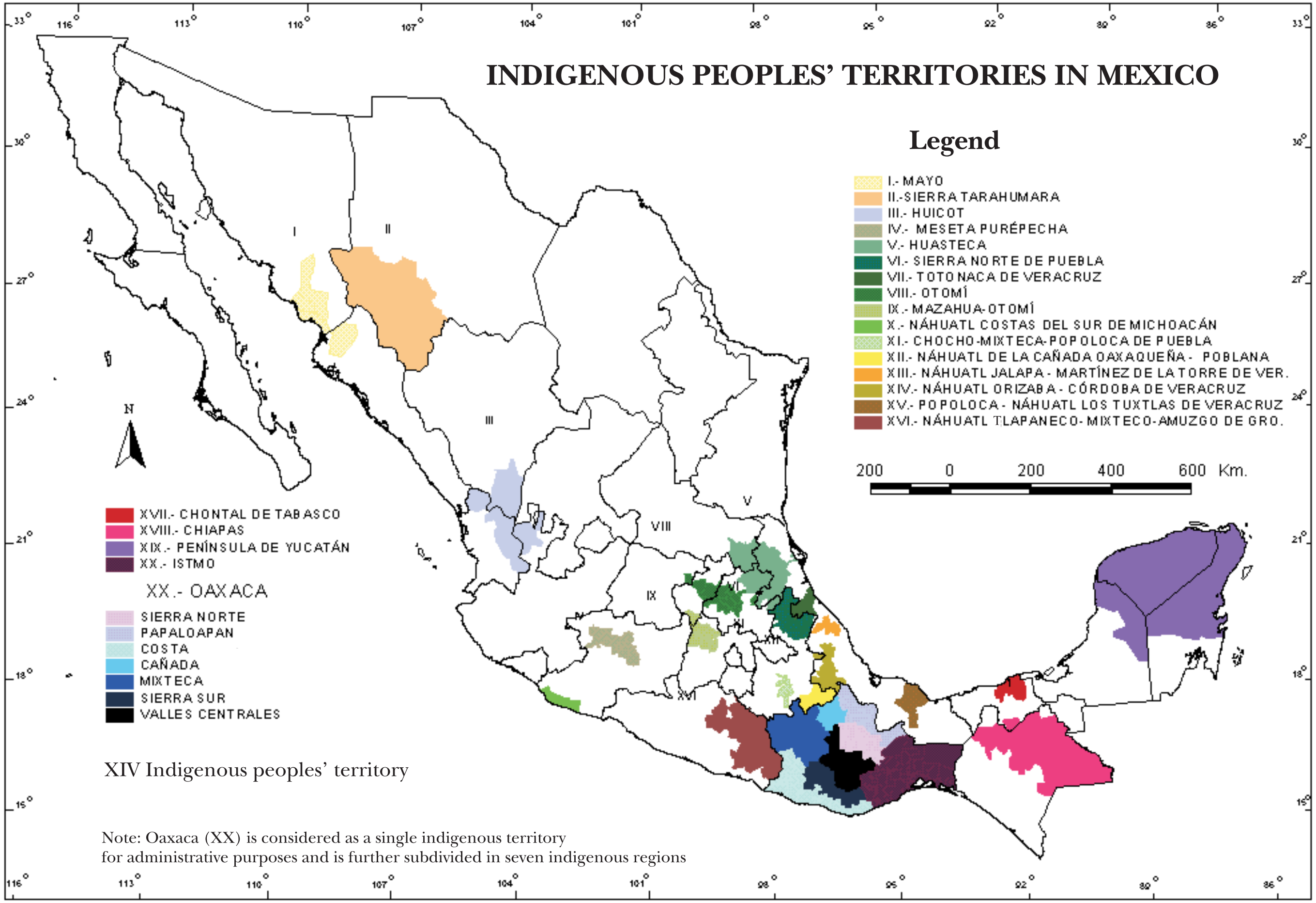



**Figure 11.2.** Indigenous peoples' territories in Mexico. **Source:** INI (1998)

(8) Ethnopedological information covers the five agro-ecological zones of Mexico, but the humid tropical lands are best represented, followed by the sub-humid temperate highlands and the semi-arid lands. Nonetheless, the analyzed ethnopedological case studies provide information on land management for all agro-ecological belts, reflecting the ecological and cultural strategy of the majority of the ethnic groups(Figure 11.3 and table 11.2).

**Table 11.2.** Selected ethnopedological studies.

| Num | AEZ[1] | Ethnic group | Region | State | Locality | Authors |
|---|---|---|---|---|---|---|
| **1** | 1a | **Totonac** | Coastal Lowlands of the Gulf of Mexico | Veracruz | Plan de Hidalgo | Medellín (1987); Barrera-Bassols et al. (1994); Ortíz (1995) |
| **2** | 1a | **Nahua** | Coastal Lowlands of the Gulf of Mexico | Veracruz | Pajapan | Chevalier and Buckles (1995); Rice et. al. (1994); Blanco (2000) |
| **3** | 1a* | **Tojolabal; Tzeltal; Tzotzil** | Las Cañadas | Chiapas | Santa Margarita Agua Azul; Majosik; Tenejapa; Poconichim; Chenalhó; Tizcao | Ruz (1983); Grossman (2003) |
| **4** | 1b* | **Chinantec** | Sierra Norte de Oaxaca | Oaxaca | Santiago Comaltepec; Ojitlan | Lucero and Avila ((1974); Martin (1993) |
| **5** | 1b* | **Mixe** | Sierra Norte de Oaxaca | Oaxaca | Tlahuilotepec; Santa María Tlahuilotepec | Martínez (1982); Martin (1993) |
| **6** | 1b | **Mestizo** | Central Chiapas | Chiapas | Ocozocuautla | Brush et. al. (1988); Bellón (1990, 1991, 1992); Bellón and Brush (1991, 1993); Bellón and Taylor (1993) |
| **7** | 2 | **Mestizo** | Coastal Lowlands of the Gulf of Mexico | Veracruz | Cantarranas; Hato de Higuera; Rancho Nuevo; La Brecha | Licona (1990, !991); Licona et. al. (1992a, 1992b); Cruz (1994) |
| **8** | 2 | **Huave** | Coastal Lowlands of the Pacific Ocean | Oaxaca | San Mateo del Mar | Lupo (1981); Zizumbo and Colunga (1982); Signorini (1997) |
| **9** | 3 | **Mestizo** | Basin of Mexico | Federal District; State of Mexico; Hidalgo | Several villages in the bottomlands of the former Texcoco Lake | Luna (1982); González (1988); Williams and Ortíz-Solorio (1988); Luna (1982); Calderón (1983); Quiróz (1983); Pájaro and Ortíz-Solorio (1987); Ordáz (198); Ortíz-Solorio (1989); Pájaro (1989a, 1989b,); Rodríguez (1990); Cajuste (1990); Ortíz-Solorio et al. (1990, 1993, 2001) |
| **10** | 3 | **Mestizo** | Central Highlands | Tlaxcala | Tetlauhca | Wilken (1987) |
| **11** | 3 | **Maya Quiche** | Guatemalan Highlands | Quetzalte-nango | San Pedro Almolonga | Wilken (1987) |
| **12** | 4 | **Otomi** | Valley of Mezquital | Hidalgo | Dení; El Nith; San Pedro Capula; Cuesta Blanca; San Miguel Tlazintla | Johnson (1977); Márquez (1983) |
| **13** | 4 | **Zapotec** | Central Valley of Oaxaca | Oaxaca | Santa María Mitla | Messer (1978) |

[1]Agro-ecological zones (AEZ): (1a) humid tropical lowlands; (1b) humid tropical highlands; (2) sub-humid tropical lands; (3) sub-humid temperate highlands, and (4) semi-arid tropical lands.
* Ethnopedological case studies provided with multi-zonal information (e.g. information from the humid tropical lowlands and highlands, and from the sub-humid temperate highlands), according to vertical zonation.

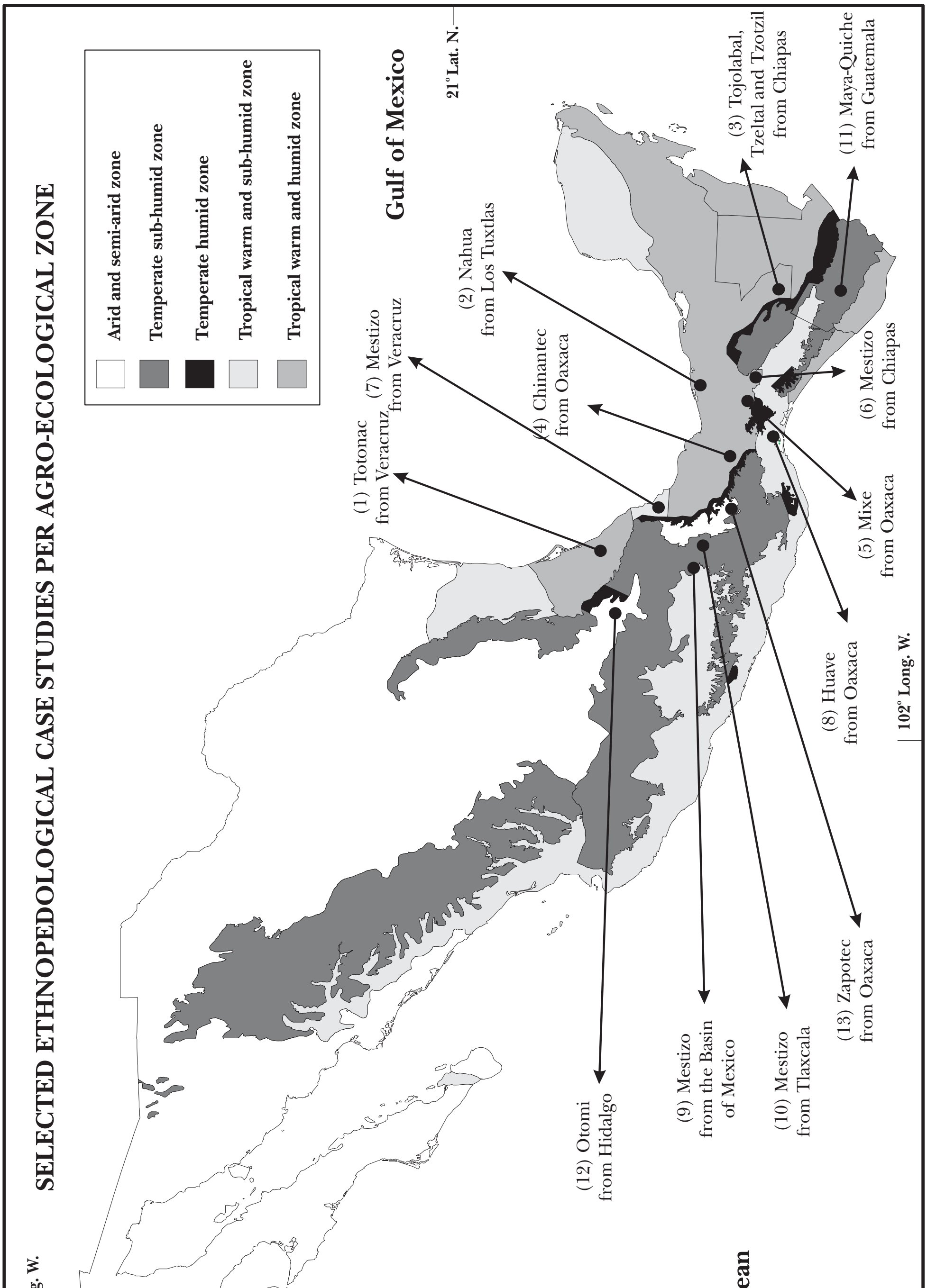



**Figure 11.3.** Selected ethnopedological studies from Mexico and Guatemala

The correlation between agro-ecological zones and distribution of ILSI, ethnic groups and indigenous regions of Mexico provides a general framework to contextualize and discuss the selected ethnopedological case studies in the following sections and in Chapters Twelve and Thirteen. Selected case studies that are discussed below were ordered from North to South, and numbered according to figure 11.3 and table 11.2.

## 11.3. THE HUMID TROPICAL ZONE

The humid tropical zone is divided into lowlands and highlands. This division makes it possible differentiating two main land management strategies. Farmers from the humid tropical lowlands focus on the on-site management of soil micro-variability in large homogeneous landscapes, such as the coastal lowlands (horizontal zonation), trying to intensify their agro-forestry systems, generally under high population pressure. Farmers from the humid tropical highlands, having access to an ample variety of agro-ecological habitats, complement the on-site soil micro-variability management with differential land management according to vertical bio-climatic zonation, in less intensified ways and generally under less population pressure. In the first case, farmers' strategy focuses on managing limited natural resources by intensifying the production systems while, in the second case, farmers' strategy is more complex, combining intensive and extensive production systems under less limited natural resources. Seven ethnopedological case studies pertaining to the humid tropical zone were analyzed into two main groups (Figure 11.4):

Those pertaining to the humid tropical lowlands:
- (1) Totonac from the coastal lowlands of the Gulf of Mexico in Veracruz;
- (2) Nahua from Pajapan, Los Tuxtlas in Veracruz;
- (3) Tojolabal from Las Cañadas in Chiapas.

Those pertaining to the humid tropical highlands:
- (4) Chinantec from the Sierra Norte de Oaxaca;
- (5) Mixe from the Sierra Norte de Oaxaca;
- (6) *Mestizo* from Ocozocuautla in central Chiapas.

### 11.3.1. The humid tropical lowlands

#### (1) Totonac ethnopedology from the coastal lowlands of the Gulf of Mexico

#### (a) Regional context

The Totonac people are one of the major ethnic groups in Mexico, with a population of 200,000 inhabitants (Ortíz, 1995). Totonacapan, their territory, comprises extensive portions of the Sierra Norte de Puebla and the northern central coastal lowlands of the state of Veracruz, within the Gulf region (Figure 11.4). Totonac from the coastal lowlands developed, since thousands of years ago, a complex and efficient natural resource management system (Barrera-Bassols et al., 1994; Barrera-Bassols and Ortíz, 1992). Contemporary Totonac production strategy is based on shifting agriculture (Vicente, 1986), agro-silviculture (Medellín, 1988), homegardening, vanilla plantations and semi-intensified cattle ranching (Toledo et al., 1994; Ortíz, 1995). It is possible to recognize a well structured and patchwork-like land-use pattern at regional and local levels within the Totonac territory. Patches of managed tropical forest coexist with patches of fallow land, *milpa* fields and small pasture plots, in a colorful mosaic over rounded sedimentary hills.

Moderately fertile soils, a multi-production strategy based on maize and a complex understanding of nature are key factors for the maintenance of a sustainable livelihood. Soils, including Phaeozems, Cambisols and Vertisols (FAO/UNESCO/DETENAL, 1979), support two maize harvest per year. *Milpa* production is based on maize-beans-squash-chili pepper, with other 28 edible species as reported by Medellín (1988). Until the 1990s, multicropping was performed without chemical fertilizers and herbicides in most Totonac villages. Until recently, maize yields in some Totonac allowed households to sell 25-50% of the production at local and regional markets (Barrera-Bassols et al., 1994).

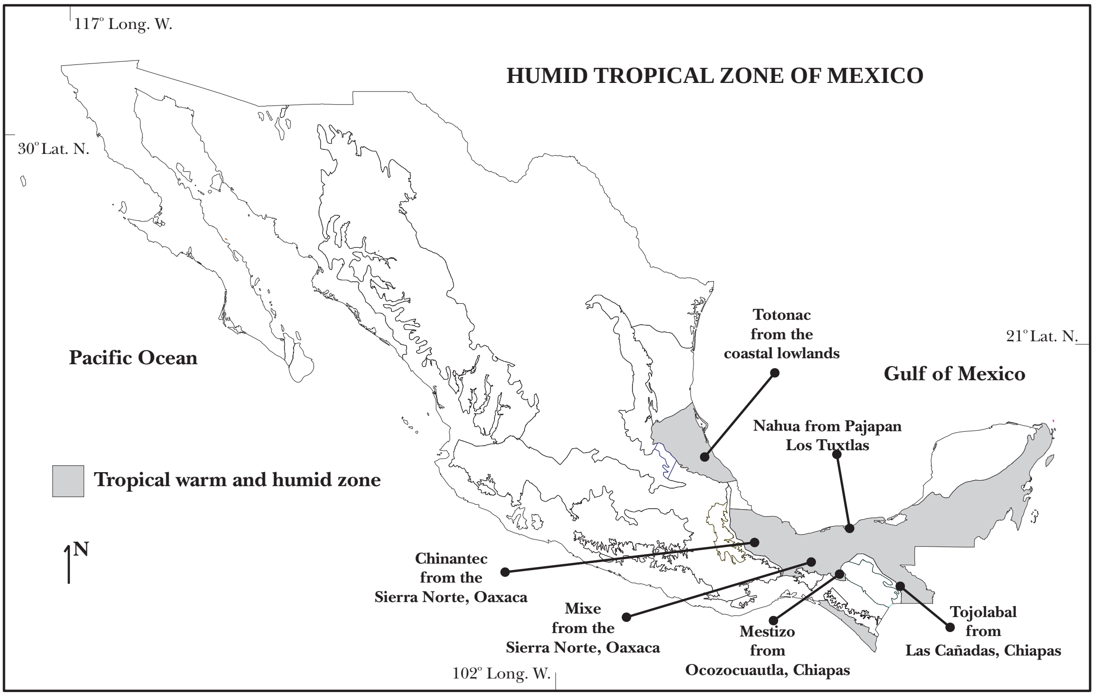



**Figure 11.4.** Ethnopedological studies in the humid tropical lands of Mexico

### (b) Totonac environmental knowledge system

The permanence of a Middle American ethnoecological knowledge system allows Totonac farmers to display a multiple land-use system strategy. A balanced distribution of managed forest plots (30%), milpa fields (30%) and pastures (30%), constitute the bases of local land management and reflects the longstanding adaptation of the Totonac ecological knowledge to ever changing conditions. Toledo et al. (1994) demonstrate this from an ethnoecological survey of the Plan de Hidalgo community. A synthesis of the environmental knowledge and management system possessed by local farmers is shown in figure 11.5. The production strategy is based on a complex understanding and management of the local soils (*Tíyat*) (Medellín, 1988; Toledo et al., 1994; Aparicio-Alegría and García-Bautista, 1995; Barrera-Bassols, fieldwork notes 1996-1997). Mulching, as part of the local shifting cultivation practice, maintains the milpa productivity over more than five years on hilly land. Local maize yield is about 1,000kg/ha, which is higher than the estimated municipal yield of 800 kg/ha using fertilizers, herbicides and machinery (Barrera-Bassols et al., 1994). Soil fertility assessment is critical for land-use decision-making. Replenishment of soil fertility is done by fallowing or by cutting, clearing and burning forest patches (slash-and-burn). Soil and water management is critical for this type of rainfed agricultural system.

### (c) Totonac soil nomenclature, soil classification and land quality assessment

Land qualities for agricultural purposes are locally assessed by a detailed recognition of soil properties, mainly color, organic matter content in the top layer, structure, texture, consistence, relief position, depth, stoniness, moisture retention capacity, drainage conditions, vegetation cover, workability and soil compaction. Soil color, relief position and moisture retention capacity are the most carefully assessed properties from the 13 soil properties that Totonac farmers recognize at micro-level. Farmers of Plan de Hidalgo, a communal *ejido* comprising 1,519 hectares, recognize 23 different soil taxa. Table 11.3 shows the Totonac soil classes and figure 11.5 shows the relief position of the main soil classes.

Texture, stoniness, relief position, drainage, presence of hardpan in the subsoil layers or as a top layer in eroded soils, depth, consistence, structure, organic matter content and color in the topsoil are used to name soil classes. Totonac soil classification is hierarchical and organized in five levels. The first level, or the unique beginner according to Berlin (1992), corresponds to the soil or land domain (*Tíyat*). The second level, or the life form level, clusters 11 soil types. The third level, or the generic level, clusters nine soil classes. The fourth level, or the specific level, clusters four soil sub-classes. Finally, the fifth level, or the varietal level, has one soil variety. Figure 11.6 shows the Totonac soil taxonomic tree.

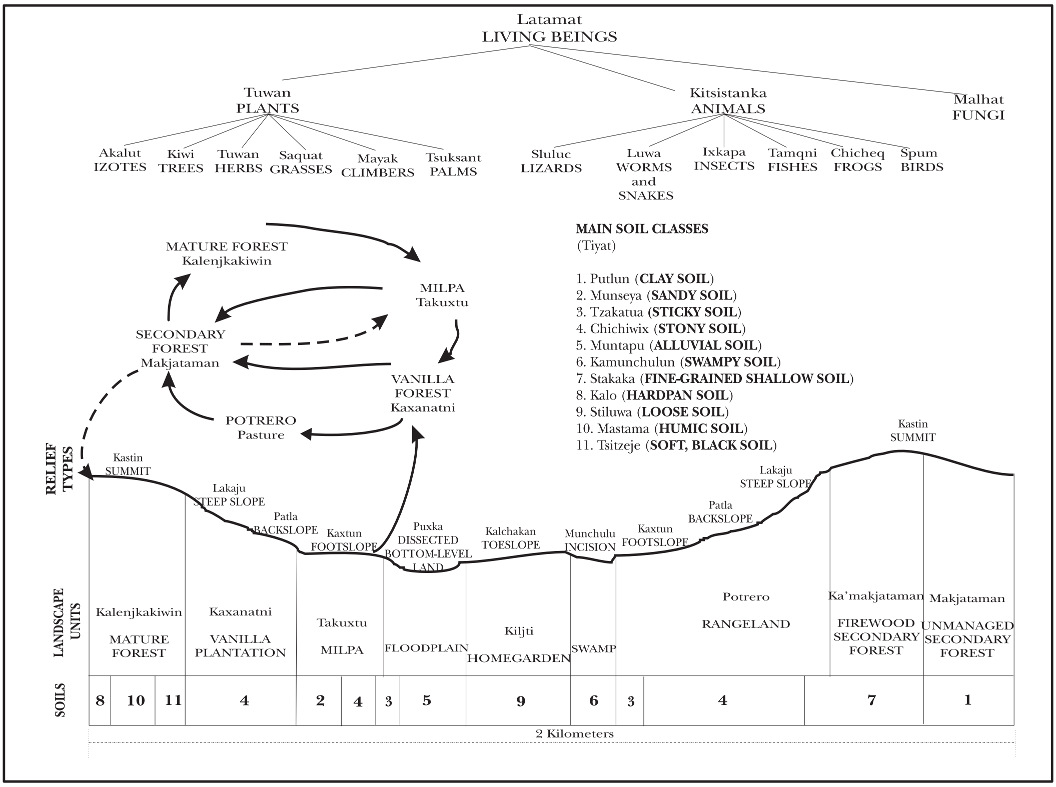



**Figure 11.5.** Totonac ethnoecological cross-section showing the taxonomy of living beings, ecological succession, relief types, landscape units and local soil classes

Totonac farmers recognize soil horizons, but do not discriminate between soil and land. The *Tíyat* lexeme is used interchangeably when referring to soil, land or terrain. Totonac farmers perceive soil and land resources in the same way scientists recognize landscapes, with a deep understanding of the processes, dynamics and relations with other biophysical factors, such as vegetation cover, plant species, soil fauna, water availability and relief position. *Tíyat* is perceived in a holistic way, always related with other natural phenomena and factors. This relational knowledge is common among shifting cultivators of tropical lands in Mexico, Belize and Guatemala. *Tíyat* is also conceived as a multidimensional domain, possessing diverse characteristics, properties and qualities, besides the soil descriptors used to label soil classes. Soil characteristics, properties and qualities are perceived as changing over time. Soil fertility and land productivity are considered the most relevant dynamic factors as part in the shifting cultivation cycle. Moreover, *Tíyat* is recognized as a polyvalent resource, suitable for agriculture, agroforestry or pasture depending on its particular qualities. It is also used as construction material, for pottery making and as medicine. *Tíyat* is managed according to crop requirements and household needs.

Ortíz (1999) studied the Totonac perception of earthworms as soil fertility indicator in Plan de Hidalgo. His study revealed a complex understanding of earthworms' activity and the significance of high earthworm population for land productivity. The permanence of managed forest patches, fallow land, *milpa* fields and pasture is a key factor for the abundance of earthworms in Totonac soils. Mulching helps maintain earthworm abundance and enhances biological activity. High organic matter content in soils and abundance of cattle manure are perceived as strongly related to earthworm abundance and activity. Totonac and Nahua from the Sierra Norte de Puebla consider earthworms as deities of the underground world, permitting the fertilization act of the land (Ichón, 1973; Beaucage, 1990, 1997).

**Table 11.3.** Totonac soil classes in Plan de Hidalgo, Papantla

| Nahua soil term | English terms | 16th century soil descriptors | Crop suitability |
|---|---|---|---|
| Pistiktal | Black soil | | Maize, beans |
| Medio Pistiktal | Gray soil | | Maize |
| Tatahuiktal | Reddish, stony soil | | Pasture, maize |
| Gostiktal | Yellowish soil | Coztli: yellow; Tlacoztli | Maize |
| Istaktal | Whitish soil | Iztac: white; Iztactlalli | Maize |
| Teposhakio | Stony soil | Tepoxca: soft pumice rock; Tepoxcatetlalli | Maize |
| Xalnelijtok | Fine-grained sandy soil | Xalli: sand; Nextli: fine-grained ash; Xallnextli | Maize; Fruit-tree plantation |
| Xalatl | Humid sandy soil | Xalli: sandy: Atl: water, humidity; Xallatl | Maize; Fruit-tree plantation |
| Xalli | Sand | Xalli: sand | Watermelon |
| Pistiksogik | Black mud | Tezoquitl: hard mud | Fruit-tree plantation |
| Gonsogik | Mud | Zoquitl: mud | Pottery clay |

**Sources:** Medellín (1988); Aparicio-Alegría and García-Bautista (1995)

## (d) Totonac soil knowledge for land-use evaluation

Totonac people of Plan de Hidalgo assess soil qualities for land-use evaluation according to crop requirements and shifting cultivation practices. Like other Middle American ethnic groups, Totonac farmers generally prefer to cultivate slope soils rahter than valley soils, because of good drainage and for crop protection from wind and frost (Figure 11.5).

Black soil (*Tsitseje' Tíyat*) is considered the most suitable for *milpa* cropping because "it is not hard, it is loose" and contains "*abono*" (organic matter), according to local soil quality assessment. It develops under dense old forest patches on hill summits and seepage slopes (*Kastin*, in Totonac) (Figure 11.5). Soil productivity for maize is high during four to six years, but sharply drops afterwards because the "*abono*" content diminishes. Consequently, land is left fallow because it becomes "tired" (*cansada*). Totonac farmers assess the color and structure of the topsoil twice a year during land preparation to evaluate if the black soil is still fertile for *milpa* production. Black color of the topsoil and structure within 60-cm depth change over time. After the third year of *milpa* production, the soil becomes grayish or whitish and hard, so that it must be fallowed, according to the local land-use evaluation.

Alluvial soils (*Múntapu' Tíyat*) located along seasonal water streams (*Puxka*) are considered highly productive for maize, beans, sweet potato, watermelon and onions. Sticky soils (*Tzakatúa Tíyat*) of the bottom of the vales (*Kaxtun*) are considered less productive than alluvial soils because of poor drainage and are cultivated only one year during the dry winter season (*Tonalmil* or *Katamakukmulh*). Sandy soils (*Munseya' Tíyat*), stony soils (*Chichiwix' Tíyat*), fine-grained shallow soils (*Stakaka' Tíyat*) and loose soils (*Stiluwa' Tíyat*) are considered less productive for agricultural purposes. Sandy soils do not retain moisture; stony soils are not easily workable, fine-grained shallow and loose "*no tienen o retienen fuerza*". Swampy soils (*Kamunchulún Tíyat*), kalo soils or *tepetate* (hardpan soil) and muddy soils (*Putlún' Tíyat*) are considered not suitable for agriculture and left under forest or pasture. Swampy and muddy soils are temporarily waterlogged, whilst washed *kalo* soils on steep slopes are not easy to work (*Lakaju*). Clayey soils are used for pottery, medicinal purposes (e.g. *Snapapa' kalo*) and house building.

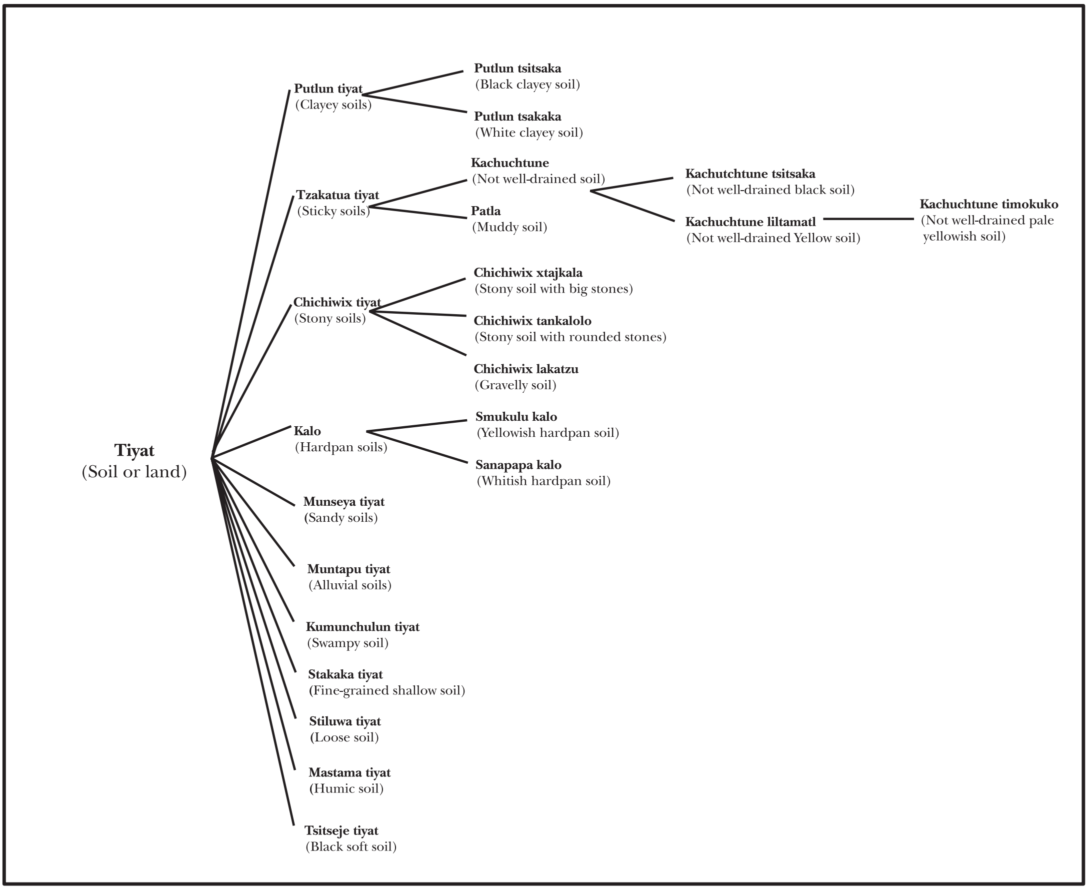



**Figure 11.6.** Totonac soil taxonomy

Farmers recognize and manage soil variability at local and at site level to satisfy their basic requirements under climatic and economic uncertainties and as part of their risk minimizing strategy. Farmers of Plan de Hidalgo have several parcels in different relief positions and with different soil classes, which allow them to diversify their production and obtain a wide range of staple goods. They use some 200 species of plants, animals and fungi, that are gathered, extracted, hunted or cultivated in a variety of agroecological units (Medellín, 1988). Most households use three to five agroecological units, adopting a multi-use production strategy. Average land area per household is 7-9 hectares, which secures food and energy self-sufficiency, plus an economic return of more than $ 8,000 per year (Toledo et al., 1994), an extraordinary surplus under current rural circumstances in Mexico (Hewitt de Alcántara, 1994).

### (e) Land in the Totonac syncretic cosmovision

Contemporary Totonac profess strong devotion to syncretic Catholicism as part of their cosmologic and ecological rationale. Popular Catholicism as practiced in Totonacapan maintains covered pre-Hispanic Middle American totemic-animist deities that play significant symbolic roles (Ichón, 1973). Religious festivities and agricultural rituals still organize social and economic life and are embodied in any daily activity. Catholic virgins and patron saints cover Middle American deities in religious festivities and in propitiatory and thanksgiving rituals (Oropeza, 1994).

Agricultural and religious calendars are still intimately related. Land is venerated as a deity. There is a strong belief among Totonac that rain, thunder, land, forest, maize and *milpa* have 'holy owners' that watch, protect or punish humans depending on their secular acts. Deities can be generous when providing plenty of food or dangerous when destroying all crops. Totonac negotiate with deities to balance their power by offering rituals, prays, promises and gifts at the church, their house chapels or sacred sites. The Three Kings (*Los Santos Reyes*) and the sun (*chichiní*) are considered the 'holy owners' of the land or *Tíyat*. The Three Kings cover three maize deities, the white maize, yellow maize and black maize, while the sun (red) represents the 'truthful' maize or wild maize, according to Oropeza (1994). Red maize is considered the 'father' maize among Totonac the one who protects the other three maize deities (Vicente, 1986; Montesinos et al., 1982). White, yellow, red and black maize varieties are the best represented in the Totonac *milpa*. Three to four maize seeds are sown in each hole using a planting stick (*coatl*: snake).

Every 6th of January, the day of the Three Kings according to the Catholic religion, land or *Tíyat* is venerated at the temple, the house chapel and the field to be cultivated the next day. After praying and promising, land is 'fed'. Special food, alcohol and tobacco are offered in the four corners and the center of the field. The four corners represent the four cardinal points, the four winds, the four thunders, the four colors, and the four 'holy guardians' (*Tajín* in Totonac and *Tlaloque* in Nahuatl) whilst the center represents the 'holy tree' or the center of the world. This ritual is offered to the land to procure benevolence from the 'holy deities' of *Tíyat* during the next agricultural cycle and to thank for the abundance of the last cropping. Land productivity also has its own 'holy deity'. In this case, the Moon is the 'owner' leading the fertilization act. Moon represents a soft female substance and rules the forces of women, water, cold, eclipse and the northern wind, which is considered benevolent for the *milpa*. The Moon represents all what is produced in the secular world. Land or *Tíyat* is the receiver of his/her holy willingness, and that is why Totonac farmers offer special devotion to his/her powerful dominion.

### (2) Nahua ethnopedology from Los Tuxtlas in Veracruz

#### (a) Regional context

Nahua ethnopedology from Los Tuxtlas in Veracruz is briefly described in recent ethnographic research (Chevalier and Buckles, 1995), reflecting the contemporary richness and complexity of soil and land resource knowledge that Nahua possess since pre-Hispanic times, as shown in Chapters Seven, Eight and Nine. Nahua of Pajapan municipality in southern Veracruz are still engaged in shifting agriculture as main subsistence activity (Blanco and Cruz, 1994). Pajapan is located close to the Gulf of Mexico, on the slopes of the de San Martín volcano which belongs to the Sierra de Santa Marta, a complex and isolated volcanic region covered until recently by tropical evergreen forest (Figure 11.4) (Paré, 1994).

The area is one of the most important biological and agricultural hot spots of diversity in Mexico (Dirzo and Garcia, 1992; Buckles and Erenstein, 1996), but recently livestock expansion caused substantial reduction of the forest cover (Dirzo and Miranda, 1991; Barrera-Bassols, 1995). Shifting cultivation on slopes with moderately fertile soils allows Nahua farmers to produce two *milpa* crops a year. This activity is combined with homegardening, fruit-tree plantation, fishing, plant gathering and hunting, as part of a multiple strategy of natural resources management (Chevalier and Buckles, 1995). Maize and beans diversity still stands high, with 15 local varieties of maize and seven local varieties of beans (Blanco, 2000). Preservation and enrichment of maize diversity remain important among Nahua households, which prefer local maize varieties to high-yielding varieties. Local maize is well adapted, reflecting four thousand years of production experience (Rice et al., 1998).

#### (b) Nahua soil nomenclature, classification and productivity assessment

Nahua farmers recognize 11 soil classes. Color, texture, stoniness, moisture retention capacity, structure, consistence, relief position and soil compaction are relevant soil attributes assessed to classify soils. Although soil names are simple, labeling is based on a multi-factorial classification taking into account eight different soil properties. The soil classification system is not hierarchical. Color, texture and stoniness are the main soil descriptors used to name soil classes (Table 11.4). Some of the descriptors are similar to those used by 16th century Nahua farmers (see tables 7.8 and 7.9 in chapter Seven). Although soil fertility is an important for shifting cultivation, it is not reflected in the ethnographic accounts. Reduction of fallow due to cattle grazing was compensated by the introduction of high yielding varieties of maize.

Soil-relief position and maize varieties are main criteria used to assess soil productivity. Soils in the lowlands and areas where it rains more than the regional average are considered to be deep and soft when moist, thus more productive and easier to work than upland soils, which are considered to be shallow, hard and dry. Both, lowland and upland soils cultivated with site-specific maize varieties, reflecting a long tradition of plant domestication and diversification. Black and gray soils are considered more suitable for agriculture than sandy soils. Texture, moisture retention capacity, drainage condition, organic matter content and structure are used to assess soil productivity for crop the same way as in the 16th century (Table 11.4).

**Table 11.4.** Contemporary Nahua soil classes, crop suitability per soil class and corresponding 16TH century Nahua soil nomenclature

| Nahua soil term | English terms | 16th century soil descriptors | Crop suitability |
|---|---|---|---|
| Pistiktal | Black soil | | Maize, beans |
| Medio Pistiktal | Gray soil | | Maize |
| Tatahuiktal | Reddish, stony soil | | Pasture, maize |
| Gostiktal | Yellowish soil | Coztli: yellow; Tlacoztli | Maize |
| Istaktal | Whitish soil | Iztac: white; Iztactlalli | Maize |
| Teposhakio | Stony soil | Tepoxca: soft pumice rock; Tepoxcatetlalli | Maize |
| Xalnelijtok | Fine-grained sandy soil | Xalli: sand; Nextli: fine-grained ash; Xallnextli | Maize; Fruit-tree plantation |
| Xalatl | Humid sandy soil | Xalli: sandy: Atl: water, humidity; Xallatl | Maize; Fruit-tree plantation |
| Xalli | Sand | Xalli: sand | Watermelon |
| Pistiksogik | Black mud | Tezoquitl: hard mud | Fruit-tree plantation |
| Gonsogik | Mud | Zoquitl: mud | Pottery clay |

**Source:** Chevalier and Buckles (1995)

Nahua ethnopedology from Pajapan reflects the permanence of pre-Hispanic Middle American knowledge systems at the eve of the 21st century. It shows a well-fitted soil-maize knowledge system in one of the oldest agricultural areas in Mexico (Coe and Diehl, 1980). The Pajapan area is interesting for further ethnopedological research, because of its multiculturality. Five ethnic groups, including Popoluca, Zoque-Popoluca, Mixe, Nahua and *Mestizo* coexist, producing maize on similar soils, allowing for cross-cultural ethnopedological comparisons.

## (7) Tojolabal ethnopedology from Las Cañadas, Chiapas

### (a) Regional context

Tojolabal people are considered a Mayan-rooted ethnic group that developed its own language and history since ancient times (Ruz, 1983). Only 35,000 Tojolabal were recorded in the last indigenous population census (INI, 1993). The majority of Tojolabal lives in the municipality of Santa Margarita in Las Cañadas region, Chiapas (Figure 11.4).

Las Cañadas region is located in southern Mexico, close to the Guatemalan border. Las Cañadas (The Canyons) is a rugged karstic mountain region. It is considered the most important biodiversity hot spot in Middle America (Challenger, 1998). Highly dissected mountains, scarps, steep slopes, hills and elongated vales and valleys constitute the main relief types, covered by evergreen tropical forest, deciduous forest, cloud mountain forest and pine-oak forest (Barrera-Bassols, 1992).

A patchwork of maize fields under shifting cultivation, organic coffee plantations, banana plantations and small-scale cattle raising are the main subsistence activities on communal land (*ejido*). Shaded organic coffee plantations are repositories of high biodiversity, mainly located in indigenous territories of central and southern Mexico (Moguel and Toledo, 1999). Certified organic coffee producers are restricted from using agro-chemicals, such as synthetic nitrogen fertilizers and rely mainly on soil management techniques to provide nutrients to the crop. A substantial part of this environment-friendly agroforestry occurs in Las Cañadas (Moguel and Toledo, 1996).

### (b) Local knowledge of soil fertility enhancement under organic coffee production

Local soil fertility management and enhancement, although not yet well studied in organic coffee agroforestry systems, is assumed to play a critical role. Grossman (2003) did an ethnopedological study on Tzeltal, Tzotzil and Tojolabal organic coffee producers, to understand the soil fertility enhancement practices used for decision making, including knowledge of litter decomposition, soil biology, and biological nitrogen fixation. Farmers were found to have a hybridized knowledge system made up of visible phenomena and information retained from organic training workshops. According to this study, farmers have an excellent understanding of the transformation from leaf material to soil and a good understanding of mineralization, but a limited understanding of moisture influence, nutrient uptake, and soil organisms. The significance of soil biology in decomposition is restricted to the organisms they can see, especially earthworms, while soil microorganisms are rarely recognized and their role in soil processes is not understood.

### (c) Tojolabal soil knowledge and management of elevation agro-ecological zones

Tojolabal farmers from Santa Margarita Agua Azul ejido were studied by Ruz (1983), an anthropologist whose ethnographic accounts show a well-adapted soil and land resources knowledge and management system. Short, partial and descriptive ethnopedological information highlights a vertical agro-ecological management zonation. Local soils are classified within each agroclimatic zone. Farmers assess soil-crop suitability for maize multicropping. The local land- use evaluation system is based on the recognition of soil properties.

Tojolabal farmers recognize six main soil classes according to color, texture, structure, consistence, parent material, moisture retention capacity and relief position. Soil nomenclature is based on color, texture, parent material and relief position. Tojolabal soil classification is not hierarchical. Soil taxa (*Lu'um*) interchangeably refer to as soil, land or terrain. Tojolabal people consider soil as a 3-D natural body and a 2-D land unit. This multidimensional perception allows local farmers to distinguish three main land unit types according to elevation, topography and agro-climatic zones (Table 11.5).

Two managed forest types cover the highlands (*tierras altas*): a tropical evergreen forest in the lower part and a cloud forest on the karstic mountain summits. Rainfall is more than 3,000 mm and temperature ranges from temperate to warm (18-20°C) on the summits. One main soil class is recognized in this agro-ecological belt: *Sejyuptun* or *tierra calosa*, a limestone-originated soil, suitable for shaded organic coffee plantations and banana plantations. Maize cropping is considered less suitable on this soil of low productivity.

Lowlands (*tierras bajas*) are constituted by moderately steep to steep hills located at the mountain footslopes. Rainfall ranges from 2,000 to 3,000 mm and the temperature regime is warm (more that 20°C). Tojolabal farmers recognize two main soil classes within this agro-ecological belt: (1) *Kik' lu'um* or black soil, rich in organic matter and well structured, ranked as suitable for maize-beans production, and (2) *Chakal lu'um* or red soil considered suitable for maize monocropping.

Elongated vales and an elongated valley constitute the bottom-level lands (*tierras muy bajas*). Here, alluvial soils are temporarily or permanently flooded. Four main soil classes are recognized: (1) *Kik lu'um* or black soil, located on the upper margins of the vales and valley, considered similar to the black soil of the lowlands and ranked as the most suitable for *milpa* production; (2) *Lok'ok,* a confined clayey soil, only used for pottery; (3) *Jij k'ab* or sandy soil not suitable for agricultural purposes and only used for pasture; and (4) the *medio-vega* or mixed-alluvial soil, a poorly structured sandy soil, with low fertility and used for one cycle of maize followed by three years of fallow. Under fallow the soil is used for grazing, until it recovers its "strength" with manure application.

**Table 11.5.** Tojolabal agro-ecological nomenclature, soil classes and land-use systems

| Agro-climatic zones | Tojolabal local soil classes | English term | Spanish term | Land use systems |
|---|---|---|---|---|
| **Tierras Altas** (Highlands) | Sejyuptun | Sandstone soil | Tierra calosa | Organic coffee plantations; banana plantations; maize |
| **Tierras Bajas** (Lowlands) | Kik' Lu'um | Black soil | Tierra negra | Maize-beans |
| | Chakal Lu'um | Red soil | Tierra roja | Maize |
| **Tierras muy Bajas** (Bottom level lands) (Flooding lands) | Kik' Lu'um | Black soil | Tierra negra | Maize-beans |
| | Lok'ok | Clayey soil | Barro | |
| | Jij K'ab | Sandy soil | Tierra arenosa | Pasture |
| | Medio vega | Mixed-alluvial soil | Tierra de medio aluvión | One year of maize and three years of fallow; pasture |

**Source:** Ruz (1983)

### 11.3.2. The humid tropical highlands

#### (4) Chinantec ethnopedology from the Sierra Norte de Oaxaca

Martin (1993) gives an example of an indigenous soil and land knowledge and management system in the humid tropical highlands of Middle America. This study reveals how Chinantec people from Santiago Comaltepec municipality in the state of Oaxaca, perceive, recognize, classify and manage soil and land resources in detailed ways, using a broader ethnoecological approach. Critical to this are the Chinantec agroecological zoning and soil fertility assessment.

#### (a) Regional context

Chinantla, the historic territory of the Chinantec, is located in the Sierra Norte de Oaxaca, within the limits of the Gulf and Oaxaca regions (Figure 11.4). Chinantla forms part of a large multicultural area neighboring the Mazatec, Zapotec and Mixe peoples, and is considered one of the most indigenous areas of Mexico. More than 90,000 Chinantec inhabitants were registered in the last indigenous population census (INI, 1993), ranking as an intermediate ethnic group by population size. The Sierra Norte de Oaxaca constitutes a complex and deeply dissected mountain range of 10,000 square kilometers, ranging from 320 to 3,400 m.a.s.l. This area can be divided into four agro-ecological zones: (a) the humid tropical lands; (b) the humid temperate highlands; (c) the sub-humid temperate highlands; and (d) the sub-humid tropical lands.

#### (b) Chinantec ethnoecological knowledge

Chinantec people have sophisticated and complex ecological knowledge of their environment. They recognize distinct environmental units at multi-scale spatial and temporal levels. Environmental discrete differences at regional, meso- and micro-levels are discriminated according to structural, relational, dynamic and processual dimensions. Five main ecological domains are distinguished: (1) soil and land resources; (2) climate and topography; (3) vegetation cover; (4) ecological succession of various vegetation types and species; and (5) land-use systems. Chinantec ethnoecology resembles the natural complexity of the tropical environments.

Their subsistence strategy mirrors an on-site adaptation to the ecological units and reflects a long-standing multiple use of the natural resources.

Chinantec recognize five vertical agro-ecological zones (Table 11.6 and figure 11.7.). This zonation is more detailed than the one conventionally used to subdivide the region (*Tierra caliente* or hot land, *tierra templada* or temperate land, and *tierra fría* or cold land). Zonation is labeled according to elevation, temperature, precipitation, topography, exposure, vegetation type and land-use. Chinantec from Santiago Comaltepec municipality have access to these five agro-ecological zones spanning a topographic and ecological gradient of some 45 kilometers. Several indigenous communities are distributed along this agro-ecological gradient, where local farmers have access to communal and private lands. These agro-ecological zones are: (1) humid tropical lowland; (2) humid tropical highland; (3) cold land; (4) sub-humid temperate land; and (5) semi-arid warm land.

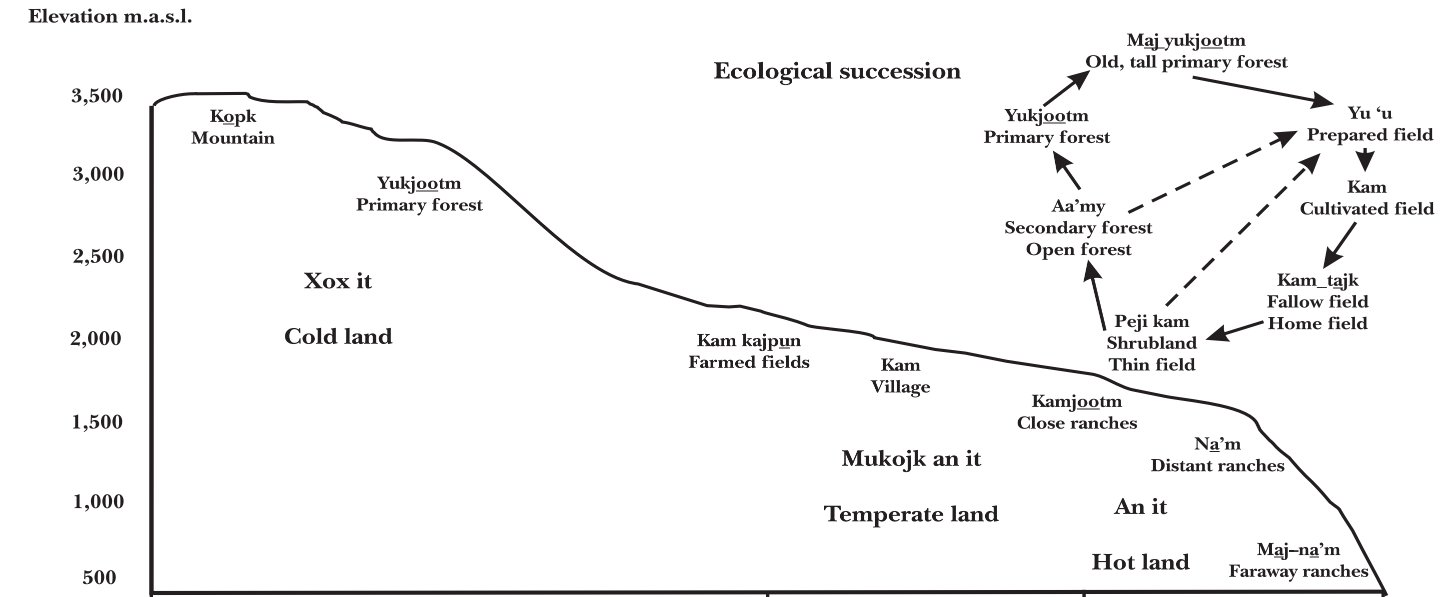
**Table 11.6.** Agro-ecological zones according to the Chinantec from Oaxaca

| Agro-ecological zone | Location | Elevation range m.a.s.l. | Rainfall mm/yr. | Temperature °C | Vegetation and land use |
|---|---|---|---|---|---|
| **Humid warm land** (G$^{w}$óo'$^{LH}$ ginée$^{L}$)[1] | The Gulf Escarpment; a sharp mountain slope facing the Gulf of Mexico | 100-1,000 | 3,000-4,000 | 21-25 | Diverse types of tropical evergreen forest are distributed in a patchwork-like pattern with milpa fields, citrus, banana and vanilla plantations and pastureland. |
| **The humid temperate land** (G$^{w}$óo'$^{LH}$ ojmi$^{H}$)[1] | Comprises the Intermediate mountains of the Gulf Escarpment | 1,000-2,200 | 2,500-3,500 | 16-20 | A dense cloud forest is intermixed with milpa fields and small plots of shaded organic coffee plantations. Hunting and fishing, plant and mushroom gathering and homegardening constitute subsistence activities |
| **Cold land** (G$^{w}$óo'$^{LH}$ g$^{w}$í'$^{L}$)[1] | Comprises the high sierra and mountain peaks | 2,200-3,400 | 2,000-2,700 | 9-14 | Coniferous forests intermixed with milpa fields. Pine logging constitutes an important commercial activity |
| **Dry temperate land** (G$^{w}$óo'$^{LH}$ kɨʉʉ$^{L}$)[1] | Comprises the upper slopes of the Interior Escarpment facing, the valley of Oaxaca | 1,500-2,000 | 1,300-2,000 | 15-18 | A dense oak-pine forest cover is intermixed with milpa fields. Sheep and fuel wood collection are important but secondary activities |
| **Dry hot land** (G$^{w}$óo'$^{LH}$ gíi$^{M}$)[1] | Comprises the piedmont of the Interior Escarpment | 1,000-2,300 | 800-1,300 | 16-21 | Sparsely covered by deciduous tropical forest intermixed with milpa fields. Commercial maize and wheat monocropping are also important |

**Source:** Martin (1993); (1) Phonetic name in Chinantec

## (c) Chinantec soil knowledge

Chinantec farmers recognize nine main soil types and four sub-types as part of their broader ecological knowledge. Color, texture, structure, consistence, organic matter, moisture retention capacity, drainage condition and stoniness are assessed to classify soils. Color, structure, consistence, stoniness and lime content are the main soil descriptors used to name soil types. Apparently, Chinantec soil classification is hierarchical.




| | | | |
|---|---|---|---|
| **Distance** | **20 km** | **5 km** | **20 km** |
| **Cultural description** | Wild area, non-inhabitated, associated with sacred rites, better known by adult men than other members of the community | Domesticated area; the *Tajk* 'house' surrounded by the *Atok* 'home garden' is the center of domestic activities | Mixture of wild and domesticated areas; secondary residences associated with a relatively rustic lifestyle |
| **Subsistence activities** | Cutting of hardwood and pines for construction; gathering of wild edible and medicinal plants; hunting | Cultivation of maize, beans and other crops; gathering of semi-cultivated greens and firewood | Cultivation of maize and other crops, especially a variety of native and exotic beans; gathering of semi-cultivated and wild useful plants |
| **Commercial activities** | None | Maize harvest partially marketed locally; imported plants sold in stores and market | Coffee growing; production of bananas, citrus fruits and other tropical crops for local sale and consumption |

**Figure 11.7.** Chinantec ethnoecological cross-section. **Source:** Martin (1993)

Different sandy soils (*G$^{w}$óo’$^{LH}$ tóo$^{LH}$*) are recognized according to color and fertility. Soil fertility assessment is critical for Chinantec farmers. Six soil properties are used to assess soil fertility: color, organic matter, texture, structure, moisture retention capacity and drainage conditions. Black soils (*G$^{w}$óo’$^{LH}$ ‘ui’$^{M}$*) are considered to be the most suitable for agriculture, whilst red, yellow and white soils are ranked as less suitable, respectively. A white sandy soil is considered to have low fertility and to be eroded, and is recognized as a leached soil (*G$^{w}$óo’$^{LH}$ sii$^{L}$*). Swampy soils (*G$^{w}$óo’$^{LH}$ ñuu$^{L}$*) are considered unsuitable for agriculture due to poor drainage conditions. Table 11.7. shows the eight main soil types and four soil classes and their local ranking for agricultural purposes.

The Chinantec soil term (*G$^{w}$óo’$^{LH}$*) is interchangeably used to refer to soil resources or agro-ecological zones, while the term (*Jee$^{L}$*) refers to specific land units, being either cultivated, fallowed or forested (Figure 11.6). The term land unit is also used to label different ecological succession stages of shifting cultivation. It refers to temporal attributes of land units and is linked to soil fertility replenishment stages of these units. In this way, Chinantec recognize seven ecological succession stages in the dry tropical deciduous forest, ranging from the primary forest stage to the cultivated field stage (Figure 11.7). More complex is the recognition of the ecological succession stages in the humid tropical forests. Chinantec recognize at least 10 ecological stages (Figure 11.7). They also recognize that succession in the humid forest is not an unilineal process, but can result in diverse secondary vegetation types depending on several ecological factors. Chinantec recognition of differences in dominant species, time of recovery and height of the secondary forest is based on microclimatic and topographic conditions and the way forest patches are managed to recover soil fertility and be cropped again. Natural ecological processes and management of forest patches gave rise to a patchwork-like land unit pattern in the Chinantec humid and temperate lands.

### (d) Chinantec recognition of plants as indicators of soil fertility

Plant species and plant associations as indicators of soil fertility are recognized according to vegetational succession stages and vegetation types. Secondary shrub dominated by *Mimosa albida* (*‘míi’$^{LH}$ tocu’$^{LM}$*), a weedy medicinal plant, is believed to enrich the soil. Depleted soils form patches of *Sticherus brevispubis* (*‘míi’$^{LH}$ minoo$^{H}$ jii’$^{LH}$*), while a slightly richer soil gives rise to fern trees, *Alsophila firma* (*‘míi’$^{LH}$ minoo$^{H}$ tóo$^{LM}$*). *Heliconia spp.* (*‘míi’$^{LH}$ mosii$^{M}$*) or *Canna spp.* (*‘míi’$^{LH}$ moikiu$^{MH}$*) large herbaceous monocots grow on humid, fertile soils. Small trees and large shrubs replace the ferns during the ‘slander secondary vegetation stage’. At this stage, Chinantec recognize other dominant species that indicate the soil fertility replenishment status. Low fertility soils are colonized by assemblies of plants such as *Vismia mexicana* (*‘míi’$^{LH}$ manée$^{M}$*) and *Hedyosmum mexicanum* (*‘míi’$^{LH}$ macrúu$^{H}$*), while richer soils support tree clusters dominated by species such as *Liquidambar styraciflua* (*‘míi’$^{LH}$ malea$^{LH}$*) and *Rapanea spp.* (*‘míi’$^{LH}$ majli$^{HL}$*).

Chinantec ethnopedology from Santiago Comaltepec reflects the intimate and long-standing relation of local farmers with their land resources. This local knowledge-based system seems to be shared by Chinantec from other municipalities and communities, reflecting a regional ethnopedology, always adapted to local environmental and economic contexts. Lucero and Avila (1974) found similar Chinantec soil classes in Ojitlán municipality, but with local emphasis on the relief position of the soil classes. Farmers of Ojitlán and Santiago Comaltepec use similar soil taxonomic principles and the relation between land-uses and soil taxa are similar as well. Similar is also the way Chinantec from different municipalities rank soil classes for agricultural purposes. Differences possibly reflect more the depth of analysis and the research approach taken in each case study rather than the Chinantec perception, classification and management of soil and land resources.

## **(5)** Mixe ethnopedology from the Sierra Norte de Oaxaca

### (a) Regional context

Mixe people are close neighbors of the Chinantec, both having a well-defined territory within the Sierra Norte de Oaxaca (Figure 11.4). Around 90,000 Mixe inhabitants were recorded by the last indigenous census (INI, 1993), a population size similar to the Chinantec. Mixe and Chinantec share similar ecological conditions but their cultural histories are distinct. They both speak contrasting languages, have their own Middle American syncretic cosmovisions and consider themselves different. Mixe developed a complex ecological knowledge, but share with the Chinantec similar land management practices that are based on *milpa* agriculture. Because of these similarities, it is interesting to analyze the way Mixe recognize, classify and manage soil and land resources and compare it with the soil and land knowledge system of the Chinantec. The vertical zonation of land-use and the assessment of soil fertility are key components of both ethnopedologies.

**Table 11.7.** Chinantec soil classes and suitability assessment for agriculture

| Chinantec soil taxa | Soil description | Agricultural ranking |
|---|---|---|
| G$^{w}$óo'$^{LH}$ 'ui'$^{M}$ (**Black soil**) | Rich in organic matter and consistently humid | Highly suitable |
| G$^{w}$óo'$^{LH}$ yúu$^{M}$ (**Red soil**) | Must be fallowed more often than black soil | Intermediate suitable |
| G$^{w}$óo'$^{LH}$ née$^{M}$ (**Yellow soil**) | Must be fallowed more often than black soil. Similar properties than red soil | Intermediate suitable |
| G$^{w}$óo'$^{LH}$ née$^{M}$te'$^{M}$ (**Sticky yellow soil**) | Difficult to plow and work; Pottery making | Not suitable |
| G$^{w}$óo'$^{LH}$ ro$^{L}$ (**Green soil**) | Uncommon soil type restricted to areas of mineral outwash | Low suitable |
| G$^{w}$óo'$^{LH}$ tóo$^{LH}$ (**Sandy soil**) | Found along river banks; it is nutrient-rich and well-drained but subjected to flooding | Low suitable |
| G$^{w}$óo'$^{LH}$ tóo$^{LH}$ ui'$^{M}$ (**Black sandy soil**) | Temporarily flooded | Low suitable |
| G$^{w}$óo'$^{LH}$ tóo$^{LH}$née$^{M}$ (**Yellow sandy soil**) | Temporarily flooded | Not suitable |
| G$^{w}$óo'$^{LH}$ tóo$^{LH}$ tee$^{L}$ (**White sandy soil**) | Temporarily flooded | Not suitable |
| G$^{w}$óo'$^{LH}$ sii$^{LH}$ (**Gravelly soil**) | Well-drained soil but quite poor in nutrients | Low suitable |
| G$^{w}$óo'$^{LH}$ tee$^{L}$ (**White soil**) | Poor quality soil never cultivated; considered leached soil | Not suitable |
| G$^{w}$óo'$^{LH}$ kuloo$^{MH}$ (**Chalky soil**) | Considered non-suitable for agriculture; Lime extraction for tortilla preparation | Not suitable |
| G$^{w}$óo'$^{LH}$ ñuu$^{L}$ (**Swampy soil**) | Permanently flooded | Not suitable |

**Source:** Martin (1993)

Martin (1993) studied the Mixe ecological knowledge system from Totontepec municipality. Totontepec is located in the Sierra Mixe, and its territory ranges from 500 to 3,000 m.a.s.l. (Figure 11.8.). Shifting cultivation based on *milpa* production, shaded coffee plantations and citrus plantations are the main subsistence activities carried out within several agro-ecological zones according to temperature, precipitation, elevation and slope exposure.

### (b) Mixe agro-ecological zonation

Mixe from Totontepec recognize three agro-ecological zones within their municipality lands (Table 11.8 and figure 11.8): (1) hot land; (2) temperate land; and (3) cold land.

### (c) Mixe ethnopedology, land-use evaluation and soil fertility assessment

Mixe farmers have a detailed soil knowledge system, including nine main soil classes recognized within the three agro-ecological zones according to soil-relief position. They handle a relief nomenclature together with climatic and meteorological knowledge at regional, meso- and micro -scales. Temperature and moisture regimes, slope aspect and soil classes are assessed for land-use evaluation purposes at parcel level. Soils are classified according to color, texture, structure, stoniness, moisture retention capacity and drainage conditions. Color, texture and stoniness are main properties used to name soils.

Apparently, the Mixe soil classification is not hierarchical, but this must be still confirmed. Soils (*Naax*) are ranked according to moisture retention capacity and drainage conditions for their agricultural potential. Dry soils (*Ta'ajts naax*) are considered "weak" or poor for planting. They are located on slopes and summits. They are "thirsty" soils, always consuming water. Swampy soils (*Nil naax*) are also assessed as non-agricultural soils. They are temporarily waterlogged due to their position at the bottom of gorges and ravines. On the contrary, good soils (*Oy naax*) for agricultural activities are the black soils (*Yk naax*) and the recently 'burned' soils (*Tooy naax*) after slash-and-burn. These soils are considered "strong" soils, with good structure, high organic matter content and good moisture retention capacity. Table 11.9 shows Mixe soil classes and their ranking for agricultural purposes.

**Table 11.8.** Agro-ecological zones according to the Mixe from Oaxaca

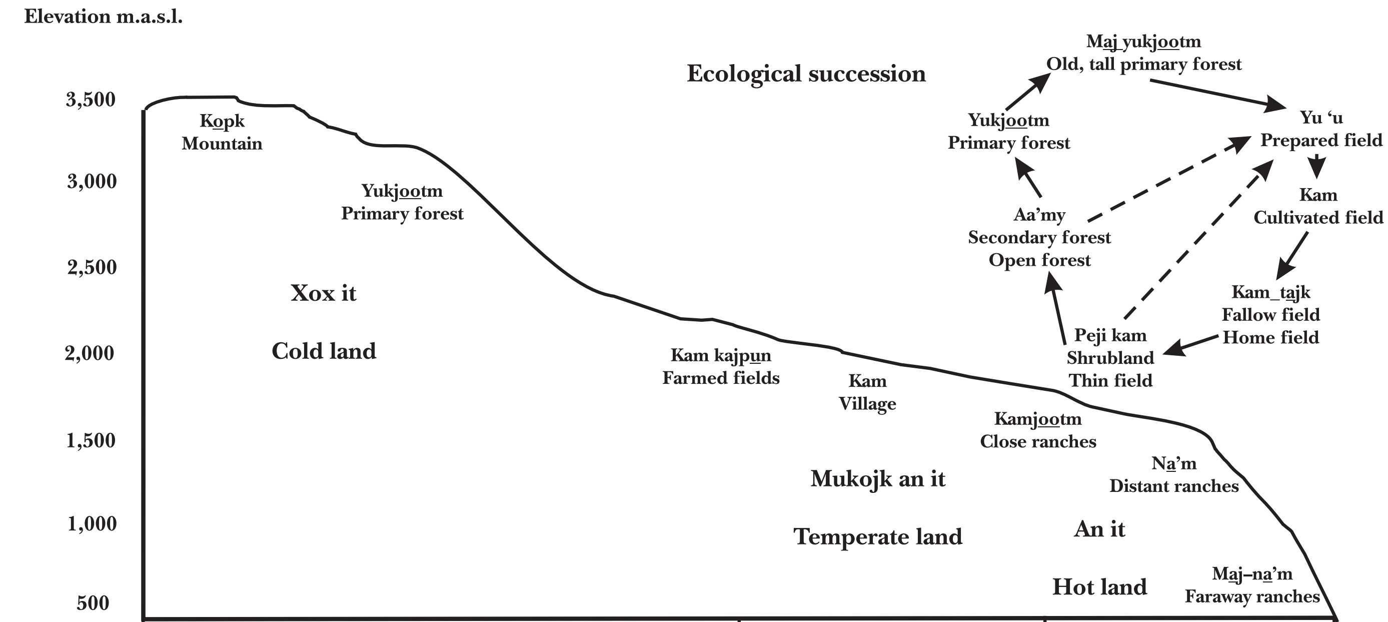
| Agro-ecological zone | Location | Elevation range m.a.s.l. | Rainfall mm/yr. | Temperature $^{0}$C | Vegetation and land use |
|---|---|---|---|---|---|
| **Hot land** (An it) | Comprises the footslopes of the Sierra Mixe | 400-1,400 | 2,100-2.500 | 20-30 | Various types of tropical evergreen forest and the lower rim of a cloud forest cover this agro-ecological belt in a patchwork-like pattern. Shaded coffee plantations, citrus plantations, small cattle ranching and milpa shifting cultivation are the main commercial and subsistence activities |
| **Temperate land** (Muhojk an it) | Comprises the intermediate mountains facing the Gulf of Mexico | 1,400-2,000 | 1,700-2,100 | 19-24 | Agricultural fields are scattered within a dense cloud forest. Shaded coffee plantations and milpa shifting cultivation constitute the main commercial and subsistence strategies |
| **Cold land** (Xax it) | Comprises the high Sierra Mixe | 2,000-3,400 | 1,300-1,700 | 16-20 | Covered by a dense cloud forest and various types of pine-oak forest. This area is unhinabited and locally considered sacred. Fuel wood collection, logging, hunting and plant gathering are the main extractive strategies |

**Source:** Martin (1993)

Mixe farmers make a clear-cut distinction between soil (*Naax*), field (*Kam*) and land or agro-ecological zone (*It*). These three domains are considered intimately linked. Mixe understanding of ecological succession is detailed and assessed through on-site recognition of the status of these three domains. Eight vegetational stages are recognized according to soil fertility status, type of field (agricultural parcel, fallowed plot, managed forest, etc.), vegetation structure and composition of vegetation types (Figure 11.8).

Soil fertility assessment is critical for Mixe agricultural decision-making under shifting cultivation. They recognize specific soil-plant relations to assess the soil fertility status of cultivated and fallow lands. This is done similarly to Chinantec procedures. Some plant species are indicators of nutrient-rich soils or sites where soils are depleted. Fallow fields dominated by *Alnus acuminata* (*Ke'emajka*) stands are searched because highly fertile soils develop beneath this nitrogen-fixing tree. On the contrary, soils covered by *Pteridium aquilinum* (*Kaa'tsimi*) are avoided, since they are "weak" and incapable of supporting crops.

Mixe recognition, classification and management of soil resources are complex, although apparently less detailed than the Chinantec ethnopedology (Martin, 1993). Ethnopedological information supports




| | | | |
|---|---|---|---|
| **Distance** | **20 km** | **5 km** | **20 km** |
| **Cultural description** | Wild area, non-inhabitated, associated with sacred rites, better known by adult men than other members of the community | Domesticated area; the *Tajk* 'house' surrounded by the *Atok* 'home garden' is the center of domestic activities | Mixture of wild and domesticated areas; secondary residences associated with a relatively rustic lifestyle |
| **Subsistence activities** | Cutting of hardwood and pines for construction; gathering of wild edible and medicinal plants; hunting | Cultivation of maize, beans and other crops; gathering of semi-cultivated greens and firewood | Cultivation of maize and other crops, especially a variety of native and exotic beans; gathering of semi-cultivated and wild useful plants |
| **Commercial activities** | None | Maize harvest partially marketed locally; imported plants sold in stores and market | Coffee growing; production of bananas, citrus fruits and other tropical crops for local sale and consumption |

**Figure 11.8.** Mixe ethnoecological cross-section. **Source:** Martin (1993)

**Table 11.9.** Mixe soil classes, soil-relief position, agricultural ranking and soil quality assessment

| Soil classes | English term | Relief position | Agricultural ranking | Soil qualities assessment |
|---|---|---|---|---|
| Tsa naax (Tierra pedregosa) | Stony soil | Bottom level of gorges and ravines; fluvial terraces | R1 | High organic matter content; stones help moisture retention; good drainage conditions |
| Yk naax (Tierra negra) | Black soil | Flat lands and hill footslopes | R1 | High organic matter content; good structure; good moisture retention capacity and drainage conditions |
| Tsapts naax (Tierra roja) | Red soil | Hilly lands | R2 | Mixed with gravelly soils; sticky; good organic matter content; good moisture retention capacity; good drainage conditions when normal rainfall regime but waterlogged when excessive rainfall |
| Po'ts naax (Tierra amarilla) | Yellow soil | Hilly lands and gorges | R3 | Mixed with gravelly and red soils; not good drainage conditions, but depend on rainfall and the amount of gravelly and red soil mixtures |
| Jok naax (Tierra polvillo) | Dusty soil | Mountain summits | R3 | Mixed with sandy and gravelly soils; poor moisture retention capacity; excessive drainage |
| P'p naax (Tierra blanca) | White soil | Banks of fluvial terraces | NS | Mixed with sand and gravel; considered not suitable for agriculture; very sticky when wet |
| N'tsts naax (Tierra arcillosa) | Clay soil | | NS | Not suitable for agricultural purposes; used for pottery making |
| Po'o naax (Tierra arenosa) | Sandy soil | Banks of fluvial terraces | NS | Low organic matter content; poor moisture retention capacity; excessive drainage |
| Naxtsaaj (Tierra gravosa) | Gravelly soil | Banks of fluvial terraces | NS | Low organic matter content; poor moisture retention capacity; excessive drainage |

**Sources:** Martínez (1982) and Martin (1993); Soil quality ranking for agricultural purposes: R1= High quality; R2= Intermediate quality; R3= Low quality; NS= Not suitable soil for agricultural purposes

a culturally based recognition of soil and land resources and soil fertility management at regional level. A study carried out in the Mixe municipality of Santa María Tlahuilotepec, close to Totontepec municipality, reflects a common soil and land knowledge-based system evolved in the Sierra Norte de Oaxaca (Martínez, 1982). Mixe deep understanding of ecological succession is crucial for on-site soil fertility assessment, linked to shifting cultivation practices. The study of the soil fertility assessment is more relevant to evaluate the Mixe ethnopedology than the analysis of the Mixe soil classification *per se*, which appears to be simple. Comparison between Chinantec and Mixe ethnopedologies could offer insight on similarities and differences between two indigenous communities that have different cultural backgrounds but share similar ecological contexts.

## (6) *Mestizo* ethnopedology from Central Chiapas

### (a) Regional context

*Mestizo* farmers from Vicente Guerrero, an ejido pertaining to Central Chiapas, possess a detailed soil knowledge system that supports maize variety choices under heterogeneous pedological conditions, partial technological innovation adoption and uncertain market conditions (Bellón, 1990). *Mestizo* farmers are now Spanish speaking, but they consider themselves as descendents of the Zoque people. By the end of the 1980s, Vicente Guerrero was a prosperous ejido based on maize production for subsistence and commercial purposes. Over the last 30 years the production strategy is based on the partial adoption of technological innovations, such as chemical fertilization, introduction of high-yielding maize varieties (HYV) and mechanization, while maintaining local maize varieties (LV) cultivated in swidden plots.

Ethnopedological, agronomic and econometric research findings show a significant relationship between Vicente Guerrero farmers' knowledge with regard to maize varieties and local soils and their technology adoption decisions (Brush et al., 1988; Bellón, 1990, 1993; Bellón and Brush, 1994; Bellón and Taylor, 1993). Farmers are able to match maize varieties with local soil qualities in a predictable way.

Vicente Guerrero ejido is located within the Ocozocuautla municipality, on the margins of the Grijalva River (Figure 11.4). Because of its elevation (800-900 m.a.s.l.), it forms part of the intermediate lands in the state of Chiapas. Temperature (24° C) and rainfall (900–1,000 mm) correspond to the interface between sub-humid and humid tropical lands. Plow agriculture (locally called *arado*) and swidden agriculture (locally called *pedregal*) based on *milpa* production are the main local agricultural systems. Plow agriculture is practiced on flat lands with low stoniness. Agricultural parcels are continuously used, with the application of high rates of chemical fertilizers. Parcels are permanently assigned as household properties. Swidden agriculture (locally called *pedregal*) is practiced on stony hills with forest cover. The use of a digging stick, cropping from one to five years and seven-year fallow are the main technical characteristics of this farming system. Agricultural parcels on these lands are collectively owned and parceled out on request. The local average yield of maize is 2.4 ton/ha, quite more than the national average of 1.5 ton/ha (Bellón and Brush, 1994).

(b) Local soil knowledge and soil quality assessment

*Mestizo* ejidatarios recognize five soil classes according to color, texture, workability, moisture retention capacity and fertility. Soil classification is rather simple and soil nomenclature is based on color, texture and stoniness. All farmers know all soil names, but not all of them know the specific properties of a soil they have never cultivated. This shows an individually oriented but shared soil expertise, according to experience, age, social status and, to some extent, schooling and farm size.

Color, organic matter content, productivity, texture, consistence, moisture retention capacity, drainage conditions, stoniness and relief position are used for agricultural soil quality assessment. Laboratory determinations show strong correlation with the local soil quality ranking: (1) soil ranking by measured organic matter content is similar to farmers' ranking of soil productivity; (2) low organic matter and large sand contents, indicating limited moisture retention capacity and excessive drainage, were ranked by locals as having intermediate to low quality (soils ranked as R3 and R4 in table 11.10.); (3) pH levels of all local soil classes are in the optimal range for maize production except for soil class ranked as R4, showing a strong correlation between soil-maize suitability and *milpa* land-use.

(c) Ranking of local maize varieties

Similarly to local soil classification and soil quality assessment, ejidatarios from Vicente Guerrero possess a detailed classification of locally used HYV maize, intermediate or 'creole' maize varieties (IMV), and traditional local varieties or landraces (LV). Fifteen maize varieties were found locally, pertaining to six distinct maize races. Locally grown maize races account for 19% of the maize races found in Mexico and 15% of the maize races found in Middle America. Many local varieties of maize or landraces, are mixtures of two or more races. The maintenance of a highly diverse genetic pool of maize in a small area (5,215 ha) requires a complex management of maize fields and, thorough understanding of maize phenology to control maize variability, specially when local and improved open-pollinated maize varieties compete for farmers' selection. Farmers have been able to balance the competition of these two types of maize. Knowledge and management of heterogeneous genetic pools and heterogeneous pedological conditions are crucial to understand the maintenance of maize variability under these circumstances.

Farmers' perception of positive and negative characteristics of maize varieties is based on three main factors: (1) varietal response to ecological conditions (wind, drought, weeds, and performance with intercropping); (2) technological requirements of maize varieties (input intensity, timing of cultural practices); and (3) yield and use of

**Table 11.10.** Correlation between local soil quality assessment and laboratory determinations of local soil classes

| Local soil class | Organic matter % | pH $H_2O$ 1:2.5 | Sand % | Clay % | Local soil quality ranking | Local soil descriptors |
|---|---|---|---|---|---|---|
| **Tierra negra** (Black soil) | 8.7 | 6.7 | 38 | 36 | R1 **Best** | Strong soil; yields well; releases nutrients slowly to the plant; sticky; can be waterlogged on level lands during wet years; drought resistant during dry years |
| **Tierra baya** (Red-brownish soil) **Tierra colorada** (Red soil) | 5.9 | 6.4 | 49 | 26 | R2 **Good** | Hold moisture well and do not suffer from drainage problems |
| **Tierra colorada-arenosa** (Sandy red soil) | 3.3 | 6.1 | 65 | 23 | R3 **Intermediate** | Lower moisture holding capacity and may suffer from drought during dry years |
| **Tierra cascajosa** (Gravelly soil) | 1.7 | 7.3 | 68 | 14 | R4 **Low** | Lowest moisture holding capacity and may suffer from drought during dry years |
| **P- value** | .0000 | .000 1 | .000 0 | .000 4 | | |

**Source:** Bellón and Taylor (1993)

each maize variety (aptness for subsistence or market, storage properties, taste). *Ejidatarios* ranked the three most important locally-grown maize varieties according to the following characteristics:

- Farmers perceive *Tuxpeño* HYV maize as having major advantages compared to local varieties: short growing cycle, drought avoidance, short height, resistance to lodging, and relatively high yield but with intensive input. Major disadvantage of this variety is its high sensitivity to growing agro-ecological conditions (*delicado* in local terms). Environmental conditions and timing of the cultural practices are critical to performance. *Tuxpeño* is one of the most productive maize races in the world. Suited for fertile soils, *Tuxpeño* dominated commercial maize production in Chiapas during the 1980s. Chiapas was ranked as the third most important maize producer of Mexico by that time. *Tuxpeño* V-524 is an open-pollinated variety referred to as *Tuxpeño*, although other *Tuxpeño* varieties are also locally grown.
- *Híbrido Amarillo* or Yellow Hybrid was the second most important maize variety (IMV) locally grown. Farmers perceive *Híbrido Amarillo* as having intermediate advantages and disadvantages on the performance spectrum between HYV and LV. This IMV yields higher by weight and is more resistant to drought (*aguantador* in local terms) than the HYV *Tuxpeño*. *Híbrido Amarillo* is recognized as a creole variety belonging to the *Argentino* race. Creole cultivars are originally improved varieties that have mixed with local landraces and acquired characteristics similar to those of the landraces. This maize variety is the most important cultivar on the slopes of the Vicente Guerrero ejido.
- *Olotillo* is the most important LV maize in Vicente Guerrero. It has a long history of adaptation to specific environments in Mexico and is a descendant of crosses with ancient indigenous races. It has a long growing cycle, is resistant to drought and lodging, needs low input intensity, but produces low yields. Local *Olotillo* varieties are cultivated on flat and hilly lands, but are specially suited for poor or unfertilized soils. Farmers consider *Olotillo* as the most resistant (*aguantador*) maize variety and especially tolerant to late weeding.

Farmers use four main agronomic criteria to select maize varieties, namely: (1) performance on different soil types, (2) ability to withstand wind, (3) drought resistance, and (4) tolerance to poorly-timed inputs such as fertilizer application or weeding. On average, each farmer plants three maize varieties and manages 2.5 different soil classes. Maize varieties are valued for different soil classes and different levels of risk. Complete variety specialization is the exception, not the rule. Farmers, who adopted HVY varieties, did not totally abandon the local varieties or landraces.

### (d) *Mestizo* soil quality assessment and maize variety adoption

An econometric model was developed to test the hypothesis that local soil taxonomy significantly influences maize variety choice (Bellón and Taylor, 1993). The analysis of technology adoption decisions was performed using farm data from a field questionnaire. Empirical data included: (a) the areas planted with HYV, IMV and LV; (b) the areas in different local soil ranking classes (R1 to R4); and (c) socio-economic variables such as farmers' age, schooling, income level, number of adult children on the farm and off-farm income. The econometric findings support the hypothesis that the local soil classification significantly controls maize variety selection. Some of the relevant findings of this analysis were:

- the highest quality ranked black soil (R1) has a significant positive association with the area planted with HYVs and IMVs. On the contrary, black soil has no significant effect on the area planted with LVs;
- as soil quality decreases, farmers shift first to IMVs and then to the more robust LVs. The lowest quality ranked gravelly soil (R4) has a significant positive association with the area planted with LVs, but no significant positive effect on the area planted with HYVs and IMVs;
- The IMVs are the only varieties that are significantly matched with the intermediate quality ranked sandy red soil (R3), and
- no soil quality class, except the gravelly soil (R4), has a significant effect on the area planted with LVs.

Findings reveal that LVs grown in Vicente Guerrero are preferred to the high-yielding varieties in low-quality soils, while HYVs and IMVs are favored on best-quality soils, where all varieties are likely to perform optimally but where HYVs are likely to have an absolute advantage over LVs. LVs are associated with low-input, familial rather than commercial production. Younger farmers allocate a significantly larger area to HYVs than older farmers do. Similarly, rich farmers allocate 2.5 more area to HYVs than medium and poor farmers do. Findings also reveal that local soil taxonomy reflects scientific soil properties and significantly explains the partial adoption of HYVs on individual farms for commercial purposes, while LVs are allocated to less productive land for subsistence needs. This production strategy maintains a high diversity of maize varieties that meets the local needs.

## 11.4. THE SUB-HUMID TROPICAL ZONE

Two local studies representing the sub-humid tropical lands were analyzed. Both are located in Mexico and illustrate a *Mestizo* ethnopedology from the Gulf of Mexico lowlands and an indigenous ethnopedology from the Mexican Pacific lowlands (Figure 11.9).

### (7) *Mestizo* ethnopedology from Central Veracruz

Mestizo ethnopedological knowledge from central Veracruz evidences complexity and sophistication, which contrasts with the assumption that *Mestizo* farmers of tropical lowlands have less accurate knowledge about natural resources, because they have recently re-colonized these lands and because they do not posses a strongly-rooted Middle American indigenous culture (language, traditions, syncretic religion, historical territory, etc.).

### (a) Regional context

*Ejidatarios* or small farmers from three coastal municipalities close to Veracruz City, the largest port of Mexico, have access to land as social property (*ejidos*) (Figure 11.9.). Mechanized rainfed agriculture based on maize and vegetable cropping, fruit-tree plantations (mango and papaya) and cattle ranching are the main production systems. The Mexican federal government during the 1930s granted Cantarranas, Hato de la Higuera, Rancho Nuevo and La Brecha *ejidos*. Nowadays, these *ejidos* belong to Puente Nacional, Paso de Ovejas and Jamapa municipalities. Since the 1930s, farmers combine subsistence activities with cash cropping and small-scale commercial cattle raising (Licona, 1991, 1992; Cruz, 1994). The *ejidos* are located in the central coastal plains of the Gulf of Mexico, consisting of gently sloping lands, deeply dissected by meandering rivers forming gorges or barrancos, interfluvial flat lands, gently sloping rounded hills and elongated valleys. Cambisols, Arenosols, Luvisols and Fluvisols are the main soils according to the FAO/UNESCO/DETENAL soil map.

### (b) Main ethnopedological research findings

Several studies carried out by agronomists on land-use evaluation, soil cartography and ethnopedology, demonstrate that *ejidatarios* recognize, classify and manage soil and land resources in complex ways (Cruz, 1994; Licona, 1991, 1992; Licona et al., 1992). *Ejidatarios* also possess detailed mental maps of the land classes. Soil mapping at parcel, local and regional levels were carried out applying the farmers' peculiar spatial land knowledge. Conventional techniques, such as photo-interpretation and soil sampling, were combined with intensive dialogue between technicians and farmers at field sites to produce accurate soil maps. This peculiar soil mapping had an accuracy of 86%, based just on photo-interpretation and an accuracy of 100% after participatory field appraisal. Farmers from various *ejidos* share similar knowledge of land classes, despite differences in labeling the soil units.

Farmer communities handle a well-structured social theory about soil and land resources despite individual cognitive differences according to age, access to different land classes and agricultural specialization. There are sharp soil and land knowledge differences between agriculturists and cattle raisers. Farmers involved in cattle raising have less accurate ethnopedological knowledge and interest about these resources because they focus more on herd improvements using external inputs (forage, synthetic food, medicines, genetic devices, interbreeding, etc.). Soil erosion due to overexploitation of pasture land was not of concern to cattle raisers, but perceived as detrimental to soil health by farmers involved in agriculture or mixed activities. Overexploitation of rangeland is one of the most important causes of land degradation in the hilly terrains of the Mexican tropics (Barrera-Bassols, 1995).

### (c) Local and technical soil classifications

There are differences between local and technical soil classes because *ejidatarios* are more concerned with recognizing soil properties in the arable layer, while soil surveyors consider all horizons to classify soils. Farmer soil classification is more detailed than the one established by technical procedures, using the FAO/UNESCO/DETENAL legend. Topsoil differences are locally recognized, which may pertain to similar soil classes, according to the technical soil classification.

Two main differences were found: (1) several local soil classes correspond to a single FAO/UNESCO soil class; and (2) a single local soil class corresponds to two FAO/UNESCO soil classes (Table 11.11). The first case is exemplified by two local soil classes, *cantilillo* (soil on the scarp) and *negra polvilla* (dusty black soil), that correspond to a Dystrict Leptosol. Both local classes have an ochric A horizon but, *cantilillo* presents more than 80% stoniness over the whole profile while *negra polvilla* has a subsurface hardpan (*capa dura* or *tepetate*) after the first 45 cm of the profile. Ejidatarios consider these two soil classes different because they require different management practices. *Cantilillo* is used as forestland, while local farmers rank *negra polvilla* as one of the best agricultural soils. The local soil class *arena* (sandy soil) illustrates the second case. *Arena* correlates with two FAO/UNESCO soil classes (Table 11.11.): Haplic Arenosol and Eutric Cambisol. *Arena* is recognized by the amount of sand within the arable layer using touching and feeling procedures, overruling differentiating criteria taken into account by the technical classification.

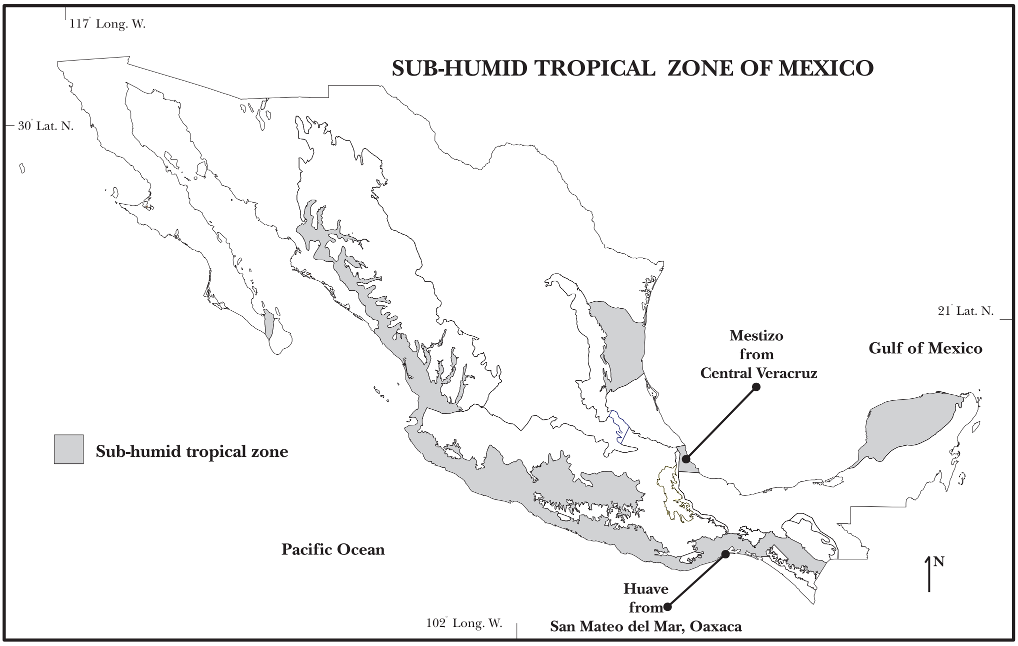



**Figure 11.9.** The sub-humid tropical zone of Mexico

**Table 11.11.** Correlation between *Mestizo* and FAO/UNESCO soil classes

| Local soil classes | English terms | FAO/UNESCO soil classes |
|---|---|---|
| **Arena** | Sandy soil | Haplic Arenosol<br>Eutric Cambisol |
| **Cantilillo** | Soil from the edge of the scarp | Dystrict Leptosol |
| **Negra polvilla** | Dusty black soil | |
| **Negra de barranca** | Black soil from the gorge | Calcic Fluvisol |
| **Canela** | Cinnamon soil | Eutric Fluvisol |
| **Barro** | Clayey soil | Vertic Cambisol |
| **Amarilla** | Yellow soil | Dystrict Cambisol |
| **Barro colorado con arena** | Reddish sandy clay soil | Chromic Luvisol |

**Sources:** Licona (1991); Cruz (1994)

## (d) *Mestizo* multidimensional soil knowledge

Soil and land resources are perceived by *ejidatarios* as a single domain. Farmers use the concept *tierra* to refer to soil, land, field, terrain and landscape. They assess soil and land resources in a multidimensional way. Three sets of factors are used to classify land (*tierra*): a set of non-biotic factors, a set of biotic factors, and a set of management factors (Figure 11.10). The non-biotic factors include soil, climate, and relief. The biotic factors include weeds and plagues. Land management is determined by land-use and land workability. Some 20 specific variables are assessed to recognize local land unit qualities for practical purposes. Ejidatarios soil assessment and land-use evaluation procedures are complex and highly utilitarian.

Using the above sets of factors, farmers recognize six similar land classes in all three *ejidos* (Licona, 1991), while ten land classes are recognized in one single *ejido* (Cruz, 1994). The detailed soil/land classification appears to be more ecological or relational than hierarchical. Several soil properties are used to classify soils, including color, texture, consistence, drainage condition, moisture retention capacity, soil cracking, soil compaction and relief position. These soil properties are carefully assessed against critical germination and phenological stages of each crop. Table 11.12 synthesizes farmers' description of local soil classes.

The behavior of the soils or land units is checked during the cropping cycle, within periods of several years and according to the rainfall regime, distinguishing between dry years (*años secos*), intermediate rainfall years (*años con temporal regular*) and rainy years (*años de buen temporal*). Quantity and distribution of rainfall control rainfed agriculture and are critical indicators for local farmers to assess soil quality, land-use and crop performance. Farmers are able to predict climatic and meteorological conditions; an aspect which is not well documented in ethnoecological surveys (Lammel et al., 1997).

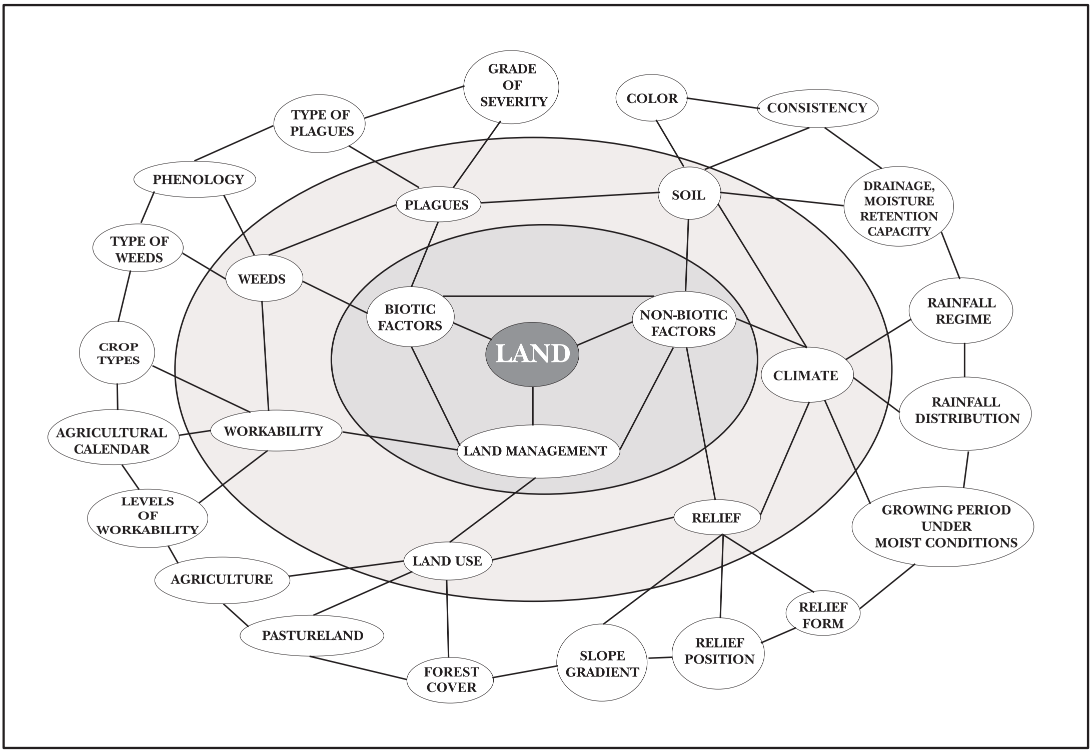



**Figure 11.10.** *Mestizo* soil knowledge as a multidimensional dominion. **Source:** Licona (1991)

Rainfall variability in sub-humid tropical lowlands requires from *ejidatarios* permanent monitoring of environmental indicators to predict crop performance. Rainfall prediction allows labor allocation and land management decision-making for each soil class or land unit to minimize potential crop failure. Farmers' evaluation of rainfall during a period of ten years (1981-1990) correlated with data provided by local recording stations (Licona, 1991). Locally assessed 'good rainfall years', 'intermediate rainfall years' and 'dry years' correlated with precipitation-evapotranspiration data. The moisture retention assessment of each local soil class correlates with bulk density, texture, hydraulic conductivity, field capacity and permanent wilting point, and available humidity laboratory determinations of soil samples from four *ejidos*.

### (e) A *Mestizo* syncretic soil nomenclature

The most conspicuous observable features of the topsoil are used to name each soil class. Color, consistence and soil-relief position are the main properties used to classify soils. Most local soil names are in Spanish, using descriptors such as *canela* (cinnamon), *bermeja* (reddish), *lajilla* (flat stone on the slope), *cascajilla* (gravelly), *barriosa* (clayey), *cantililla* (cliff edge) and *calichuda* (rich in carbonates) which were probably adopted from Spanish colonizers since the 16th and 17th centuries (Williams and Ortíz-Solorio, 1981). Spanish adaptations to Nahua soil descriptors are less used, but *tepochilla* (*Tepoxtli*: a type of volcanic rock) and *tizate* (*Tizatl*: white soil rich in carbonates) reflect ancient

**Table 11.12.** Local soil classes in *ejidos* from central Veracruz

| Local soil classes | Local description of soil classes |
|---|---|
| Barro negro<br>**Black clayey soil** | Black when moist; hard when dry, plastic and sticky when wet. Clayey soils, easily flooded and cracked when dry. Prone to plagues and weeds such as the cieneguilla; not easily workable. It is possible to crop maize during the spring-summer cycle when good rainfall conditions; possible to cultivate beans, tomato and chili pepper during the autumn-winter cycle when sufficient rainfall. Not a good soil for agriculture and for pasture. |
| Barro colorado<br>**Reddish clayey soil** | Reddish; hard when dry, very sticky and plastic when wet. Clayey soils on the hills. A special weed (*amolillo* or *campanilla*) grows on these soils. Not easily workable; plow does not penetrate when dry; very cloddy when wet. Maize can be cultivated but land will not give good production; this land is not strong (*fuerte*), but can be used as pasture. |
| Barro colorado con arena<br>**Reddish clayey soil with Sand** | Similar to barro colorado, but with less sand (*arena*) in the topsoil. Sand was washed away because these soils are located on steep lopes. Occasionally, there are small stones within the topsoil and that is why the soil is not easily workable. |
| Lomas barriosas-arenosas<br>**Sandy-clayey hills** | Similar to barro colorado con arena; main difference is that it contains more sand in the topsoil. They dry quickly, but are more easily workable than other *barro* (clayey) soils. These soils are located on gently sloping hills. |
| Arena<br>**Sand** | Loose and soft soils. They dry very quickly and are weak (*débiles*); not good for agriculture. Sowing should be done at the beginning of the rains otherwise maize plants can be "burned" by the sand; hot soils (*suelo caliente*). |
| Canela<br>**Cinnamon** | Soils located near the rivers, on flat and narrow land strips. Strong soils (*fuertes*) where all crops can be grown with good productivity. Brownish soils, not sandy but loamy (*francos*). Easy to work and always moist, even during the dry season. Best soils for agriculture. |
| Canela con arena<br>**Cinnamon with sand** | Located near canela soils, but with more sand in the topsoil. Less strong (*fuerte*) than the former but easily workable. Less productive than *canela* soils. |
| Tierra negra<br>**Black soil** | Soft soils when dry, not plastic and sticky when wet. They are also called grained soils (*tierra de grano*), because the structure becomes granular after plowing. Good soils for agriculture, especially for vegetables. Always moist, even during the dry season; easy to work because they are loose soils (*tierra suelta* or *blanda*). |
| Lajilla<br>**Slab-stone like soil** | Soil of intermediate strength (*medianamente fuertes*). The presence of flat stones (*lajas*) is their principal characteristic. They are located near the black soils or the clayey black soils (*barro negro*). |
| Tizate<br>**Chalky soil** | Shallow grayish-brown (*pardo*) soils having a hardpan within the first 30cm of the profile. Hardpan is white (*tepetate blanco* or *tizate*). Very weak (*débiles*) soils; only maize and beans grow with low productivity. They are located on hills. |
| Amarilla polvilla<br>**Dusty yellowish soil** | Dark yellowish soils; soft to slightly hard when dry, plastic and sticky when wet. Clay-loam soils, easily workable; strong soils (*fuertes*) for any crop, even during abundant rainfall, but crops tend to die when insufficient rainfall. Good agricultural soils. |
| Negra polvilla<br>**Blackish yellowish soil** | Sandy loam soils; very black when moist; soft to slightly hard when dry, non-plastic and slightly sticky when wet. Conditions of workability and crop performance similar to tierra amarilla and negra de barranca soils. Crops easily dry when insufficient rainfall or (*mal temporal*). |
| Negra de barranca<br>**Black soil of canyon** | Very black when wet; slightly hard when dry, non-plastic and slightly sticky when wet. Loamy (*franco*) soils. They ar e located on the bottom-level flatlands of gorges; problems with weeds. Workability is similar to tierra amarilla. All crops can be cultivated during the spring-autumn period, but weeds are difficult to combat. Fruit trees such as mango or papaya, grow well in these soils. |
| Cantilillo o Tepochilla<br>**Soil on the scarp** | Shallow dark-yellowish soils. Located on scarps and covered by forest. |
| Calichuda<br>**Chalky soil** | Similar to tizate; they present a white hardpan within the first 30 cm of the profile. This white hardpan is called "*tepetate* or *caliche*". Very weak soils (*débiles*); only maize and beans grow, but with low productivity. Located on hills. |

**Sources:** Licona (1991); Cruz (1994)

Middle American soil knowledge. Locally assessed soil properties generally correlate with technical determinations. Soil color assessment (yellow and black) correlates with the color chart although not as detailed as the technical annotation. Soil consistence assessed as hard, soft or loose (*tierras duras, blandas* or *sueltas*), and heavy, plastic or sticky (*tierras pesadas, chicludas* or *pegajosas*) correlates with laboratory determinations of bulk density and particle size distribution within the first 40 cm of sampled profiles. Relief form, slope gradient and relief position are also locally assessed and correlate with the technical relief nomenclature (Table 11.13.).

*Mestizo* soil classification and land-use evaluation allow ranking local agricultural land classes according to soil productivity, soil workability, type of land management, crop suitability and labor allocation. Land management and technological choices are site-specific, depending on each soil class or land unit and on the ever-changing environmental conditions of the Mexican sub-humid tropical lands (Licona et al., 1992). *Mestizo* soil/land knowledge-based system shows versatility and effectiveness to maintain food production under dynamic environmental conditions as part of a risk-minimizing strategy. *Mestizo* ethnopedology from central Veracruz reflects the critical importance given to the soil resource by local farmers for multiple use of marginal lands.

**Table 11.13.** Correlation between local and technical relief nomenclature and soil classes

| Local relief nomenclature | Technical relief nomenclature | Local soil classes |
|---|---|---|
| **Terrenos planos sobre lomas** | Flat interfluves<br>0 – 3% slope | Barro<br>Tierra negra polvilla |
| **Terrenos planos en el fondo de barrancas**<br>**Banquetillas** | Toeslope<br>Alluvial terraces<br>0 – 3% slope | Tierra negra de barranca<br>Tierra negra polvilla |
| **Faldas** | Footslopes<br>3 – 8% slope | Barro<br>Tierra amarilla<br>Tierra negra polvilla |
| **Lomas** | Convex interfluvial lands<br>0 – 8% slope | Tierra negra polvilla<br>Tierra amarilla |
| **Cantiles** | Scarps<br>< 30% slope | Cantilillo |

**Source:** Licona (1991)

## (8) Huave ethnopedology from San Mateo del Mar, Oaxaca

### (a) Regional context

Huave people live in San Mateo del Mar, an indigenous municipality of the southern state of Oaxaca. The most recent indigenous population census recorded 17,500 Huave inhabitants, a small ethnic group at risk of disappearance (INI, 1993). Huave make up 90% of the local total ethnic population, most of them living in extreme poverty conditions (INI, 1993).

San Mateo del Mar municipality is located in the coastal lowlands of the Pacific Ocean, in the Isthmus of Tehuantepec (Figure 11.9). The territory is on a littoral bar between two coastal lagoons, the Mar Superior and the Mar Inferior. Land is exposed to flooding during the rainy season in scattered depressions, named locally *bajiales*. Flat hills and elongated coastal dunes constitute major elevations, dissected by permanent streams and rivers originating from the neighboring Sierras. Wind activity shapes the local landscape, especially during the dry winter. The locals consider wind erosion detrimental to their subsistence activities (Signorini, 1979; Zizumbo and Colunga, 1982).

The local climatic regime is sharply divided into two main seasons: the dry season in autumn, winter and spring, and the wet season in the summer. Mean annual temperature is high (>25°C), and rainfall is highly variable and unpredictable, with less than 900 mm/y. Irregular rainfall, marginal soils and temporal flooding are main environmental constraints for agricultural activities; thus Huave subsistence strategy was historically based on fishing and shrimp collection. Over the last two decades, however, the importance of agriculture has increased (Signorini, 1997).

Huave developed two different ways to cope with environmental uncertainties and limitations. Firstly, locals still maintain a profound sacralized perception and understanding of natural phenomena, resembling their pre-Hispanic cosmovision, but now molded by a syncretic popular Catholicism. Myths and rituals are intimately linked to wind, rainfall, sea-water, thunder and clouds, as main natural factors influencing the everyday livelihood and as supernatural beings capable to give comfort or tragedy (Signorini, 1997). Predicting the behavior of these phenomena is central to Huave subsistence strategy. A detailed assessment of local meteorological conditions help Huave to cope with natural risks and balance their relation with the supernatural beings (Lupo, 1981). Secondly, Huave developed a sophisticated soil knowledge and land management system to cope with the harsh and uncertain environmental conditions for their subsistence. A diversified agricultural system, based on maize multicropping, allows covering partially local basic needs (Zizumbo and Colunga, 1982).

(2) Huave ethnopedology and land-use evaluation

Huave possess detailed soil knowledge at meso- and micro-scales. Soil variability is carefully assessed and managed within distance of a few meters. A key factor for this is the assessment of soil fertility and land productivity. Central to the understanding of Huave agricultural strategy is their relational knowledge about soil productivity, relief, soil erosion and herbaceous vegetation. These four factors are on-site assessed for land-use decision-making (Zizumbo and Colunga, 1982).

Huave soil taxonomy is complex and detailed. Soils (*Iet*) are first divided into agricultural and non-agricultural types, showing a utilitarian organization of the soil domain. Not surprisingly, agricultural soil types are further divided into soil classes with more detail than the non-agricultural soil classes. Eleven soil taxa are hierarchically organized according to texture, wind erosion susceptibility, moisture retention capacity, drainage conditions, structure, color, consistence, stoniness and cracking (Figure 11.11.). Few soil descriptors are used to name soil classes: texture, drainage conditions, stoniness, relief position, salinity and taste. Huave soil classes strongly correlate with the FAO/UNESCO/DETENAL soil legend (1970). The local classification is slightly more detailed accurate than the technical one (Table 11.14).

Huave farmers do not make strict distinction between soil and land. The *Iet* morpheme refers both to soil and land resources, showing a multidimensional view of the landscape. Huave developed a detailed land-use evaluation system using soil–relief position as main criterion. Relief is classified into four main types according to elevation, slope steepness and form: *bajial, tierra colgada, tierra baja* and *tierra alta* (Table 11.15). Relief controls drainage and erosion susceptibility, whilst soil controls moisture retention capacity and crop performance, according to Huave farmers. The relation between soil and relief is critical to Huave classification of agricultural lands or agro-habitats. Huave recognize 11 soil classes within the four relief types, leading to 18 agro-habitats which are assessed according to crop performance under multicropping (Table 11.15). Figure 11.12. shows the detailed distribution of soil types within an ideal 1 km cross-section.

The characterization of soil–relief position shows the degree of detail of Huave land evaluation for agricultural purposes (Table 11.15):

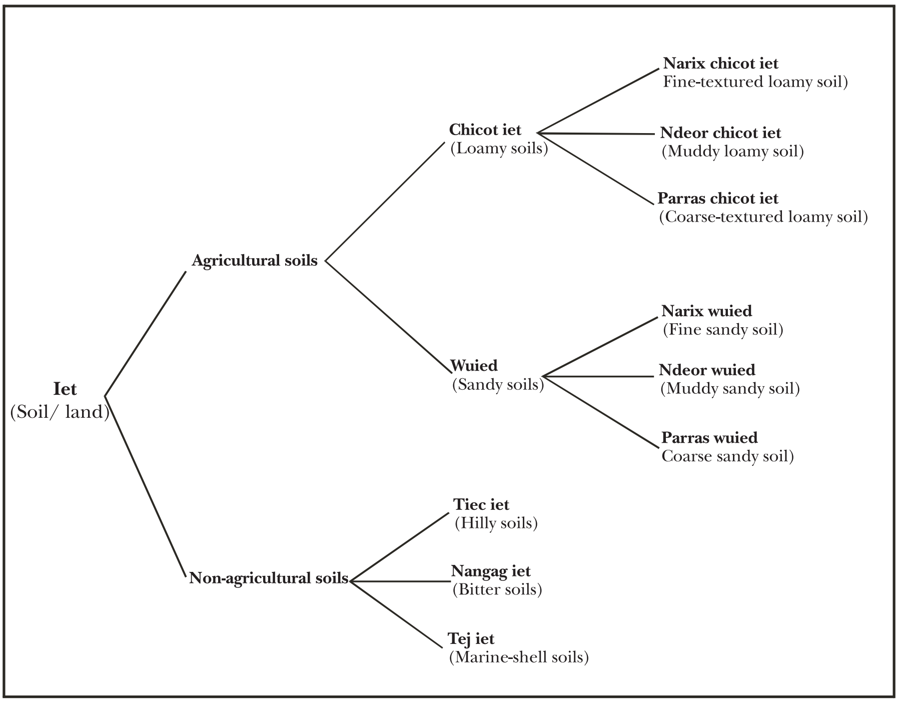



**Figure 11.11.** Huave soil taxonomy. **Source:** Zizumbo and Colunga (1982)

**Table 11.14.** Correlation between Huave soil classes and the FAO/UNESCO/DETENAL Soil Legend (1970)

| Huave soil classes | English terms | FAO/UNESCO/DETENAL |
|---|---|---|
| Narix chicot iet | Fine-textured loamy soil | Eutric Fluvisol |
| Chicot iet | Loamy soil | Haplic Phaeozem |
| Parras chicot iet | Coarse-textured loamy soil | Haplic Phaeozem associated with Lithosol |
| Ndeor chicot iet | Muddy and cracking soil | Pelic Vertisol |
| Tiec iet | Hilly soil | Lithosol |
| Nangag iet | Bitter soil | Halosol |
| Nagtix iet | Saline soil | Halosol |
| Narix wüied | Fine sandy soil | Eutric Regosol |
| Parras wüeid | Coarse sandy soil | Eutric Regosol |
| Ndeor wüeid | Muddy sandy soil | Eutric Gleysol |
| Tej iet | Marine-shell soil | |

**Source:** Zizumbo and Colunga (1982)

(W) *Wüiek* or bottom-level lands are concave and temporarily flooded with variable moisture retention capacity according to micro-topography. These land units are less prone to wind erosion and receive sediments favoring the development of herbaceous plants. Three different sandy soil classes are distinguished (Figure 11.12). Soil-relief position allows Huave farmers to recognize soil moisture retention capacity, hardness and cracking when dry, wind erosion susceptibility and herbaceous plants' performance. According to this, $W_3$, $W_1$ and $W_2$ are sandy soils ranked from high to low agricultural suitability, respectively.

(R) *Rondon iet* or hanging lands are moderately sloping and temporarily flooded in the lower areas, and present a moisture retention capacity gradient from the lower to the upper levels. The performance of herbaceous plants is less favored. Hanging lands are considered more susceptible to wind erosion than *Wüiek* lands. Soils $R_1$, $R_2$ and $R_6$ have lower moisture retention capacity than soils $R_4$ and $R_7$ (Figure 11.12). $R_4$ soils are good for agricultural purposes. $R_7$ soils are limited for agricultural activities because of hardness and cracking during the dry season.

(NK) *Nagmiek iet* or lowlands are susceptible to temporal flooding, depending on their elevation above the bottom-level lands. They are gently sloping and present a well-established moisture retention capacity gradient. Soils $NK_1$, $NK_4$, $NK_5$ and $NK_7$ are ranked as having low to high moisture retention capacity and low to high performance of herbaceous plants, respectively. Soil $NK_5$ is considered the most susceptible to wind erosion, while soil $NK_7$ is the hardest during the dry season (Figure 11.12.).

(NP) *Nagtep iet* or highlands are not subjected to temporal flooding, but have excessive drainage. Soil $NP_4$ is ranked as the best agricultural soil within this land unit because of its high moisture retention capacity, good herbaceous plants' performance, and low susceptibility to wind erosion. Soils $NP_1$ and $NP_5$ are good agricultural soils, although $NP_5$ is somewhat susceptibility to wind erosion because of its loose structure. Soils $NP_2$ and $NP_6$ are ranked as less suitable for agricultural purposes because of low moisture retention capacity, bad performance of herbaceous plants and high susceptibility to wind erosion.

Huave farmers from San Mateo del Mar in Oaxaca developed a well-structured soil and land resources knowledge at meso- and microscales to cope with marginal soils and scarcity and irregularity of rainfall. A hierarchical soil taxonomy and a detailed recognition of soil–relief position enable Huave farmers to establish a complex multicropping strategy. This is an interesting example of how local people recognize marginal soils and take advantage of their low productivity to cope with uncertainty. It reflects the contrast between limiting environmental conditions and well-adapted soil knowledge and land management.

**Table 11.15.** Huave agro-habitat classification according to soil-relief position

| Soil classes | Soil description | Relief types | | | |
|---|---|---|---|---|---|
| | | **Wüiek** Bajial (Bottom-level land) **W** | **Rondon iet** Tierra colgada (Hanging land) **R** | **Nagmiek iet** Tierra Baja (Lowland) **NK** | **Nagtep iet** Tierra Alta (Highland) **NP** |
| **Narix wüeid** | Fine sandy soils; low moisture retention capacity; highly susceptible to wind erosion; not in flooded areas | $W_1$ | $R_1$ | $NK_1$ | $NP_1$ |
| **Parras wüeid** | Coarse sandy soils; gravelly soils, excessive drainage; low moisture retention capacity; high susceptibility to wind erosion; locally mixed with Narix wüied | $W_2$ | $R_2$ | | $NP_2$ |
| **Ndeor wüeid** | Black or grayish soils; hard soils; cracking when dry; good moisture retention capacity | $W_3$ | | | |
| **Chicot iet** | Dusty soils; not blocky soils; sticky when wet; muddy soils; not cracking when dry; grayish soils; intermediate susceptibility to wind erosion; high moisture retention; poor drainage conditions | | $R_4$ | $NK_4$ | $NP_4$ |
| **Narix chicot iet** | Fine-textured soil; very dusty; easily eroded by wind; very low water retention capacity; sediments brought by the river | | $R_5$ | $NK_5$ | $NP_5$ |
| **Parras chicot iet** | Soils located in the vales between hills; not muddy; not sticky; gravelly soils; very low moisture retention capacity | | $R_6$ | | $NP_6$ |
| **Ndeor chicot iet** | Hard soils; muddy soils; blocky structured soils; non-dusty soils; cracking when dry; black or grayish soils; good moisture retention capacity; located in flooded areas | | $R_7$ | $NK_7$ | |

**Source:** Zizumbo and Colunga (1982)

## 11.5. THE SUB-HUMID TEMPERATE HIGHLANDS

Three ethnopedological case studies corresponding to the sub-humid temperate highlands of Mexico and Guatemala are discussed in this section (Figure 11.13). These examples correspond to densely populated rural areas, where *Mestizo* small-farmers and indigenous communities combine subsistence and commercial agriculture in a variety of soil types and relief patterns. The partial adoption of technological innovations in combination with traditional land management practices reflects syncretic and flexible soil and land resource knowledge systems.

### (9) *Mestizo* ethnopedologies from the Basin of Mexico

### (a) Regional context

The Basin of Mexico is one of the most extensive studied areas of Middle America from an ethnopedological point of view. Densely inhabited since ancient times, this region is located in the Mexican central highlands (Figure 11.13). Formerly the center of the Aztec Empire, the Basin of Mexico is currently one of the largest urbanized areas in the world. Mexico City and surroundings have a population of more than 20 million people (INEGI, 2001). A drastic reduction of the rural areas during the last 50 years because of explosive urban expansion diminished the historical role of agriculture in the region. Nevertheless, a considerable rural population is still engaged in small-scale agriculture on the slopes surrounding the basin, the bottom-level land of the former Texcoco Lake and the shrinking chinampa system in the southern part of the basin. Ethnopedological studies

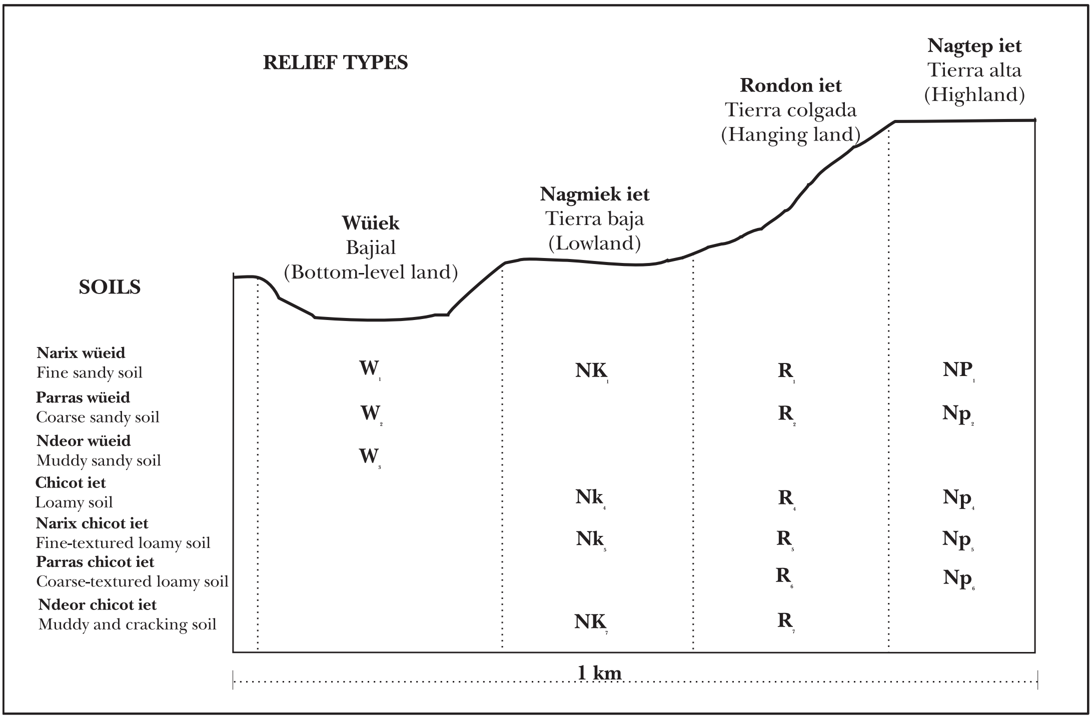



**Figure 11.12.** Huave soil-relief cross-section and corresponding agro-habitats. **Source:** Zizumbo and Colunga (1982)

in these areas reveal a remarkable permanence and renewal of soil knowledge and land management systems based on *milpa* cultivation in *Mestizo* villages.

(b) Twenty years of ethnopedological research

Studies carried out on this region reflect a structured attempt to develop a comprehensive ethnopedological methodology integrating farmers' soil and land knowledge systems into conventional land-use evaluation procedures for agricultural purposes. Based on an agronomic approach, this ethnopedological research trend developed during the last 20 years is considered as the Mexican Ethnopedological School, stimulated by the pioneer work of Williams (1980a,b and c, 1981) and Williams and Ortíz-Solorio(1981) in the vicinities of the former Texcoco lake. More than 20 ethnopedological studies at local and regional levels among *Mestizo* and indigenous villages have been conducted or coordinated by Ortíz-Solorio (1990, 1993) and Ortíz-Solorio and Guitierrez-Castorena (2001), focusing on three main topics:

(a) the study and comparison of local soil knowledge and land management systems with technical procedures, including laboratory determinations of sampled local soil classes and conventional soil quality assessment and land-use evaluation (Luna, 1982; Ordaz, 1989; Pájaro, 1989; López et al., 1992);
(b) the development of an ethnopedological mapping method at local and regional levels, integrating information provided by local farmers into conventional soil survey and cartography (Gónzalez, 1988; Ortíz-Solorio et al., 1989; Licona et al., 1992), and
(c) the study of local ethnopedologies as part of the analysis of the agricultural production process at parcel, local and regional levels (Licona et al., 1992).

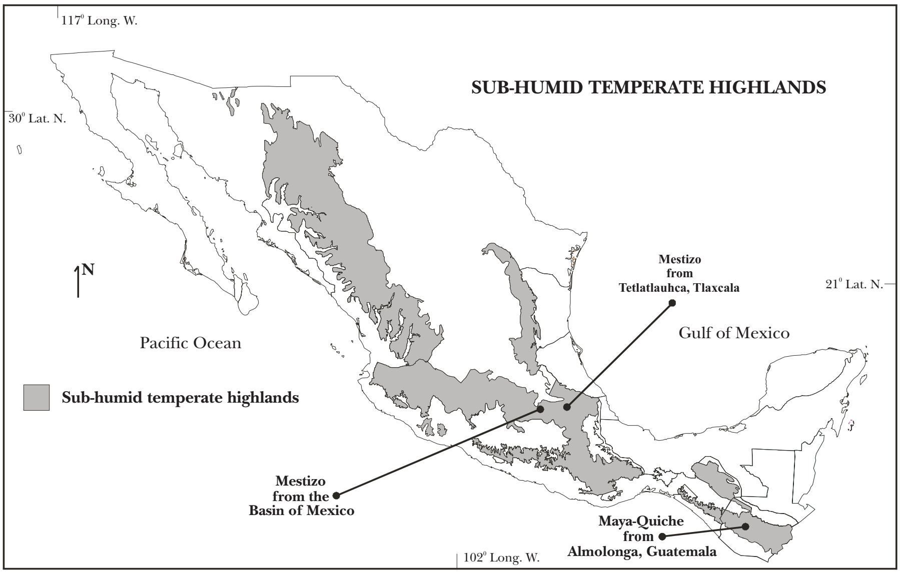



**Figure 11.13.** The sub-humid temperate highlands of Mexico and Guatemala

Other ethnopedological topics covered in this region include: (a) the study of local knowledge about the role and use of weeds and their distribution within soil classes (Espinoza, 1987); (b) the study of the local use of domestic ashes as soil amendments to improve fertility, structure and texture in clayey soils (Carrillo, 1988); (c) the study of local land reclamation techniques in saline soils and *tepetate* soils (Quiróz, 1983); and (d) the study of local soil-crop suitability assessment according to soil classes and specific crops (Luna, 1982; Calderón, 1983; González-Mateos 1988; Zelaya, 1992).

An attempt to recognize local soil classes using remote sensing techniques, applying multi-factorial analysis to classify MSS satellite images and comparing results with ethnopedological information at regional level, was also done. Results show a strong correlation between classified digital information and textural classes of soils recognized by local farmers (Cajuste, 1991). A comparison between local soil classification systems within areas having similar soil classes, relief types and agricultural systems, and within areas having different soil classes, relief types and agricultural systems, was conducted to recognize the level of consistence of local ethnopedologies at regional level. Main objective was to understand similarities and differences in the ways local farmers perceive, classify and manage soils and land units within similar or different geographical units (Luna, 1982; Calderón, 1983; Quiróz, 1983). These studies also showed moderate correlation between local and technical soil classification systems and revealed, in some cases, more detailed recognition of soil variability by local farmers than by scientists.

### (c) Ethnopedological research assumptions

Ethnopedological studies carried out by Ortíz-Solorio(1990, 1993 ) were based on the assumption that this research approach would benefit soil survey for land-use planning in rainfed agricultural areas of Mexico, where several technical limitations impeded the implementation of conventional approaches. Among these limitations were: (a) reduced number of soil surveyors (less than 100) at country level at the beginning of the 1990s; (b) financial and time restrictions for detailed (1:5,000 to 1:10,000) and semi-detailed (1:15,000 to 1:25,000) soil survey for land-use planning in a country with more than 20 million hectares. Seventy-five years would be required to cover the rainfed agricultural areas of Mexico with a cost of $ 1,000 per km$^2$ and 40 days/man/km$^2$, applying conventional procedures of semi-detailed soil survey and land-use planning (Ortiz-Solorio et al., 1990).

Ortíz-Solorio and collaborators (Ortíz-Solorio, 1990, 1993; Licona, 1991; Licona et al., 1992) proposed an alternative soil survey method for land-use planning in rainfed agricultural areas of the country to cope with the technical and financial limitations mentioned above. Four main research considerations were taken into account:

(a) there is a detailed soil information historically possessed by local farmers, that can be easily integrated during the technical soil survey procedure, and that local soil information is spatially framed by farmers, making it possible to compare and integrate pedologic and ethnopedological maps at plot, local and regional levels;
(b) local soil knowledge systems are mainly utilitarian and inserted into more ample agronomic knowledge systems, making it possible to integrate local information about soil and land management for agricultural purposes into conventional land-use planning procedures, after being compared and formalized with scientific soil information, and
(c) the integration of ethnopedological information into the soil survey and land-use planning procedures would substantially reduce financial costs, time allocation and expert training, minimizing technological transfer failures while integrating endured local experiences in a participatory approach.

The integration of the local and technical soil and land information systems as an alternative methodological approach required prior assessment of the local theorization about the soil resource. Williams and Ortíz-Solorio (1981) found conceptual similarities and differences about the soil resource between scientists, technicians and local farmers. Farmers use the term "land" when referring to the technical concept of the soil resource. Both, the technical and the local soil knowledge-based systems are taxonomically structured, although farmers use only a few observable properties to classify soils. Local soil classes are described and assessed in a multi-dimensional way, including 'external' factors such as climate, vegetation, relief and land management, resembling the concept of landscape according to Christian and Steward (1968). Farmers tend to assess soil as an observable 2-D body for utilitarian purposes and monitor its behavior during the annual cycle and within several annual cycles. In contrast, scientists classify soil as a 3-D body on the basis of a technical description of soil profiles that include surficial and subsurficial horizons and with the support of laboratory determinations to corroborate observed properties. Scientists classify soils according to properties, not necessarily utilitarian, which cover the whole soil depth, while farmers classify land according to the properties and behavior of the arable layer for practical uses. These differences in classification criteria affect the correspondence between technical and local soil classes. Ortíz-Solorio (1990) proposed the concept of 'farmer land unit' (*concepto de tierra campesina*) as "a specific area of the terrestrial surface that includes all, directly (in the arable layer) or indirectly (in the plant), observable attributes of the biosphere at parcel level that affect its use and management". According to this, the arable layer constitutes the intersection between the technical soil concept and the farmers' land concept.

### (d) Mapping farmers' land units for land-use evaluation purposes

Farmers' soil conceptualization as a land management unit allowed the development of an ethnopedological mapping procedure, that includes not only the local soil classes but also the relation between these classes and other environmental and production factors locally assessed (Ortíz-Solorio and Gutierrez-Castorena, 2001).

The ethnopedological mapping procedure is rather simple. It requires a cadastral map, aerial photos, the selection of local key-informants, the application of questionnaires, soil sampling and laboratory determinations of selected local soil classes, and the permanent discussion of preliminary results with the farmers until the final soil map is socially corroborated and approved (Licona, 1991). Cadastral maps are required for fieldwork recognition and preliminary mapping of the local soil classes at parcel level, according to the owners' soil and land management experience of selected parcels. Questionnaire survey allows establishing the local soil classes on selected parcels and collect data on related environmental and production factors.

Questionnaire survey intends to cover all local soil classes and provide data on parcels, environmental factors associated with the soil classes and land-use systems, agricultural techniques applied at each local soil class and related soil and agricultural restrictions. Information gathered by questionnaires and soil boundaries drawn on the cadastral map allow recognizing relations between local soil classes and other environmental and production factors, such as relief and land-use, and establishing soil-relief-land-use patterns. The transfer of preliminary local soil boundaries to aerial photos and the recognition of soil-relief-land-use patterns permit the extrapolation of ethnopedological information by photo-interpretation. Laboratory determination of selected soil properties allows to compare local and technical soil classes for land-use evaluation purposes.

Preliminary ethnopedological mapping and related environmental and production information at each local soil unit are discussed and corroborated with farmers until reaching consensus. This is the final quality assessment procedure held by technicians and local farmers before the redaction of the final report. An alternative land-use planning could be further established with the participation of local farmers, soil surveyors and extensionists. Therefore, ther should be cooperation with types of knowledge, rather than the frequent competition between them (Ortíz-Solorio and Gutierrez-Castorena, 2001)

Six ethnopedological surveys were done in the Basin of Mexico, applying the method described above (Pájaro and Ortíz-Solorio, 1987; Ordáz, 1989; Ortíz-Solorio, 1989; Pájaro, 1989, 1990) and more recently in other rural areas of Mexico (Licona, 1991; Cruz, 1994; Andrade et al., 1998). Some relevant findings of these studies are:

(a) ethnopedological survey generates more detailed soil maps than the detailed conventional procedures or the soil maps produced by INEGI, the national cartographic agency, using the FAO/UNESCO soil legend;
(b) a minimum of six local soil classes was recognized in areas smaller than 1,000 hectares;
(c) financial costs and time allocation were less when applying the ethnopedological survey than when applying the conventional soil survey and land-use planning procedures;
(d) ethnopedological findings in nearby rural localities of the former Texcoco lake show similar local soil classes but different land management systems, which allowed to identify local appropriate technologies than can be easily transferred;
(e) ethnopedological studies allow communication between soil surveyors, agronomists and local farmers, and reorientation of agronomic research according to local problems and solutions, and
(f) soil and ethnopedological surveys are not exclusive but complementary approaches.

The systematic ethnopedological effort conducted by researchers and graduate students in the Basin of Mexico during the last 20 years has not yet been well recognized by the national agronomic institutions and governmental agencies related with rural development. Local soil information is neglected and considered as non-scientific, thus impeding the development of an alternative, adapted and economical approach that could solve some of the local rural problems that Mexico faces today. This is reflected in the limited dissemination of these research findings in national and international scientific journals and the limited financial support to further develop and enhance methodological tools and empirical information and, most of all, establish a communication bridge between technicians and local farmers.

## (10) *Mestizo* ethnopedology from Tetlatlauhca, Tlaxcala

### (a) Regional context

Tetlatlauhca municipality is located in southwestern Tlaxcala state, central Mexico (Figure 11.13.). The name of the municipality is strongly related to the Nahua ethnopedology of the 16$^{th}$ century and also reflects its current land management and agricultural systems. The Nahuatl morphemes *tetlalli* (hard or stony soil), *tlatlauhco* (in the irrigation ditch), *tlalauiyic* (good and soft soil, fertilized with humus) and *tlaluitectli* (worked down, crumbled and beaten soil) are combined to name this municipality, reflecting a variety of soils and land management systems (see tables 8.2 and 8.4 in Chapter Eight). A *tlaluitectli* soil was described by a 16th century Nahua farmer as the land "… which is worked down, crumbled. I beat the land. I work the land with blows" (Sahagún, 1963). *Tlaluitectli* is an anthropogenic soil derived from a volcanic tuff hardpan (*tepetate*), that is commonly found in central Mexico (Williams, 1972). This soil type is also found in Tetlatlauhca municipality along the valleys of Puebla-Tlaxcala, bordering the Malinche volcano (4,461 m.a.s.l.) that belongs to the Trans-Mexican Volcanic Axis.

Tetlatlauhca municipality is inhabited by a *Mestizo* population, 75% of which was engaged in agricultural activities by the end of the 1980s (Wilken, 1987). Local agriculturalists combine subsistence and commercial crop production. Maize and vegetables are cultivated combining traditional and modern technologies. This densely populated municipality (300 inhabitants/km$^2$) constitutes an *ejido* (social property regime), comprising 4,460 ha of land. Ninety five percent of the territory is agricultural land (*tierras de labor*) and 60% of this land is dedicated to rainfed agriculture (*tierras de temporal*), 22% to irrigated agriculture (*tierras de riego*), 11% to subirrigation agriculture (*tierras de jugo o humedad*), and less than 1% to homegardening.

Tetlatlauhca is located at the edge between hilly and flat lands. Elevation ranges from 2,200 to 2,400 m.a.s.l., with an annual mean rainfall of 800 mm and an annual mean temperature gradient from 22 to 26$^o$C, corresponding to the sub-humid temperate highlands or *Altiplano Central*. Fertile alluvial or lacustrine soils are easily accessible in the flat lands, whilst shallow and tuff-derived volcanic soils are located on the slopes and summits of adjacent hills. Main constraints for agricultural activities are rainfall seasonality, frost during the dry winter, eroded shallow hardpan soils on the slopes, and waterlogged and saline soils in the lowlands. In general, soil nutrient status is good, but water table is higher in the flatlands.

### (b) *Mestizo* soil knowledge

Local farmers developed a flexible soil classification system and a complex land management system when intending to manage both hilly and bottom-level lands with a variety of soil types and when intending to cope with environmental disadvantages (Wilken 1987). Local classification combines pre-Hispanic Nahua soil nomenclature, colonial soil descriptors and modern technical pedological information; it is thus highly syncretic. Chemical fertilizers are massively used on drained fields and raised bed systems for intensive vegetable production. Agro-chemicals, organic fertilizers and inorganic amendments, such as sand and silt are combined to maintain soil fertility and improve soil texture and structure.

Local soil classification is rather simple (Table 11.16.). It is based on color and texture, but structure, salinity, depth and parent material are also assessed to establish local soil taxa. Soil discontinuities and mixtures are used as modifiers (e.g. reddish yellow soil or slightly salty soil).

Although the local soil classification recognizes only a few major soil types, it is highly flexible and allows accounting for slight soil variations by means of modifiers. Soil descriptions and properties are always linked in the mind of the farmers, who classify and assess on the basis of both inherent and management characteristics of soils. Less intensive cultivation of the hilly lands is reflected in less detailed soil classification (Table 11.16.). Because descriptive terms, such as color and texture, relate to both fertility and workability, local soil properties can be identified with considerable precision at micro- and macro scales. Thus, classification emerges as a facet of traditional resource management, matching in complexity the cultural significance of the resource involved (Wilken 1987).

Five soil types are recognized within the hilly lands, while eight soil types are recognized within the bottom-level lands, including the *tepetate* soils at the edge between the hilly and the bottom-level lands. *Tepetate* soils are anthropogenic soils, derived from different hardpan materials, requiring distinct soil amelioration measures according to the type and location of the hardpan within the soil profile. *Tepetate* soils are therefore subdivided according to the color, consistence and structure of exposed or sub-surficial tuff material.

Properties assessed by farmers and laboratory determinations of texture, organic matter content, nitrogen and lime contents are moderately correlated (Tables 11.16. and 11.17.). Potentially good agricultural soils, such as *barro pardo* (brown clayey soil), are ranked as having low quality because of workability restrictions (*fuerte* or hard soils). In contrast, less suitable agricultural soils according to their inherent properties, such as the *barro amarillo* (yellow clayey soil), are ranked as having good quality because of their fertility and workability can be easily improved. Some of the land amendments are described in table 11.16.

Generally, soils and their qualities are readily organized by most local farmers according to soil-crop suitability and productivity and according to the feasibility of different management practices. The local recognition that different soils require different land management measures allow adopting multicropping or monocropping strategies and a selective combination of chemical and organic fertilizers for each soil type, agricultural plot or within each agricultural plot, according to soil mixtures and discontinuities. Poor soils (*tierras pobres*) or weak soils (*tierras débiles o flojas*), supporting low plant densities, can be enhanced by agronomic measures. Labor, economic status of the households and cash availability play a central role in the implementation of the local soil knowledge. This is of particular relevance for the management of the *tepetate* soils or the drained fields (or *camellones*).

### (c) Land management and land amendments

A variety of land management measures is required to cope with local environmental disadvantages and meet the commercial demands and subsistence needs during the whole year. Soil amelioration and soil and water conservation strategies are critical to these purposes. The following management measures are just some of the most relevant ones, thus do not reflect land management complexity as a whole.

*Tepetate* soils require high labor investment to convert a non-agricultural material into anthropogenic soil with reasonable fertility. Where soil depth does not meet plowing conditions, a few centimeters of the underlying *tepetate* are broken and incorporated to the topsoil each season. Where soil erosion has exposed a *tepetate* layer, farmers break up and pulverize this surface layer with plow and crowbar to form an agricultural layer. Despite lacking organic matter, some kinds of *tepetate* have the chemical and physical properties to be converted into reasonably good agricultural soils (Table 11.17.). Sand bedding and manure addition help ameliorate soil texture and structure. These measures are similar to those applied to *tepetate* soils during the pre-Hispanic times in Central Middle America (see Chapter Nine and figure 9.3).

Farmers from Tetlatlauhca mulch their raised-field soils. They spread *acacapa* (water hyacinth, *Echiornia crassipes*) over newly planted fields and later bury it with cultivation. Three objectives are achieved by spreading and burying this aquatic plant: (a) drains (*zanjas*) are cleared of clogging aquatic weeds; (b) field surfaces are protected by mulching, modifying micro-climate conditions; and (c) organic material is added to the soil. Mulching is done in compound ways, lying different mixtures of organic and inorganic materials on the topsoil. Erosional debris and aquatic plants deposited in the drainage canals are collected and spread over the drained-fields (or *camellones*) and other field surfaces. *Lama* (muddy soil) and silt are added to enhance soil fertility and ameliorate topsoil structure. Sand bedding and manure are also used to ameliorate clayey soil structure or sandy soil texture, respectively. These techniques are similar to those applied in the *chinampa* system since the pre-Hispanic times (see Chapter Nine).

Nitrogen fixation by plants is believed to benefit soils; thus multicropping is a common practice on nutrient-poor soils. Maize-beans and beans-tomato are crop associations considered essential to invigorate the soil. If the soil under cultivation is particularly deficient or exhausted (*tierra débil o cansada*), a single crop of broad beans or another legume may be planted to 'benefit the soil' (*beneficiar la tierra*).

Farmers of Tetlatlauhca are masters in water management, either to control run-off water in canals or drain fields with high water table. Irrigation systems in this municipality are complex and diverse. The construction and maintenance of a network of drainage canals are complemented with irrigation by pot or jar (*riego a bote o cántaro*) and with sub-irrigation. Sub-irrigation is commonly combined with furrow and splash irrigation. Sub-irrigated fields (*tierras de jugo* or juicy lands) are constructed by widening networks of open

**Table 11.16.** *Tetlatlauhca* soil classification and quality assessment

| Mestizo soil type | Description and management | Local quality assessment |
|---|---|---|
| **Hill soils** | | |
| **Barro amarillo** (Yellow clay soil) | Clay loam soil; sticky (fuerte) and not easily workable. Applications of manure improve the fertility of these soils and make them easy to work | Good but not exceptionally fertile soil |
| **Barro blanco** (White clay soil) | Whitish clay loam derived from light-colored clay deposits. Fertility and tilth can be improved with manure, but often available amendments are saved for more valuable basin bottom-level soils | Variable quality |
| **Barro colorado** (Red clay soil) | Sticky (fuerte) clay soil. Generous applications of manure are needed to improve fertility and tilth, but these are not frequently made | Medium quality |
| **Barro pardo** (Brown clay soil) | Exceptionally hard and sticky (fuerte) clay loam soil that can be worked only when moist. Because field preparation must be delayed until the onset of soaking rains, only fast-maturing maize varieties or other short-season crops can be cropped on these soils. Low fertility and management restrictions | Low quality |
| **Tierra blanca** (White soil) | Light, sandy clay loam soils with high lime content; only few crops, such as onions and husk tomatoes, do reasonably well on these soils | Low quality |
| **Tepetate soils** | | |
| **Tepetate amarillo** (Yellow tepetate) | An anthropogenic soil derived from a light, weakly consolidated formation that is easy to break up | The resulting soil has good working properties (not fuerte) and, after organic materials have been added, is of medium quality |
| **Tepetate colorado** (Red tepetate) | An anthropogenic soil derived from medium hard consolidated reddish tepetate not easy to break up | Low quality but acceptable after addition of nutrients and organic matter |
| **Tepetate pardo** (Brown tepetate) | Well cemented and resistant to pulverization. The resulting soil is cloddy and very difficult to work; seldom used for agriculture | Low quality |
| **Valley-bottom soils** | | |
| **Tierra fuerte** (Compact or sticky soil) | Also named Tezoquite (from the Nahuatl Tezoquitl: heavy clay), these are silty clay loam soils, difficult to work because of sticky; sol fertility is maintained with animal manure or chemical fertilizers or both, and texture may be improved by adding sand | Very good quality |
| **Tierra arenosa** (Sandy soil) | Sandy loam soils; easily workable whether wet or dry; can be subdivided into tierra arenosa gruesa (coarse-grained sandy soil), being less fertile, and tierra arenosa delgada (fine-grained sandy soil); the last one has good moisture retention capacity, and soil fertility noticeably improves with manure and chemical fertilizer | Good quality |
| **Tierra negra** (Black soil) | A high organic content soil, reclaimed from bog lands | Very good to good quality, especially after few years of cultivation |
| **Salty soil** | | |
| **Tequesquitudo** (Salty soil) | (From the Nahuatl Tequisquitl: saline soil). Any soil, often tierra arenosa (sandy soil) with high salt content, although low concentrations may not seriously impede cropping | Very low quality |

**Source:** Wilken (1987)

drainage canals into boggy soils (*tierras pantanosas*) and open swamps (*ciénega*). The purpose of this practice is to adequately drain the field during the wet season and supply subirrigation water during the dry season.

**Table 11.17.** Laboratory determinations o*f Mestizo* soil classes from Tetlatlauhca, Tlaxcala (1 to 15 cm depth)

| Mestizo soil types | pH $H_20$ | EC 1mmho/cm | O. M. % | $NO_3$-N (ppm) | P (ppm) | K (ppm) | Zn (ppm) | Fe (ppm) | Lime % | Sand % | Silt % | Clay % | Texture | CEC Meq/100g soil |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Hill soils** | | | | | | | | | | | | | | |
| **Barro amarillo (Yellow clayey soil)** | 6.2 | 0.3 | 1.0 | 2 | 2 | 260 | 0.6 | 13.4 | Low | 42 | 22 | 36 | Clay loam | 21.8 |
| **Barro blanco (White clayey soil)** | 6.4 | 0.3 | 0.5 | 1 | 1 | +500 | 0.3 | 3.0 | Low | 23 | 43 | 34 | Clay loam | 69.0 |
| **Barro colorado (Red clayey soil)** | 6.8 | 0.3 | 0.4 | 2 | 1 | 465 | 0.3 | 7.6 | Low | 40 | 29 | 31 | Clay loam | 39.0 |
| **Barro pardo (Brown clayey soil)** | 6.2 | 0.6 | 2.0 | 9 | 17 | 380 | 0.7 | 20.7 | Low | 43 | 23 | 34 | Clay loam | 11.2 |
| **Tierra blanca (White soil)** | 8.0 | 0.5 | 1.9 | 3 | 6 | 313 | 0.6 | 2.8 | High | 52 | 12 | 36 | Sandy clay loam | 18.4 |
| **Tepetate soils** | | | | | | | | | | | | | | |
| **Tepetate amarillo (Yellow tepetate)** | 7.5 | 0.6 | 0.2 | 0.8 | 1.3 | 398 | 0.5 | 9.6 | - | - | - | - | - | - |
| **Soil derived from tepetate amarillo after first year of cultivation** | 6.5 | 0.4 | 1.0 | 0.4 | 0.5 | 203 | 0.6 | 17.0 | - | - | - | - | - | - |
| **Soil derived from tepetate amarillo after several years of cultivation** | 7.5 | 0.7 | 1.0 | 0.8 | 1.3 | 440 | 1.3 | 11.4 | - | - | - | - | - | - |
| **Tepetate colorado (Red tepetate)** | 6.8 | 0.2 | 0.4 | 1.2 | 3.5 | 423 | 3.5 | 11.4 | - | - | - | - | - | - |
| **Soil derived from tepetate pardo (Brown tepetate) after several years of cultivation** | 6.9 | 1.2 | 0.3 | 11.6 | 1.0 | 293 | 1.0 | 23.6 | - | - | - | - | - | - |
| **Valley-bottom soils** | | | | | | | | | | | | | | |
| **Tierra fuerte (Heavy soil)** | 7.2 | 0.6 | 5.3 | 6 | 13 | 484 | 13 | +40.0 | Low | 19 | 42 | 39 | Silty clay loam | 39.8 |
| **Tierra arenosa (Sandy soil)** | 8.1 | 0.6 | 1.6 | 3 | 1 | 258 | 1 | 12.2 | Medium | 64 | 12 | 24 | Sandy clay loam | 19.8 |
| **Tierra negra (Black soil)** | 6.0 | 0.8 | 6.7 | 5 | 5 | +500 | 5 | +40.0 | Low | - | - | - | - | 34.0 |
| **Salty soil** | | | | | | | | | | | | | | |
| **Tequesquite** | 8.3 | 6 | 1.1 | 1 | 1 | 195 | 1 | 8.9 | Medium | 78 | 7 | 15 | Sandy loam | 11.8 |

**Source:** Wilken (1987)

Tetlatlauhca farmers combine extensive with intensive agricultural systems, adopting selective land management measures according to soil properties and qualities. The combination of traditional and modern technologies is reflected in their perception and knowledge of the local soil resource. Most farmers readily handle the local soil classification when combining inherent soil properties and potential land management measures and when combining pre-Hispanic, colonial and modern soil descriptors in a hybridized, flexible and well-adapted knowledge-based system.

## (11) Maya-Quiché ethnopedology from the Guatemalan Highlands

### (a) Regional context

Almolonga municipality is located in the western Quetzaltenango highlands, a volcanic mountain region of central Guatemala (Figure 11.13). Steep slopes and a narrow valley constitute the main landscapes of San Pedro Almolonga. The rugged topography (2,400-2,900 m.a.s.l.) assures that climatic conditions vary markedly over short distances. Most of the hill and bottom-level soils are derived from volcanic materials. More than 80% of the annual rainfall (900 mm) concentrates in four months, from June to September and the annual average temperature is 16°C. Rainfall and temperature are strongly controlled by topography.

Almolonga municipality has 2,000 ha of which only 293 ha ($^{+}$/-15%) are ranked as productive. Population density (362 inhabitants/km$^2$) and scarcity of agricultural land give exceptionally small farms (less than 0.5 ha). Nevertheless, most of the residents of this small municipality rely on agricultural activities. Dense agricultural population and intensive resource management are well correlated; thus it is not surprising that Maya-Quiché small farmers have developed detailed soil classification and land evaluation systems (Wilken, 1987).

### (b) Maya-Quiché soil knowledge

Farmers from Almolonga recognize color and textural classes to name soils. Two basic colors (yellow and black) and textures (sand and clay) are applied together with few modifiers of both soil properties (e.g. little, some, much) to distinguish minor soil differences. These are the bases of an indigenous soil classification that appears to be rather simple at first glance, but is actually complex and fine-tuned.

Soil-relief position is assessed to make sharp distinction between hill and valley soils. Sandy and sandy loam soils on the hills, derived from volcanic deposits, are generally used for subsistence maize and receive little attention other than plowing and cultivation and occasionally light applications of chemical fertilizers. Shallow soils are locally differentiated by color. Valley soils are so modified by management practices that they must be recognized by finely graded descriptions of color and texture. These soils are intensively managed and irrigated for commercial vegetables. Multicropping with massive applications of organic and inorganic amendments is the main characteristic of this agricultural system.

Responses to treatments are used to support local land-use evaluation in the bottom-level lands, more than in the less intensive systems of the hilly lands. In fact, there are two different soil classification systems according to inherent soil properties and soil management measures. Hill soils are classified by color and texture and evaluated by individual inherent soil qualities, while mixed valley soils are described by combinations of modified texture and color terms (e.g. degree of abundance of clay or sand and color gradients). These soils are evaluated more in relation to their ability to respond to treatment than to their inherent quality.

### (c) Correlation between local quality assessment and laboratory determinations

Three soil types are recognized within the hilly lands (Table 11.18), while the anthropogenic soils in the valley are more difficult to classify because of alluvial mixing and anthropogenic modification at micro-level. Local soil quality assessment shows moderate correlation with pH, organic matter content, nitrogen content and textural classes (Table 11.19). Farmers recognize six valley-bottom soils.

## (d) Land management and land amendments

Small vegetable plots (*tablones*) of the valley of Almolonga are intensively managed to maintain soil productivity for commercial purposes. Soil fertility is maintained and enhanced by combined measures. Maize straw mixed with cow manure is buried in the *tablones*. Leaf litter, gathered from nearby mixed oak-pine forests, manure and urine are also mixed to improve soil quality. Other local techniques include the

**Table 11.18.** Maya-Quiché soil classification and quality assessment

| Maya-Quiché soil type | Description and management | Local quality assessment |
|---|---|---|
| **Hill soils** | | |
| | Sandy to sandy clay loam soils; it is probably the most extensive of the hill soils used for subsistence maize. Farmers may apply small amounts of chemical fertilizerto increase yields not only of maize grain but also of stalks and leaves, which are valued for animal fodder | Moderate quality |
| **Tierras arenosas (Sandy soils)** | Sandy loam soils; apparently, this soil is similar to tierras amarillas, except that it contains higher percentages of sand from the nearby volcanoes | Not relevant quality |
| **Tierras negras (Black soils)** | Clay loam soils, with textural characteristics similar to those of tierras amarillas but with higher organic matter contents; tierras negras are considered of ordinary quality, perhaps because of the local farmers' concentration on valley-bottom soils and on management rather than on the intrinsic qualities of the various hill soils | Moderate quality |
| **Valley-bottom soils** | **Plot sample and land management description** | **Local quality assessment** |
| **Tierras medias negras no tratadas (Untreated half black soils) Tierras medias negras tratadas(Treated half black soils)** | Plot sampled on the edge of a tablón. This border had escaped most of the chemical and organic amendments, whereas the plot received heavy applications of both. This sample and the following were taken from the same tablón but one on its edge and the other in the centre, respectively. Both show striking differences; levels of nitrogen and of most other fertilizer minerals are much higher in the center than on the edge. The content of organic matter is exceptionally high, a characteristic shared with other valley-bottom soils that are periodically treated with broza and manure | High quality |
| **Tierra algo arenosa (Somewhat sandy soil)** | Sample from a heavily managed tablón; regular applications of broza, manure and chemical fertilizers are reflected in high levels of minerals and organic matter | High to moderate Quality |
| **Más barro y negro (More clay and black)** | This sample is somewhat darker and has a higher clay content than the "average" valley-bottom soils in the estimation of local farmers; broza and other organic amendments and chemical fertilizers were constantly applied | High to moderate Quality |
| **Pura arena (Pure sand)** | Is texturally almost identical to the sample of tierra algo arenosa (somewhat sandy soil), but the sandy nature of this soil dominates the farmers' description, possibly because levels of organic matter are lower | Moderate quality |
| **Pura amarilla (Pure yellow soil)** | A light-colored soil from the valley edges, located on flat to gently sloping surfaces; this tablón was not irrigated or treated with broza; only chemical fertilizers are applied to produce subsistence maize. Thus, although this soil resembles the hill soil tierra amarilla, it differs markedly in mineral content and texture | Moderate quality |
| **Puro barro o tierra negra (Pure clay or black soil)** | Plot-side canals permit hand irrigation and applications of broza, manure and chemical fertilizers to ameliorate the soil's natural deficiencies so that it can be pressed into intensive use | Moderate to low quality |

**Source:** Wilken (1987)

burying of stubble in hoe-tilled fields, creating ephemeral ridges and furrows, and working with gravity to bury old planting surfaces. Mulching with leaf litter (*broza, hojarasca*) is commonly applied to improve tilth and moisture retention capacity of the soils intensively managed for vegetable production. Farmers apply manure to sandy soils and leaf litter to clayey soils. Bedding mixtures of leaf litter and manure produce good results in any soil, according to local experience. Specific leaves are recommended for particular soils. Easily worked soils (*tierras suaves*) are benefited with alder (*aliso*) and cypress (*ciprés*) leave litter, while pine needles and oak leaves are effective in sticky or compact (*duro*) soils.

Field surface management of *tablones* or *camellones* consists of the construction and maintenance of raised beds. Rounded or flat-topped raised beds are created. Soils are first loosened and cleaned of weeds with broad hoes (*azadón*), then carefully shaped into flat-topped beds about 150 cm wide and 30 cm high. The purpose of

**Table 11.19.** Laboratory determinations of Quiché-Maya soil classes (1 to 15 cm depth)

| Maya-Quiche soil types | **pH** $H_2O$ | **EC** 1mmho/cm | **O. M.** % | **$NO_3$-N** (ppm) | **P** (ppm) | **K** (ppm) | **Zn** (ppm) | **Fe** (ppm) | **Lime** % | **Sand** % | **Silt** % | **Clay** % | **Texture** | **CEC Meq/100g soil** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Hill soils** | | | | | | | | | | | | | | |
| **Tierra amarilla (Yellow soil)** | 6.5 | 0.2 | 2.8 | 1 | 10 | 283 | 1.5 | +40.0 | Low | 48 | 27 | 25 | Sandy clay loam | 24.4 |
| **Tierra arenosa (Sandy soil)** | 6.7 | 0.2 | 1.3 | 2 | 21 | 134 | 1.4 | +40.0 | Low | 73 | 15 | 12 | Sandy loam | 11.8 |
| **Tierra negra (Black soil)** | 6.4 | 0.1 | 4.0 | 1 | 22 | 175 | 0.8 | 21.4 | Low | 43 | 27 | 30 | Clay loam | 27.0 |
| **Valley –bottom soils** | | | | | | | | | | | | | | |
| **Untreated media negra (half black) soils** | 8.4 | 0.7 | 1.9 | 3 | 21 | 148 | 1.6 | +40.0 | Low | 78 | 12 | 10 | Sandy loam | 12.0 |
| **Treated media negra (half black) soils** | 6.9 | 0.4 | 8.0 | 27 | +80 | 325 | +10.0 | +40.0 | Low | 72 | 15 | 13 | Sandy loam | 28.8 |
| **Algo arenosa (Somewhat sandy)** | 6.5 | 0.4 | 10.8 | 70 | +80 | 405 | +10.0 | +40.0 | Low | 72 | 16 | 12 | Sandy loam | 36.8 |
| **Más barro y negra (More clay and black soils)** | 7.1 | 0.4 | 7.2 | 20 | 66 | 80 | 6.3 | +40.0 | Low | 68 | 18 | 14 | Sandy loam | 28.2 |
| **Pura arena (High sand content soils)** | 6.9 | 0.3 | 4.5 | 51 | +80 | 95 | +10.0 | +40.0 | Low | 72 | 16 | 12 | Sandy loam | 19.0 |
| **Pura amarilla (Pure yellow soils)** | 6.0 | 0.5 | 3.8 | 99+ | 52 | 133 | 4.5 | +40.0 | Low | 65 | 21 | 14 | Sandy loam | 21.6 |
| **Puro barro o negra (Pure clay or black soils)** | 6.2 | 0.4 | 9.6 | 33 | +80 | 70 | +10.0 | +40.0 | Low | 60 | 25 | 15 | Sandy loam | 37.4 |

**Source:** Wilken (1987)

these raised beds is to provide a good-quality planting bed, with loosened soil for improved root development, and a field surface that traps and makes effective use of rainfall, while maintaining a well-aerated root zone.

Water management is critical for valley land management in Almolonga. A pronounced dry season from November until May makes irrigation mandatory for year-round cropping and advisable on stand-by basis even during the rainy season. To cope with seasonal water scarcity, farmers make use of scoop-irrigation (*riego con pala*). Water is extracted from drains and canals with a shovel and sprayed over the tablón surface.

Multicropping is critical to the maintenance of commercial production tablones during the whole year. Scheduling is the key-factor in areas like Almolonga where sharp rainfall seasonality and low temperatures during the dry winter season can severely affect crops. Time and space intercalation of fast-maturing vegetables is essential to maintain continuously production, similar to the chinampa system in central Mexico (see chapter Nine). Tight scheduling and intensive cultivation require a strict control of the soil and land resource, supported by a fine-tuned soil classification system, such as the one developed by the Maya-Quiché from the Guatemalan Highlands.

### 11.6. The semi-arid tropical zone

Two case studies are analyzed to show indigenous ethnopedologies in semi-arid tropical regions, where complex soil and land resources knowledge systems developed in areas with rainfall scarcity and marginal lands (Figure 11.14).

#### (12) Otomi ethnopedology from the Mezquital Valley

#### (a) Regional context

Otomi people live in central Mexico since ancient times. Formerly hunter-gatherers, Otomi were forced to become sedentary by Spanish colonists and settled mainly in the semi-arid and fragile highlands of the Mexican Central Plateau since the colonial times (Manrique, 1969; Galinier, 1987). Today, Otomi constitute an intermediate ethnic group by population size, with some 600,000 Otomi language-speaking inhabitants distributed in the states of Hidalgo, Mexico, Querétaro, Veracruz and Puebla (INI, 1993).

About 50 % of Otomi inhabitants concentrates in the state of Hidalgo, particularly in the semi-arid highland of the Mezquital Valley. Living in extreme poverty, Otomi base their subsistence on small-scale sheep herding, uncertain *milpa* agriculture and some off-farm income. Low biological productivity and complex ecology make the Mezquital Valley very fragile, especially vulnerable to anthropic intervention (Challenger, 1998). Extended soil erosion, rainfall scarcity and irregularity, frost, shallow soils on sedimentary and volcanic hills are the main limiting factors for agricultural activities in one of the harshest environments of Mexico. Rainfed agriculture is strongly constrained by low rainfall (500 mm/y). Low temperatures during the dry winter cause a long period of frost (Márquez, 1982; Galinier, 1987 and 1990).

Desertification sprawls over the whole region due to historical overgrazing and deforestation (Melville, 1992). Concentration of the most productive areas in the hands of a few landowners and the expulsion of Otomi from their best lands since the 16$^{th}$ century accentuated desertification. The Mezquital Valley was heavily deforested, loosing almost the totality of its pine-oak forests during the first 50 years of the Spanish colonization. Overgrazing by some four million sheep caused the expansion of a xerophytic bush (*matorral xerofítico*) and extended soil erosion over this formerly fertile and irrigated agricultural region (Johnson, 1977; Bernard and Salinas, 1989; Melville, 1994; Challenger, 1998). Explosive growth of sheep herds because of favorable ecological conditions accounted for 50% of the sheep population in Central New Spain during the 16$^{th}$ century (Simpson, 1952). More recently, the Mezquital Valley has been affected by severe soil salinization and contamination by plaguicides and nitrates because of poor management of an extensive irrigation system, which recycled residual water from nearby Mexico City during the last 50 years (Bernard and Salinas, 1989).

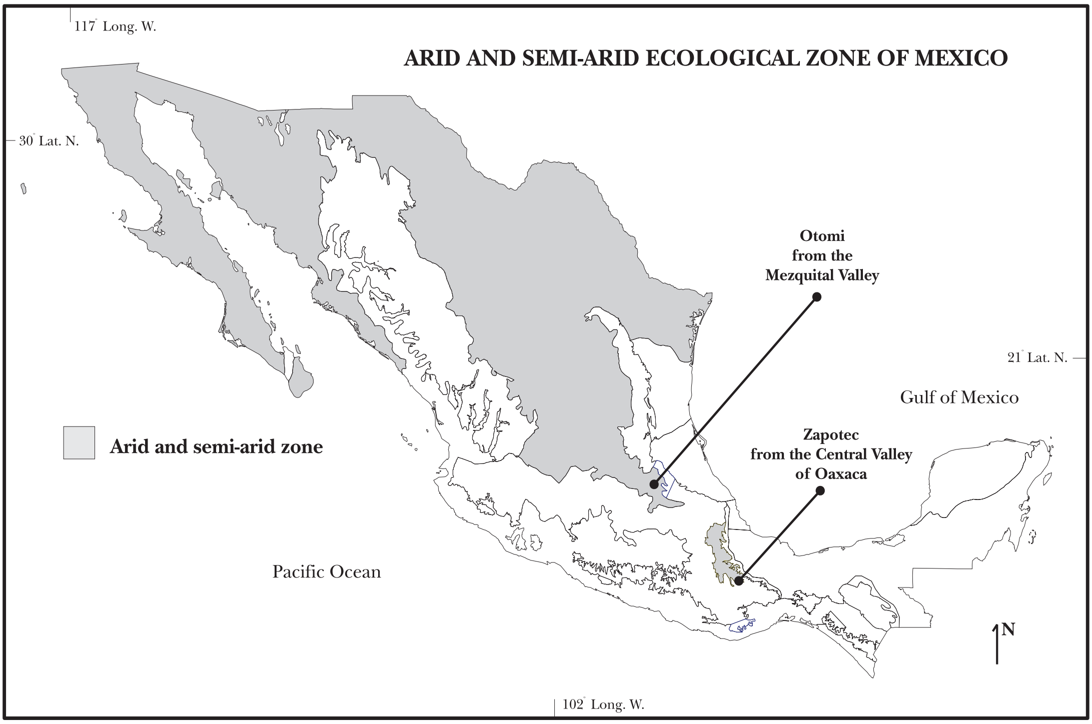



**Figure 11.14.** Arid and semi-arid zone of Mexico

### (b) Otomi soil knowledge and land management

Otomi developed a sophisticated soil and land knowledge and management system, based on the detailed recognition of their limited resources (Johnson, 1977). Floodwater farming, the construction of check-dams (or *atajadizos*) in gullies, agricultural terraces (or *bordos*) on interfluves, and careful evaluation of soil erosion/deposition constitute the main soil and water conservation and management practices evolved by Otomi farmers. These practices are carried out to maintain, enhance and restore soil fertility. Farmers are used to reclaiming sloping land without assistance from the technical agencies, more interested in developing irrigation schemes. Soil and water conservation and management practices still resemble those of the pre-Hispanic Central Middle American agricultural systems (see Chapter Seven).

Otomi agricultural techniques show a good understanding of slope dynamics and subsurface hydrology (Johnson, 1977). Management of sedimentation is preferred to erosion prevention. In some cases, upslope erosion is even stimulated to trap sediments downslope. Locals perceive of soil detachment as difficult or impossible to avoid, because no measure can possibly control precipitation. Sediments are allowed to move into the fields where Otomi farmers want to trap and accumulate them. Otomi manage soil detachment, transport and sedimentation, respecting and positively using the natural processes involved (Johnson, 1977; Bocco, 1991) Table 11.20 shows the main land reclamation techniques and soil and water conservation practices in Tlapaxco village (Bocco, 1991).

Otomi from the Mezquital Valley recognize three main land unit categories: landscape, terrain and field. This categorization is based on relief type and slope gradient, which relate to different soil–water conditions. Soil and water relations are on-site assessed to evaluate crop potential. Evaluation of crop potential constitutes the center of the Otomi ethnoscience and is done according to soil fertility, suitability of specific crops and labor allocation. Landscape is considered a natural land unit, while terrain and fields are considered products of human labor operating on their intrinsic natural conditions. Seven terrain types are recognized according to a web of associations between vegetation, relief type, slope gradient, accessibility and soil-water relations (Table 11.21). Relief is divided into three main classes: mountain, hill and lowland, which are further subdivided

**Table 11.20.** Land reclamation and soil and water conservation measures in Tlapaxco, Mexico

| Measures | Techniques |
|---|---|
| (1) Inside the gully | (A) Disposal of crop residues at gully heads to decrease runoff speed in the approach channel and to collect sediments<br>(B) Construction of layered, earth/shrub (and stone if available) filtrating check dams to control channel activity and trap sediments, specially in tributaries of the main channel. The dams, locally called "retranques", are similar to the "trincheras" of indigenous peoples in the southwestern USA and northeastern Mexico, and are similar to "atajadizos" of Otomi people in Central Mexico<br>(C) Planting long -rooted grass called "Pasto carpeta" or Carpet grass on gully walls to improve soil strength and protect them from rainfall impact<br>(D) Breaking seepage scarps to reduce their height and angle and to increase slope stability |
| (2) On eroding slopes | (E) Disposal of residues and stones on bare soil or exhumed subsoil to decrease speed of overland flow and trap sediments coming from upslope. After some material is captured, rows of nopal ( *Opuntia spp.*) or maguey *(Agave spp.*) are planted to create colluviation steps. A layer of trapped soil 10 inch thick was observed after three years of treatment<br>(F) Plowing the sod (turf) on undulating grass areas, specially where tributaries start, to stimulate the removal of the surficial horizon upslope by overland flow and collect it further d ownslope. The trapping is accomplished by piling the sod obtained upslope and creating "retranques" downslope. After several years, the original irregular slope is leveled by erosion/deposition and can be plowed<br>(G) Construction of small ditches to diver t overland flows and collect subsurface flows. The "charcos", seasonally flooded elliptical depressions, which form along the seepage scarps, are thus drained |
| (3) Preventing techniques on unaffected land | (H) Plowing parallel to contours to varying depths, according to the irregularities of the slope, to control water movement. The farmers describe this activity as "controlling the 'gravity' of the milpa" |
| | (I) Disposal of excess water from the milpa by constructing a number of ditches to avoid the concentr ation of drainage in single spots. The main ditches are protected with nopal and maguey |
| | (J) Separation of milpas from each other by grassed areas three to six feet wide to avoid concentration of drainage and create protected footpaths |

**Source:** Bocco (1991)

into five sub-classes by slope gradient, including the recognition of gullies. Field types are classified according to type of labor needed, form, size and shape, and potential for specific crop varieties.

### (c) Otomi soil and water conservation strategies

Otomi consider the field as the basic land management unit, where ecological knowledge (Corpus) and labor (Praxis) interplay enabling crop production. Several agricultural systems based on *milpa* production are performed according to field type. These systems require different labor input, constitute complex risk-avoidance and food security strategies, and imply the management of different land units and soil classes at household level. Check-dam agriculture, *bordo* agriculture and sloping and flat land agriculture are considered yield-secure, yield-risky and yield-very risky, respectively. The first two depend on runoff management practices, while the third one depends only on rainfall performance. The first two need high labor inputs, while the third and more risky one needs low labor inputs.

Each field type requires specific labor input even if it belongs to the same agricultural system. Five key concepts are translated into a set of operational dichotomies when evaluating agricultural field types. Wet season/dry season is contrasted to recognize gully functioning and to assess soil and water management practices. Water entrance/water exit is assessed to evaluate runoff speed, transportation and deposition of sediments, potential flooding, and surface water drainage within the field and outside the field. Erosion/deposition is evaluated as a function of slope gradient and as a function of type of labor needed. Concentrated flow/open flow dichotomy is assessed to define the type of soil conservation practices needed at field site. Finally, concentrated moisture/dispersed moisture operates to recognize secure cropping areas and risky cropping areas.

Otomi conceptualization of soil–water relations is central to the evaluation of field types and the performance of diverse agricultural techniques. This relational knowledge is based on four main assumptions, according to Otomi narrative. First, the inextricable link between soil and water is considered as 'soil depends on water'. Second, soil–water relations are seen as a process as 'water complicates soil because it changes it'. Third, soil–water relations are recognized as erosion/deposition-specific dynamics as 'water can wash soil away or it can build up soil'. Fourth, as water-flooding agriculture depends on runoff, Otomi assess the location and intensity of water flow within the watershed to find potential agricultural soils downslope.

**Table 11.21.** Otomi classification of terrain as a land management unit and type of labor needed to transform it into a field

| Terrain nomenclature | English term | Key attributes | Appropriate labor |
|---|---|---|---|
| Terreno montoso | Terrain covered with vegetation | Vegetation | Clear vegetation |
| Terreno enjoyado<br>Terreno plano<br>Terreno laderoso | Gullied terrain<br>Flat terrain<br>Hilly terrain | Relief and gradient | Built appropriate type of wall |
| Terreno pedregoso<br>Terreno tepetatoso<br>Terreno salitroso | Stony terrain<br>Terrain with hardpan<br>Saline terrain | Soil- water relations | Clear stones<br>Break crust<br>Drain or fertilize |
| Terreno particular<br>Terreno comunal | Private terrain<br>Communal terrain | Access | Rent, buy, share crop<br>Free access |

**Source:** Johnson (1977)

The Otomi notion of 'water complicates soil because it changes it' does not stand only for erosion/deposition dynamics, but also includes soil formation processes and soil fertility and productivity assessment. Salinization and soil compaction are recognized according to this assumption. Salinization is considered as a function of water logging. Permanent and temporary water saturation of soils are considered main causes of salinization. Otomi recognize different salinization stages and implement several reclamation techniques to overcome the problem or change the land-use when salt-affected soils are no longer suitable for agriculture. Water complicates soil because it makes it saline.

Compaction is also considered as a function of water activity. Water hardens the check-dam or *atajadizo* soils (*terremotos* or *tierra tepetatosa*). The formation of topsoil clods makes difficult to work the land. Time intervenes in hardpan formation, as water 'complicates' soils over different periods of time. This assumption permits Otomi farmers to recognize different hardpan or *tepetate* soils. Soft or hollow *tepetate* soils are 'less complicated' by water than hard *tepetate* soils. Soft or hollow hardpan soils form over short time periods of water activity, while real hardpan soils form during long time periods, according to Otomi perspective. Salinization and compaction are used to assess soil fertility and land productivity in three classes: good soils, improbable soils and non-agricultural soils (Figure 11.15). Water does not complicate all soils the same way, because soils present different properties. Black soft and deep soils and *elame* or muddy soils are considered to be the best ones for agricultural purposes, while yellowish and white soils are perceived as having been salinized some time in the past.

### (d) Otomi soil taxonomy

Seven basic soil types are locally recognized and no sharp distinction between soils and a loose conglomerate rock or cantera, tepetate, hardpan and solid stone, is made. Soils are arranged along a gradient of hardness and salinity, but each soil class possesses individual attributes, limitations and uses. Otomi soil taxonomy is hierarchical. Various (13) soil classes are recognized(Table 11.22).

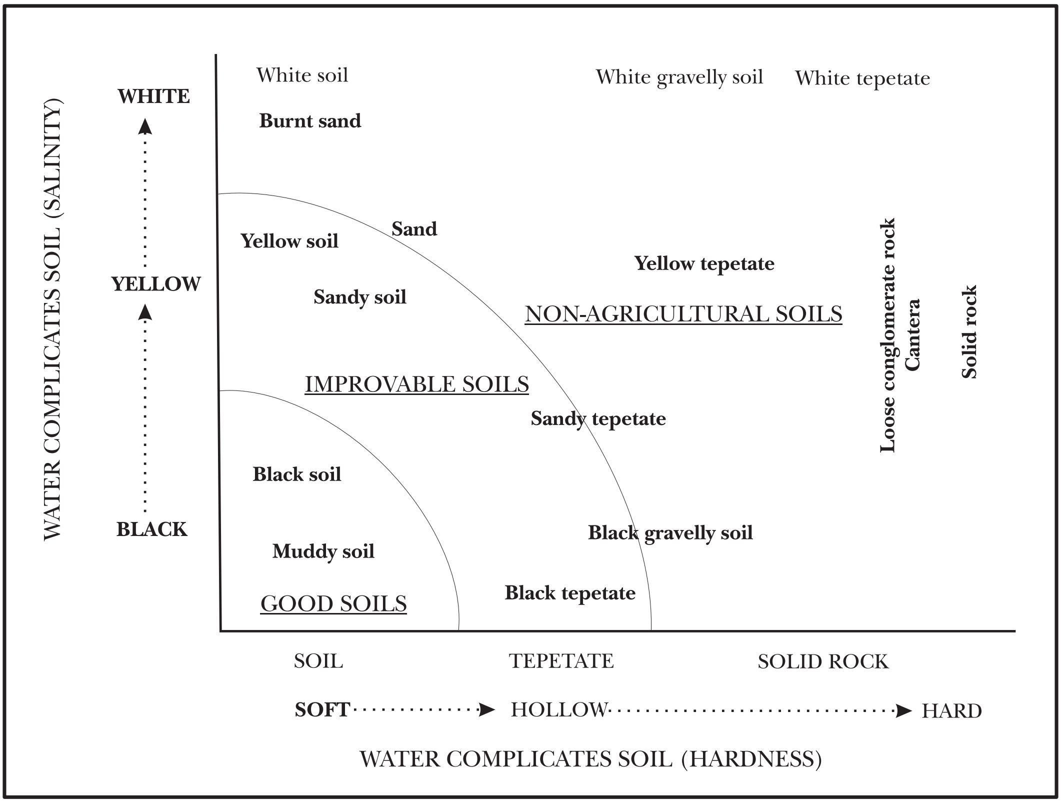



**Figure 11.15.** Otomi soil and water dominion. **Source:** Johnson (1977)

Soils are classified according to color, texture, structure, consistence, organic matter content, drainage condition, moisture retention capacity, stoniness, salinity, relief position, alkalinity, depth, presence of hardpan, workability and fertility (Johnson, 1977). Color, texture, consistence, hardpan, stoniness and structure of the topsoil are the main descriptors used to give soil names.

The main discriminating criteria to assess soil productivity are:

- soils are either cultivable or not cultivable;
- alkalinity is measured by taste. 'Sweet' soils are cultivable, while 'not sweet' soils are not cultivable(saline soils, for example);
- soil consistence is either hard or not hard;
- soils are qualified according to moisture retention capacity and drainage condition, using two contrasting criteria: soils that are not complicated by water and soils that are complicated by water, and
- soils are also assessed for construction in two groups: soils that are used as construction material (mainly for check-dam and *bordo* walls) and soils suitable for construction.

## (e) Otomi land-crop suitability assessment

Soil suitability for crops is assessed according to the five criteria given above. Otomi recognize that different soils suit different crops. Three main soil groups are distinguished for this purpose: (a) best soils are well suited for long-cycle maize and bean varieties (*tardío*); (b) improbable soils are suited for short-cycle maize and bean varieties (*violento*); and (c) very improbable soils are suited for maguey (*Agave spp.*) and nopal (*Opuntia spp.*) plantations. Table 11.23. shows the three soil groups, their limitations for agricultural purposes and the type of input needed to improve soil productivity.

**Table 11.22.** Otomi soil classification

| | Soil types | Soil classes |
|---|---|---|
| All soils | Soil | Muddy soil (elame) |
| | | Black soil |
| | | Yellow soil |
| | | Sandy soil |
| | | White soil |
| | Sand | Sand |
| | | "Burnt' sand |
| | Gravel | Black gravel |
| | | White gravel |
| | Tepetate (Hardpan) | Black tepetate |
| | | Sandy tepetate |
| | | Yellow tepetate |
| | | White tepetate |
| | Cantera<br>Solid stone<br>Salitre | |

**Source:** Johnson (1977)

### (f) Otomi soil knowledge and agricultural systems

Recognition and assessment of agricultural soils allow Otomi farmers to perform four main agricultural systems: *atajadizo, bordo, ladera* and *plan*, and *elame.* All are based on *milpa* multicropping, relief position, labor allocation and investment. The main characteristics of these agricultural systems are synthesized in table 11.24 and figure 11.16.

One commonality among these four agricultural systems is the mechanism enabling topsoil to build up. These techniques allow farmers to overcome limitations of poor or even shallow soils. A common strategy used to deal with stony and hardpan soils is simply waiting until floodwater sediments and organic debris cover them. Otomi recognize and discriminate soil profiles and soil horizons (*bancos*) and are fully aware of soil detachment, transportation and deposition. Moreover, the Otomi concept of 'water complicates soils' reveals the good understanding of erosion/deposition and, to some extent, of the dynamics of subsurface hydrology. Otomi fundamental soil concepts reside in the soil–water dominion. Otomi do not think exclusively in terms of soils, but think in terms of soil–water relations (Johnson, 1977; Iwanska, 1971).

Johnson (1977) compared Otomi soil knowledge with the one possessed by agricultural extension agents working in the Mezquital Valley. The comparison between Otomi and technical (*técnico*) ethnosciences and soil narratives revealed fundamental issues to be considered by rural developers in the region and elsewhere:

(a) a comparison between technical and Otomi domains of soil knowledge is rather difficult at the outset. The difficulty relates to the fact that the technical soil knowledge exists at two distinct levels. Agricultural extension agents possess a general, well-informed knowledge, but place emphasis on aspects of their own particular specialization areas. Another level of knowledge is that of the soil specialists, who carry out a soil survey in the region using laboratory determinations, which are then put into particular uses by the local technician. Well-informed generalists can call upon specialists whenever these are needed;

(b) the comparison of the Otomi soil knowledge to that of the well-informed agricultural extension agent has the disadvantage of making the technical soil knowledge appear to be more rudimentary than it actually is;

(c) regarding soil taxonomy, Otomi possess a complex, detailed and well-suited soil classification, while the agricultural extensionist, possesses no comparable soil classes;

(d) lack of communication between technician and soil specialist limits the possibilities for suitable rural development policies and measures. A detailed soil survey was conducted by specialists in the Mezquital Valley. Soil series were mapped according to the USDA soil taxonomy, but local agricultural extensionists ignored this information;

(e) Otomi make no sharp distinction between soil, exhumed hardpan and solid stone, the latter thus being non-soil material from the scientific point of view. Unspecialized technicians characterize soils in general terms and select possible land-uses according to soil depth. Sloping soils are generally considered poor and eroded. Valley soils where alluvium has accumulated are considered more promising. Otomi have an in-depth understanding of local soil dynamics, while technicians characterize soils in a more static way.

**Table 11.23.** Otomi soil suitability ranking for agricultural purposes, soil limitations and measures needed for soil productivity improvement

| | Soil ranking | Location | Soil types | Soil limitations | Measures needed |
|---|---|---|---|---|---|
| Cultivable soils | **Best soils** | Gullies and interfluves | Deep black soils | Hardness | Build atajadizo and bordo; Deep plowing to break up terremotos |
| | | Large dams | Elame soils | Frost | Correct seedling timing |
| | **Improbable soils** | Slopes and flats | Yellow soils | Salinity | Fertilizer, domestic ashes |
| | | Slopes and flats | Sandy soils | Drainage condition | Fertilizer; build bordo |
| | | Gullies, interfluves and slopes | Black hardpan | Relatively good soils | Must be broken up |
| | | Gullies, interfluves and slopes | Hollow hardpan | Relatively good soils | Must be broken up; Fertilizer |
| | | | Burnt soils | Lack of strength | Fallow; fertilizer |
| | **Very improbable soils** | Gullies and interfluves | White soils | Too saline | Fallow; fertilizer; grazing |
| | | Gullies, slopes and interfluves | Terrero | Too hard | Must be broken up; fertilizer |
| | | Gullies and slopes | White gravel | Drainage condition | Fertilizer; compost adding |
| | | Slopes | Yellow hardpan | Drainage condition | Must be broken up; fertilizer |
| | | Slopes | White hardpan | Too hard | Must be broken up; fertilizer |
| | | Slopes | Stony soils | Drainage condition | Fertilizer; compost adding |

**Source:** Johnson (1977)

(f) technicians and Otomi soil knowledge correlates in description of alluvial soil profiles, recognizing similar horizons and relations between components, although Otomi have less access to cultivate these soil types;

(g) the Otomi concept of 'water complicates soils' does not appear in the technical soil knowledge but can be found in scientific literature specializing in soil carbonation and salinization, and

(h) Otomi farmers have developed a great number of techniques to enhance on-site soil–water conditions, while introduced practices conduce to soil homogenization using standard measures and large equipment to reclaim shallow and other problem-soils and control soil erosion. Otomi and agricultural extensionists have a different approach to soil erosion control.

Otomi farmers of the Dení community in the Mezquital Valley possess complex knowledge about soil and land resources. This knowledge system is shared with farmers from other localities within the same region and with similar cultural background. Márquez (1982) made a comparative ethnopedological research in four Otomi communities of the Mezquital Valley. Seven main soil classes were recognized with names similar to those from Dení. Concepts used to name the soils are notoriously similar (Table 11.25).

Márquez (1982) conducted a statistical analysis to compare soil laboratory determinations of Otomi soil classes with soil properties locally assigned to each soil class. Variance and t- statistics demonstrate that: (1) Otomi local

**Table 11.24.** Otomi agricultural systems

| Agricultural systems | Main characteristics |
|---|---|
| **Atajadizo or checkdam system** | Consists of fields made in a gully. High labor investment is needed to build up an atajadizo. Floodwater sediment trapping and water management are carefully performed. Engineering skills are needed to construct two walls and a floodgate. An external wall is built with solid rocks and cemented with mortar. The main purpose of this wall is to hold back the runoff water coming from the upslope watershed. A second or double wall is built in a similar way to hold the soil that accumulates, with a floodgate (compuerta) to spill over the extra runoff water and prevent flooding. Field leveling is important to prevent micro-local flooding and distribute the trapped sediments evenly. Although the atajadizo soils are considered the best agricultural soils, they have some limitations due to their hardness and need to be broken up wit a pickax. The soils are heavy and dense (tupído) when black soil accumulates. The soil shrinks when dry and strangles crop roots when forming large hunks (terremotos); it is very difficult to plow. Nevertheless, breaking up the terremotos allows to plant late maize and beans (tardío) because of good soil moisture retention. Planting maguey on the atajadizo wall permits to strengthen the wall by holding the gravel and trapped sediments. Fruit trees, such as pecans and peaches, are also planted on the wall. The atajadizo agricultural system is built up during several years according to the amount of trapped sediments and the amount of water that needs to spill over. |
| **Terracing system (Bordo)** | Bordos or terraces are built on the interfluves between gullies. They can be divided in two field types according to slope gradient and drainage condition: sloping fields (terrenos laderosos) and flats (planes). A bordo system should be able to trap and hold water that runs downslope and allow it to spill over to the next bordo downslope. Bordos are steps down the hillside. They are not leveled, so they can be considered as semi-terraces. High labor investment is needed to improve bordo soils. Firstly, Bordos can be built up with almost anything: plants, sediments, soil removed elsewhere and stones. Maguey plantation helps strengthening the bordo walls. Mesquite (*Prosopis spp.*) is widely used on the flats for the same purpose. Breaking up the "improbable" hardpan or tepetate soils gives two possibilities: one is building up bordo walls with large pieces of hardpan; the other is letting small pieces of hardpan dissolve by rainfall to give fresh sediments to the topsoil; thus the 'burnt soil' (weak, unfertile soil) will be fertilized. As upslope runoff water does not wash in much new soil, organic debris and manure are needed to improve soil fertility. Bordo soils need several measures to improve soil fertility. Composting (componer el suelo) with sheep, goat or cow manure, household trash, domestic ashes and soil from other terrain, is mainly used. Constructing channels within the bordo fields to improve soil irrigation is another measure. Household trash and domestic ashes enhance soil structure and soil fertility. Composting is a balanced measure. According to Otomi narrative, manure and ashes call for water, while mixed household trash balances hot and dry with cool and moist. Sheep and goat manure is considered to strengthen the soil (picoso) and, although it has long-lasting properties, it is perceived as hot and dry, while household trash is cool and moist. Bordo soils are considered less productive than atajadizo soils, and crops often fail because of lack of rain or late rains and early frost. They are more dependent on rainfall than atajadizo soils. Maguey plantation on the bordo walls contributes to holding and strengthening the soil. Steep, stony and dry conditions need more maguey to be planted. Short-cycle maize and bean varieties (violento) are planted on bordo soils. |
| **Sloping and flatland systems (Agricultura de ladera y plan)** | This agricultural system needs less labor input than the two previous ones. It depends on rainfall rather than on floodwater. It corresponds also to the group of "very improbable" soils; thus Otomi farmers do not use chemical fertilizer because it would be rapidly washed away. Nevertheless, this high-risk agricultural system is locally considered of good productivity, when there is enough rainfall during the critical periods of crop development. With sufficient rain, the sloping and flat fields may be more productive than the atajadizo soils that will shrink and harm the crops. Otomi call soils developed in these fields as "not very complicated by water" because they are less exposed to flooding over time. Short-cycle maize and bean varieties (violento) are cultivated for no more than 2 to 3 years. |
| **Elame system** | This special agricultural system is called elame because it stands on fresh sediments and organic debris (lama) trapped behind large dams. Elame is a very productive rainfed system, so farmers take great care of these fields. It is based on the accumulation of floodwater during the rainy season when the floodgates are closed. Floodgates are open during the dry season to spill out water once sediments and water are trapped. Very fertile, moist silty soils are used then to cultivate short-cycle maize and bean varieties (violento). Nevertheless, crops run the risk of being burned by frost during February, March or even April. Replanting is usually impossible since by August the dam starts accumulating water and late-planted fields can be flooded out. |

**Source:** Johnson (1977)

soil knowledge is consistent at regional level, although it presents local adaptations; (2) Otomi soil classification possesses scientific bases; (3) Otomi soil diagnostic properties vary according to each soil class within similar and different landscapes; (4) comparison of four local ethnopedologies shows analytical consistence of the Otomi soil classes, with similar denominations and local diagnostic properties within similar and different landscapes; and (5) the Otomi soil knowledge is consistent in land-use and management of each local soil class.

**Table 11.25.** Comparison of soil classes among five Otomi communities of the Mezquital Valley

| Otomi soil classes (Hai) | English terms | El Nith | San Pedro Capula | Cuesta Blanca | San Miguel Tlazintla |
|---|---|---|---|---|---|
| | Elame soil | Dark soil; very fertile soil; it cracks and hardens during the dry season; clayey, sticky soil | Dark silty soil; it cracks when dry and sticks when moist; good moisture retention capacity | | |
| **T'axhai** | White soil | White soil; improbable soil; stony soil | White ash-like soil; improbable soil; stony soil | Dust-like soil; shallow soil; improbable soil | White soil; it drains fast and needs a great volume of water; it is dusty; it is like flour; improbable soil |
| **'Bomuhai** | Sandy soil | Loose and soft soil; grained-like soil | Very porous soil; loose and soft soil; it drains fast; it is eroded by wind | | |
| **Xido** | Tepetate | Hard, whitish soil | Hard soil; very improbable soil; it drains fast | Hard soil; very improbable soil | Hard soil; whitish soil; very improbable soil |
| **'Bohai** | Black soil | Very dark soil; all crops can be cultivated. It cracks and hardens when dry; good moisture retention capacity | | Black or very dark soil; cracks and hardens when dry; sticky when moist; good moisture retention capacity | Black or very dark soil; all crops can be cultivated; it cracks and hardens when dry; good moisture retention capacity |

**Sources:** Johnson (1977) and Márquez (1982)

## (13) Zapotec ethnopedology from Mitla, Oaxaca

### (a) Regional context

The Zapotec people is the third most populous indigenous group in Mexico. Some 700,000 Zapotec inhabitants were censed on the basis of language at the end of the 1990s (INI/World Bank, 1998). Most Zapotec in the state of Oaxaca live in three regions: (a) the Sierra Zapoteca (Sierra Norte de Oaxaca); (b) the Central Valleys of Oaxaca; and (c) the Pacific coast or the Tehuantepec Isthmus. These three regions correspond broadly to three agro-ecological zones: (a) the sub-humid temperate highlands (Sierra Norte de Oaxaca); (b) the semi-arid tropical lands (Central Valleys of Oaxaca); and (c) the sub-humid tropical lands (Pacific coast or Tehuantepec Isthmus).

San Pablo de la Villa de Mitla municipality is located in the Central Valley of Oaxaca, between the semi-arid lands and the sub-humid temperate highlands. Mitla has a population of some 11,000 bilingual Zapotec inhabitants (Figure 11.14) (INI/World Bank, 1998). The meaning of Mitla (*Mictlan* in Nahuatl) is "the highest place or the town of the souls or dead" (Messer, 1978). Mitla was an important ceremonial centre during pre-Hispanic times. A complex archaeological site highlights its ancient religious importance.

Archaeological and palinological research findings demonstrate that the area was inhabited since 8,000 BC (Flannery and Blanton, 1978). Pollen analysis revealed that this area is one of the earliest agricultural centers of Middle America (Flannery and Blanton, 1978). Maize pollen found near Mitla were dated to be from 4,000 to 5,000 BC The evolution of complex agricultural systems based on maize cropping was also traced by palinological analysis. Pollen of squash, tree crops, fibers, *Chenopodium* and *Amaranthus,* avocado, cotton, chili pepper and maguey (*Agave spp.*) corroborate agricultural activity in the Central Valley of Oaxaca since 5,000 BC .

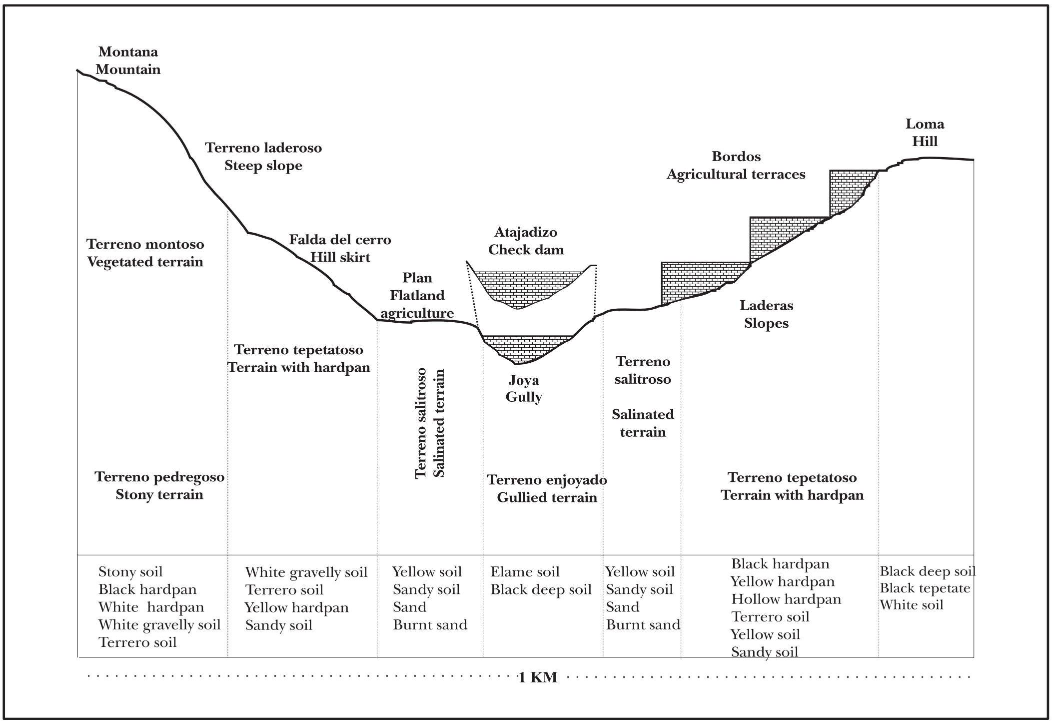



**Figure 11.16.** Otomi soil-relief cross-section and corresponding agricultural systems. **Source:** Johnson (1977)

Elevation ranges from 1,600 to 1,850 m.a.s.l., and mean annual temperature from 18 to 20°C between hills and valley bottoms. The mean annual rainfall ranges from 500 to 700 mm, as usual in the semi-arid highlands of central Mexico. Rainfall variability and uncertainty, frost occurrence during the dry winter, marginal soils on the hills and temporal floodings in the lowlands constitute the main environmental limitations for agricultural activities. Nevertheless, agriculture remains an important economic activity for contemporary *Mitleños*, although decreasing in importance since the 1970s (Messer, 1978). Zapotec villages from the Central Valleys of Oaxaca show high rates of out-migration. Environmental degradation and extreme poverty since the colonial times are the main causes of mass migration. To cope with these constraints, *Mitleños* still attached to the land undertook two main strategies: partial technological innovation adoption and the maintenance of an endured agrarian tradition are hybridized. An ethnopedological recount reveals this syncretism (Messer, 1978).

### (b) Local agro-ecological zoning

*Mitleños* recognize four main agro-ecological units within their territory:

(a) the low alluvial lands (1,600 to 1,700 m.a.s.l.) or permanently humid terrain (*yuh Khop*) correspond to the bottom-level lands temporarily flooded by the Tecolula and Mitla rivers. Deep and temporarily flooded black alluvial soils allow double cropping within the year. Maize-beans-squash multicropping fields are located on the riverbanks. Sugar cane plantation is also an important activity;

(b) the high alluvial lands (1,700 to 1,800 m.a.s.l.) are located at the upper margins of the valley. Here, soil varies in thickness and productivity. Local farmers recognize two main soil types: (1) soils with good yields but susceptible to erosion by heavy rains, and (2) thick soils providing good yields with sufficient rains, but highly risky during years with marginal rainfall. *Milpa* fields are scattered within patches of thorny scrub or Mezquital (*Prosopis* spp.). Maize-beans-squash multicropping is mixed with useful "weeds", such as *Chenopodium* and *Amaranthus,* and with maguey plantations;

(c) the piedmont or thorny scrub area (1,800 to 1,850 m.a.s.l.) is marginally used for agricultural purposes. Maize monocropping and maize-maguey intercropping are the main agricultural systems. Bare or shallow limestone soils are highly prone to water and wind erosion. Agricultural terraces and irrigation channels are still maintained to enhance soil fertility, catch sediment run-off and temporarily irrigate cropping fields, and

(d) mountain or hilly lands (*yuh dahn*) (1,850 to 2,000 m.a.s.l.) are reduced in extent and marginal for agricultural activities. Pine-oak forests degraded by sheep over-grazing and fuelwood extraction since the colonial period is the main vegetation cover.

The local agro-ecological zonification resembles the colonial categorization of land-use qualities. The low alluvial land or "*tierra de pan llevar*" is considered first-class land for agriculture because of high yields. The high alluvial land or "*tierra de pan sembrar*" is considered second-class for agriculture. The piedmont and hilly lands are considered third agricultural class with marginal and risky yields.

### (c) Zapotec soil/land classification

Farmers from Mitla recognize eight soil types within their territory. Soil depth, moisture retention capacity, texture and stoniness are the main properties and soil descriptors used to name soil taxa. Zapotec soil classification is hierarchical, although rather simple. Three clustering levels organize the local taxonomy. Land and soil concepts are not sharply differentiated. The land morpheme (*yuh*) refers at the same time to soil, land and agro-ecological terrain (Figure 11.17.), and is placed at the first level of the taxonomy. Three main land types are recognized at the second level of the taxonomy, when farmers are questioned about the types of land that they possess or manage (*so nahkh syu? Lu?*). These three main land classes are labeled according to bio-climatic criteria and are referred to as countries: the hot country (*yuh le*), the temperate country (*yuh nahl*) and the cold country (*yuh bidi*). These classification clusters resemble the colonial zonification used to distinguish rural landscapes in America according to climate, elevation and vegetation.

The temperate country is the only type of the bio-climatic unit occurring in the Mitla territory, thus all soil taxa clustered in the third and last taxonomic level correspond to this country. The recognition of the other two bio-climatic countries reflects the historical unity of an ancient Zapotec territory, the kinship ties of *Mitleños* with other villages, and the historical circulation of *Mitleños* within the state of Oaxaca. The third and last taxonomic level clusters eight soil/land classes, which are labeled using soil attributes such as consistence, structure, texture, color and moisture availability in dichotomic manner (e.g. thick vs. shallow; sandy vs. stony; black vs. yellow; moist vs. dry).

### (d) Zapotec soil quality ranking

Moisture retention capacity is the most important soil property used for agricultural soil quality assessment. This criterion is linked to other soil properties, such as soil-relief position, color, depth and productivity. Bottom-level valley soils (*yuh hop*) are temporarily flooded and double cropped during the year. These soils are named as juicy lands (*tierras de jugo*) due to their favorable moisture retention capacity. These are black (*yuh yas*), thick (*yuh naL*) and moist (*yuh koph*) soils, but as color, thickness and moisture vary within fields. They are named according to the dominant property. Hill soils (*yuh dahn*), located on non- flooded lands or in the piedmont, are considered thin (*yuh las*) and/or yellow (*yuh gohts*). These soil types can be cropped only once a year for four to five consecutive years. They are considered as second or third agricultural land classes, because of inadequate moisture retention capacity and susceptibility to water and wind erosion.

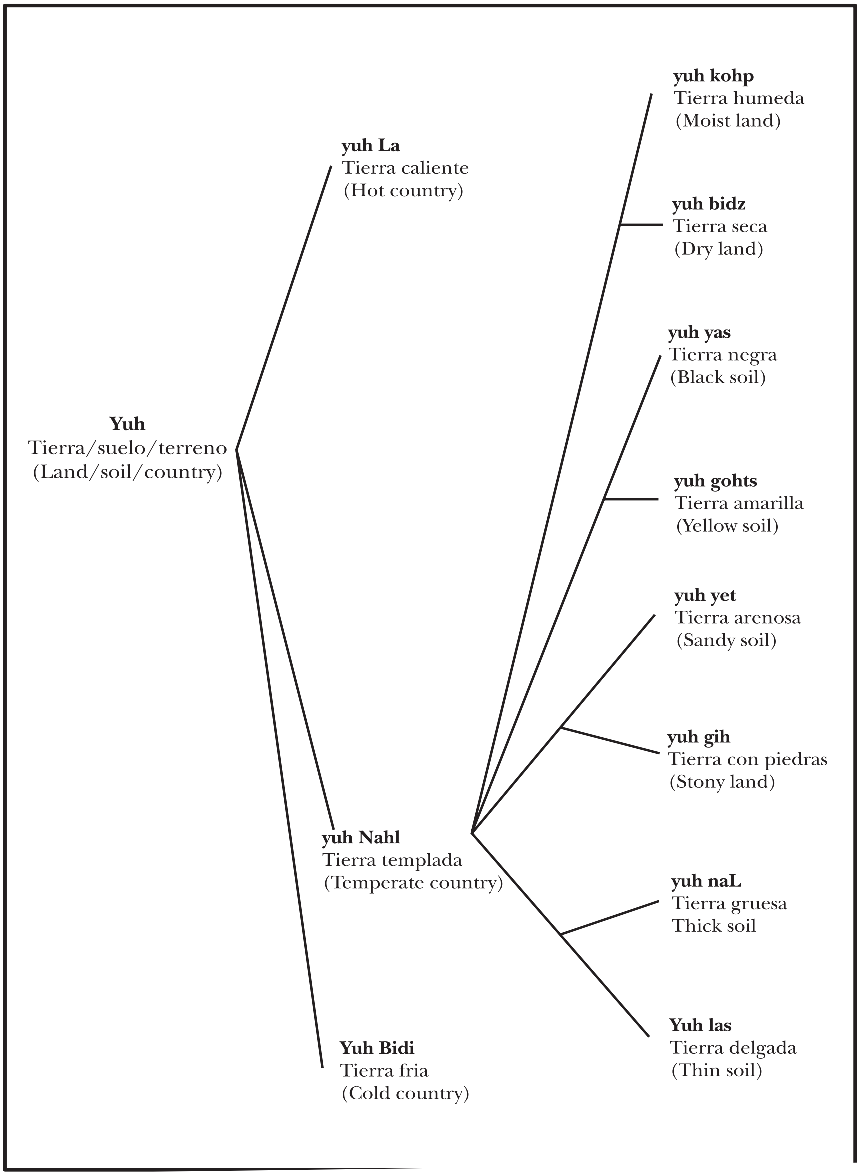



**Figure: 11.17.** Zapotec soil taxonomy. **Source:** Messer (1978)

### (5) Soil knowledge and the local agricultural strategy

*Mitleño* farmers consider all soil/land types potentially suitable for agriculture. Diverse land management enhances potentialities or diminishes limitations according to soil type within each agricultural field. Farmers intend to manage at least two fields, generally with different soil types. One agricultural field may be near the river (thick soil) and the other away from the river (thin soil). Management of diversity of fields intends to diminish crop failure due to environmental uncertainties and produce an ample variety of crops to supplement the daily diet of the households during the year.

The local agricultural strategy is based on the perception of a set of environmental constraints and dynamics, such as the amount and timing of rains and frost, and the occurrence and severity of plagues.

This is performed according to soil quality, availability of seeds, and the implementation of adequate skills and technology for seed mix, terracing, channeling, weed control and soil fertility enhancement via organic fertilization. The economic position of the household and the availability of cash are critical factors. Soil and water conservation is based on the maintenance of adequate soil moisture during the cropping cycle, the soil fertility enhancement via amendment of animal and plant manure during various crop cycles, and appropriate fallow when land is "tired" and requires to "rest" (fallow).

Central is the farmer's assessment of soil behavior. Farmers carefully assess soil "readiness" during the first rainfs of June. The soil is ready to be sown when the topsoil is moist but not wet. A white dry top layer with moisture a few centimeters beneath means that the soil is ready. Thick soil (*yuh naL*) takes longer than thin soil (*yuh Lâs*) to get moist enough for planting after one or two heavy rains. It yields well in a season with low rainfall, while soaking may endanger the crop.

Two maize races and various local varieties were carefully adapted to each soil/land type. These crops are drought-resistant and have different phenologies. Yellow maize is more suitable for the hilly lands (*yuh dahn*), while white maize grows better on the valley lands (*yuh koph*). *Milpa* multicropping enhances or maintains soil fertility on the hilly lands, according to farmers' perception. Mixtures of legumes with maize seeds are sown on thin lands (*yuh Lâs*), constituting common cropping systems in Mitla fields.

*Mitleño* agricultural strategy relies on individual knowledge, although knowledge is socially shared as part of the local institutional livelihood. A combination of modern and traditional technological implementation depends on the mastery of land management, household economic position and cash availability. The use of tractor, ox-pulled plow or digging stick relies on soil knowledge and economic opportunities. Terracing, mounding, composting and channeling play an important role. The use of electrical water pumping, management of run-off water and flooding are also combined depending on skills, opportunities and restrictions. Gender, age, individual aptitudes and attitudes toward agricultural activities shape *Mitleños'* soil knowledge and land management. Differences in knowledge between individuals are due to the exposure to and interest in agriculture. Curiosity and occupational commitment to agriculture usually result in a greater mastery of the agricultural factors, such as the soil and land resources.

# CHAPTER TWELVE

# THE MAYAN ETHNOPEDOLOGY FROM THE YUCATÁN PENINSULA

## 12.1. INTRODUCTION

Contemporary Mayan ethnopedology of the Yucatán Peninsula has been well documented. Research carried out during the second half of the 20th century shows an endured soil-human relationship linked to shifting cultivation in an extensive area with marginal karstic soils (Dunning, 1992), rainfall scarcity and rainfall irregularity as main environmental constraints for agriculture. Mayan soil and land resources knowledge and management appear to be consistent at regional, municipal and local levels. Soil classes are recognized, named, classified and managed in similar ways by Mayan farmers from distant areas within the Yucatán Peninsula, showing a well-established regional soil culture.

It was only recently that soil researchers and agronomists became aware of the richness and well-suited ethnopedological system possessed by the local farmers of this region. Several tried to integrate the Mayan soil nomenclature into their own technical knowledge and practice, making possible the dialogue between technicians and local farmers (Duch, 1989; Hernández-Xolocotzim et al., 1990). This innovative effort could be beneficial to problem-solving in land-use planning, adoption of agricultural technology and natural resource management, despite the persistent conviction held by governmental agencies and research institutes that the Mayan ethnopedology is primitive and ill-suited for implementation in rural development (Pool-Novelo, 1980). The former has led to the failure of several attempts to modernize rural production in the Yucatán Peninsula and the dramatic increase of deforestation in the region (Ewell, 1984; Ewell and Merrill-Sands, 1987; Gómez-Pompa et al., 1991; Dunning, 1992; Terán and Rasmussen, 1994; Faust, 1998).

This chapter discusses the Mayan ethnopedology integrating Cosmos, Corpus and Praxis in a structured way. The main objective is to demonstrate the complexity and suitability of this knowledge-based system and its potentiality for seeking sustainable resource management in cooperation between technicians and local populations. Section 12.2 describes the regional context. Section 12.3 shows the complexity and richness of the Mayan soil/land nomenclature. Section 12.4 discusses the Mayan soil taxonomy. Section 12.5 establishes a comparison between the Mayan and the technical soil classification systems. Section 12.6 describes relevant aspects of the Mayan knowledge on soil-relief-vegetation relationship at regional and local levels. Section 12.7 discusses how the Mayan soil knowledge is applied for agricultural land-use evaluation under shifting cultivation practices. Section 12.8 highlights the symbolical perception of the land in contemporary Mayan cosmology, which cannot be separated from the technical knowledge when analyzing the ecological and productive rationale of Mayan farmers.

## 12.2. REGIONAL CONTEXT

### 12.2.1. The Maya from the Yucatán Peninsula

Mayan people constitute the second most important indigenous people by population size in Mexico and much probably the most important in contemporary Middle America. According to the last indigenous population census in Mexico (INI, 1993), approximately 1 million Yucatec-Mayan language-speaking inhabitants live in the states of Yucatán, Quintana Roo and Campeche, within the Mexican portion of the Yucatán Peninsula. Also about 1 million Yucatec-Mayan language-speaking inhabitants live in Guatemala and Belize (Grimes, 1996). Approximately 3.5 million Mayan-language speakers live in Mexico and Central America (Grimes, 1996). Large portions of the Yucatán Peninsula are part of the current transnational Mayan territory, although Mayan populations are also present in the Sierra Lacandona, the Chiapas Highlands and the Guatemala Highlands. Cultural vitality, big population size and permanence of a long-standing subsistence strategy characterize Mayan people.

### 12.2.2. Environmental setting of the Yucatán Peninsula

The Yucatán Peninsula is a shelf formed by marine limestone that was slightly uplifted during the Plio-Quaternary (Ferrusquía-Villafranca, 1993) (Figure 12.1). Over an area of 168,000 km$^2$, this flat to slightly undulating limestone relief, with scattered hummocks and hillocks (*altillos*) of elevations not higher than 100 m, is subjected to karstic processes, with limited groundwater resources. Water does not flows across the surface in streams and rivers; it rather seeps into the limestone base and flows underground to the sea. Underground water levels vary greatly over short distances, depending on the variations of the karstic relief. Scattered patches of acidic bottomland soils, clayey and impermeable, transform into shallow lakes or swamps (*bajos*) during the rainy season. Some of the *bajos*, which form at the foot of limestone ridges, are deep enough to hold water throughout the year. Naturally formed or man-made dolines are locally called *aguadas*, both depending on the yearly rains to replenish water (Faust, 1998) (Figure 12.2).

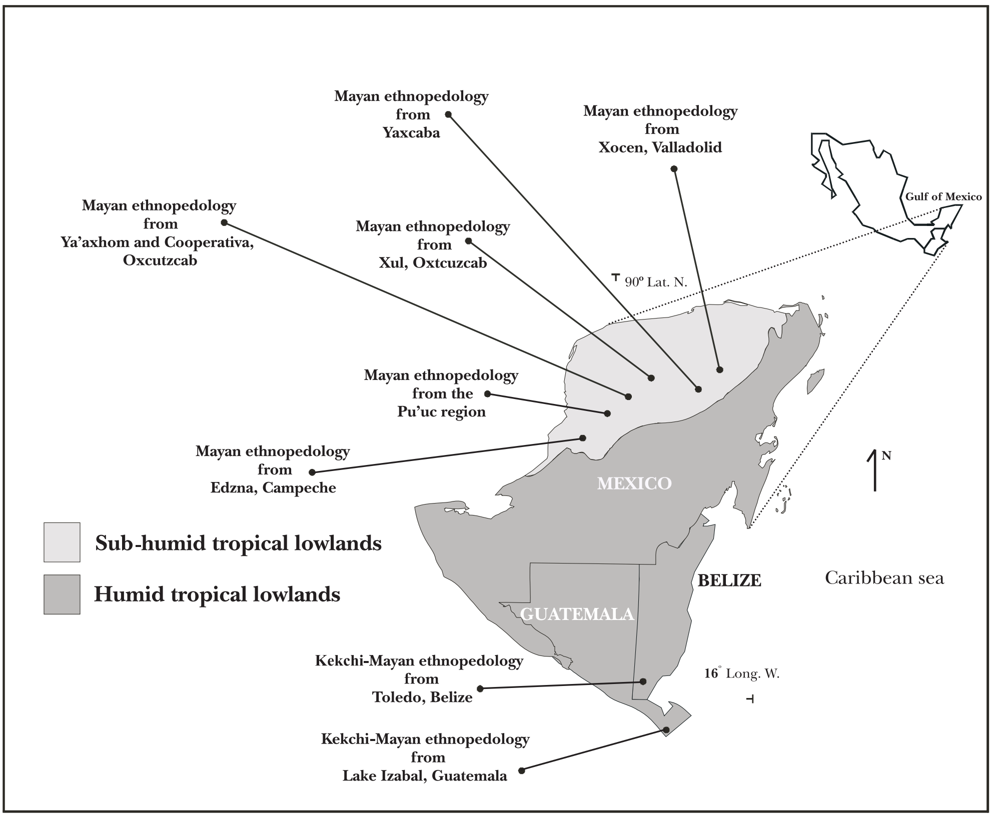



**Figure 12.1.** The Yucatán Peninsula

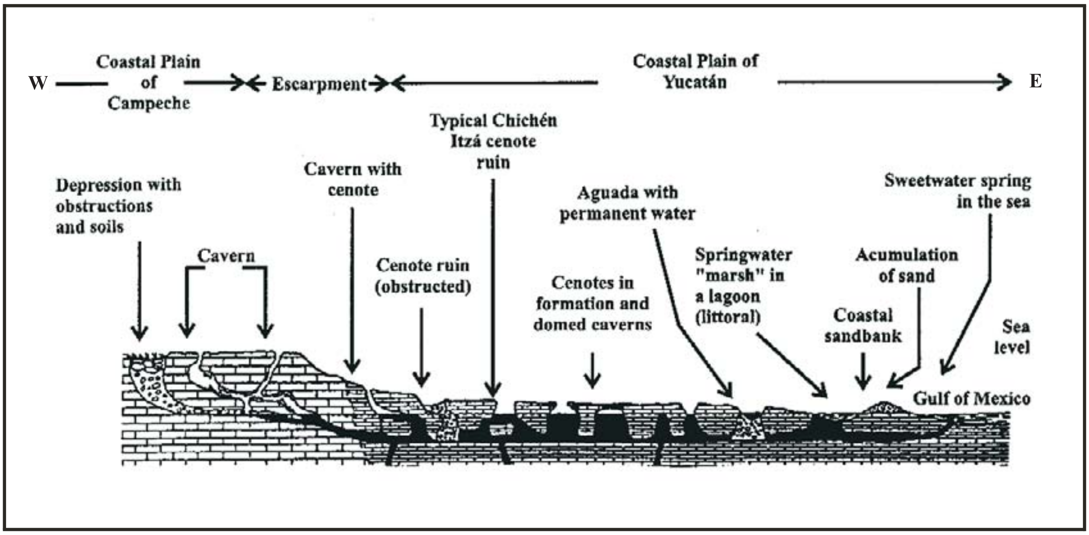



**Figure 12.2.** Geomorphic model of the Yucatán Peninsula

Climate is tropical with markedly distinct wet and dry seasons. Annual mean temperature is high (26° C), with slight variations during the year. Annual rainfall increases from the northwest to the southeast of the Peninsula (500–1,500 mm/y), ranging from semi-dry to sub-humid and humid tropical. Important portions of the Peninsula have sub-humid tropical climatic conditions, with a dry season during the winter (November- April) and a rainy season during the summer (May-October). Rainfall scarcity during half of the year, rainfall irregularity, scarcity of groundwater and shallow soils are the main environmental constraints for agriculture (Ewell and Merrill-Sands, 1987; Hernández-Xolocotzim et al., 1990). Soils are recent and shallow to moderately deep, generally alkaline, but reaction depends on the karstic relief position, drainage conditions and parent material. These soils have formed from calcimorphic alluvial and colluvial sediments, distributed in complex patchy associations controlled by the microrelief patterns (Hernández-Xolocotzim, 1959; Robles-Ramos, 1958). Clay soils are typical in the southern lowlands, whereas soils on limestone outcroppings are more frequent in the northern Yucatán Peninsula. A typical soil toposequence includes:

(a) calcimorphic soils with good drainage on the higher positions;
(b) calcimorphic soils with moderate drainage on gentle slopes; and
(c) hydromorphic soils with poor drainage on the flat lowlands and bottom-level lands.

Lithosols, Rendzinas, Luvisols, Cambisols, Vertisols and Gleysols are well distributed all along the Peninsula, according to the FAO/UNESCO/DETENAL soil legend (1970). They are not easy to classify using conventional taxonomies so that almost everyone specializing in Yucatán soils, including governmental agencies, research agencies and extension services, use the Mayan soil nomenclature (Ewell, 1987; Dutch, 1989). Generally, soils are too shallow and stony to allow agricultural mechanization; therefore, *milpa* shifting cultivation with low average maize yields is the best adapted system to the patchy karstic landscapes of the region (Pool, 1980).

Diverse types of secondary and primary seasonal tropical forests, including on low-height deciduous and semi-deciduous formations (*selvas bajas caducifolias y sub-caducifolias*), medium-height deciduous and semi-deciduous tropical forests (*selvas medianas caducifolias y sub-caducifolias*) and tall evergreen formations (*selvas altas perennifolias*), dominate the Yucatán Peninsula (Miranda, 1959; Rzedowsky, 1978; Harcourt et al., 1996). Vegetation distribution follows the climatic zoning of the Peninsula, ranging from the low forests in the dry northwest to tall forests in the humid southeast. Forests are distributed in a patchwork-like pattern due to shifting cultivation, with the inclusion of tropical plantations and pastures.

### 12.2.3 The Mayan subsistence strategy

Mayan farmers combine subsistence and commercial activities (Terán and Rasmussen, 1994; Faust, 1998). Some commercial activities are complementary to the subsistence-oriented *milpa* production, such as bee-keeping, citrus plantations and vegetable production. Small-scale irrigation provides surplus to meet regional market needs, especially in the southern area, but *milpa* production provides a more or less even flow of income throughout the year to minimize risk under uncertain market conditions and to maintain long-term security of the farmer's household. Although *milpa* yields are low and uncertain, the system is maintained because it gives the farmers' household partial control over food security providing a crucial portion of the basic consumption needs. An increasing number of goods and services is purchased with cash income from agro-commercial activities and off-farm activities (Ewell and Merrill-Sands, 1987; Terán and Rasmussen, 1994; Faust, 1998).

The Mayan *milpa* system constitutes a highly complex multicropping strategy involving different agricultural activities during the year and within several years (Zizumbo and Sima, 1988;Terán and Rasmussen, 1994; Remmers and Ucán-Ek', 1996). It also includes other productive activities, such as sylviculture and tree management, hunting, gathering and extractive practices (Flannery, 1982; Gómez-Pompa et al., 1987, 1990, 1991, 1993). Multi-strategy land-use continuum is based on the association of managed forests–cropland–fallowland–homegarden-old recovered forests (Pérez del Toro, 1942; Varguez-Pasos, 1981; Terán and Rasmussen, 1994; Remmers and Ucán-Ek', 1996). This agroforestry continuum provides a wide array of goods and services during the year cycle (Hernández-Xolocotzim and Padilla, 1980; Sanabria, 1986; Remmers, 1993). Maya *milpa* includes annual, biannual and perennial cultivars with up to 87 different crops (Terán and Rasmussen, 1994), and tree crops (Remmers and Koeyer, 1992) within a single village.

The Mayan *milpa* system is well adapted to the variable, patchy and difficult agroclimatic and geopedological characteristics of the karstic landscape. Mayan farmers adjust the agricultural calendar according to the probability of a favorable sequence of first rains, midseason drought (*canícula*) and patchy associations of shallow soils controlled by microrelief at local and parcel levels (Pool-Novelo, 1980; Ucán-Ek' et al., 1982; Illsley, 1984; Pérez-Pool, 1984; Dunning, 1992; Terán and Rasmussen, 1994; Faust, 1998). Central to this are the assessment and management of forest regeneration for soil fertility replenishment. Soil fertility management constitutes the key factor for the Mayan *milpa* production (Sanabria, 1986; Zizumbo and Sima, 1988;Terán and Rasmussen, 1994).

The Mayan ecological knowledge, based on the analysis of climate-relief-soil-vegetation relations, enables the maintenance of the *milpa* system even when external conditions limit the possibility of subsistence cropping, as is the case nowadays. The Mayan *milpa* proved to be sustainable since ancient times and still plays a principal role in the Mayan subsistence strategy, despite common and simplistic assumptions on its negative environmental impact, low yields and 'primitive' techniques (Dove, 1983, 1985; Challenger, 1998). The Mayan ethnopedology reflects the complexity of agricultural adaptation to the heterogeneity and variability of marginal soils at regional, local and parcel levels. It also reflects a flexible and dynamic knowledge-based strategy, constantly reshaped to cope with environmental and economic scarcities and uncertainties.

## 12.3. The mayan soil nomenclature

The vast and rich Mayan soil nomenclature reflects a deep practical cognition by local farmers from the Yucatán Peninsula. So far, this is the most extensive indigenous soil terminology among all Middle American ethnic groups including *Mestizo* populations. Mayan soil nomenclature shows also the richness of the Mayan language, which is spoken by more than 3 million people, most of them living in the rural areas of southern Mexico, Guatemala and Belize. Table 12.1 shows soil and land terms, which are commonly and widely used by Mayan farmers.

Eighty descriptive terms referring to soil characteristics, properties and attributes according to color, texture, structure, consistence, moisture retention capacity, moisture condition, soil erosion, soil depth, soil fertility, stoniness, relief position, soil–relief–vegetation relations and anthropogenic soils, were found. The review of this terminology shows the following aspects:

1) soil terms referring to relief position, soil-relief-vegetation relationship, stoniness, texture, structure and consistence account for 62.5% of the Mayan soil nomenclature;
(2) soil terms referring to fertility, moisture retention capacity, drainage regime and color account for 27.5% of the Mayan nomenclature;
(3) all of these soil properties and attributes are directly or indirectly related to soil fertility, land management and workability under shifting cultivation in karstic landscapes;
(4) soil terms referring to erosion, depth and anthropogenic soils cover only 10% of the Mayan soil nomenclature (Figure 12.3);
(5) although Mayan farmers are not aware of long-term soil formation processes, they are able to recognize and name soil erosion and fertility depletion processes when assessing shifting cultivation practices;
(6) soil depth and stoniness play a critical agricultural role in shallow and marginal soils and reflect Mayan farmers' recognition of the soil as a 3-D body; nevertheless, the topsoil is considered the diagnostic horizon for the Mayan soil classification;
(7) *Lu'um* (soil, land and field in the Mayan language) is a comprehensive relational dominion that surpasses the scientific concept of soil body, because it considers the karstic landscape as an integral unit where soil-relief-vegetation relationships and dynamics play a fundamental role for the Mayan agricultural systems, and
(8) *Lu'um* is a holistic dominion reflecting pervasive and discrete structures, dynamics and processes in the soil mantle and on the entire landscape.

**Table 12.1** Contemporary Mayan soil nomenclature

| Maya soil terms (Lu'um) | Maya etymology | English terms | Spanish terms |
|---|---|---|---|
| **Soils named by color** | | | |
| **Box lu'um** | Box: light black | Light black soil | Suelo negro claro |
| **Ek' lu'um** | Ek': dark black | Dark black soil | Suelo negro obscuro |
| **Kancab lu'um** | Kan: yellow<br>Cab: reddish or syrup | Reddish-yellow soil | Suelo amarillo rojizo |
| **Chak Kancab lu'um** | Chak: red | Yellowish-red soil | Suelo rojo amarillento |
| **Chak lu'um** | Chak: dark red | Dark reddish soil | Suelo rojizo obscuro |
| **Ya'axhom lu'um** | Ya'axhom: green | Green soil | Suelo verde |
| **Sahkab lu'um** | Sahkab: white | White soil | Suelo blanco |
| **Soils named by texture, structure and consistence** | | | |
| **Tzekel lu'um** | Tzekel: flat stone | Flat stone soil | Suelo pedregoso de laja |
| **Chich lu'um** | Chich: gravel | Gravelly soil | Suelo gravoso |
| **Puus lu'um** | Puus: loamy | Loamy soil | Suelo franco |
| **Tatakei lu'um** | Tatakei: sticky | Sticky soil | Suelo pegajoso |
| **Kas tatakei lu'um** | Kas: half<br>Tatakei: sticky | Slightly sticky soil | Suelo medio pegajoso |
| **Kat lu'um** | Kat: heavy clay | Heavy clay soil | Suelo arcilloso pesado |
| **Kuut lu'um** | Kuut: fine-grained whitish clay | Fine-grained, whitish clayey soil | Suelo blanco y arcilloso fino |
| **Tas lu'um** | Tas: soft | Soft soil | Suelo blando |
| **Chöchök lu'um** | Chöchök: loose | Loose soil | Suelo suelto, flojo |
| **Buy lu'um:** | Buy: hardness | Harden soil | Suelo endurecido |
| **Tul luk'** | Tul luk': mud | Muddy soil | Suelo lodoso; lodo |

**Continue Table 12.1 (Continued).** Contemporary Mayan soil nomenclature

| Maya soil terms (Lu'um) | Maya etymology | English terms | Spanish terms |
|---|---|---|---|
| **Soils named by moisture retention capacity and moisture condition** | | | |
| **Lu'um qu dzudzic há** | Dzudzic: to absorb<br>Há: water | Soil with good drainage | Suelo que absorbe bien el agua |
| **Lu'um matech uh dzudzic há** | Matech uh: to impede<br>Dzudzic: to absorb<br>Há: water | Soil with poor drainage conditions | Suelo que no absorbe el agua |
| **Ak'alche'** | Ak'alche': swamp | Swampy soil | Suelo pantanoso |
| **Kas chul lu'um** | Kas: half<br>Chul: moist | Half moist soil | Suelo medio mojado |
| **Lu'um tupis chuli** | Tupis: field capacity<br>Chul: moist | Soil moisture at field capacity | Humedad al punto de capacidad de campo |
| **Lu'um hach chul** | Hach: excessive<br>Chul: moist | Soil moisture at wilting point | Humedad al punto de marchitez |
| **Ak' akannak lu'um** | Ak': humid<br>Akannak: fatty, greasy | Humid and greasy soils | Suelo húmedo y mantecoso |
| **Soil erosion** | | | |
| **Kuch lu'um há** | Kuch: sheet<br>Há: water | Soil subjected to sheet erosion | Suelo con erosión laminar |
| **Xot lu'um há** | Xot: gully<br>Há: water | Soil subjected to gully erosion | Suelo con erosion de cárcava |
| **Tzekel hal lu'um** | Tzekel hal: to become stony | Soil becoming stony | Suelo que se convierte en pedregoso |
| **Soil depth** | | | |
| **Hayan lu'um**<br>**Hayil lu'um** | Hayan or hayil: shallow | Shallow soil | Suelo Delgado |
| **Tantan lu'um**<br>**Tatah lu'um** | Tantan or tatah: deep | Deep soil | Suelo profundo |
| **Soil fertility** | | | |
| **Ka'kab** | Ka'kab: fertile and ridged | Fertile ridged soil | Suelo fértil y elevado |
| **Kul ek' lu'um** | Kul: good<br>Ek': black | Fertile black soil, good for milpa | Tierra negra fértil para milpa |
| **Kuxa' an lu'um** | Kuxa' an: fertility | Fertile soil | Suelo fertile |
| **Xib lu'um** | Xib: sterile | Sterile soil | Suelo estéril |
| **Xibhal lu'um** | Xibhal: to sterilize | Depleted soil | Suelo cansado |
| **Sis lu'um** | Sis: juicy and fertile | Juicy and fertile soil | Suelo jugoso y fertile |
| **Ts'u lu'um** | Ts'u: soft, sticky, rotten, heart, center, tender | Fertile soil | Suelo fertile |
| **Nonot' lu'um** | Nonot': impoverished | Impoverished soil | Suelo empobrecido |
| **Stoniness** | | | |
| **Tzekel** | Tzekel: flat stone | Flat stone | Laja |
| **Chaltun** | Chaltun: flat stone | Flat stone | Laja |
| **Ch'ich lu'um** | Ch'ich: stony | Stony soil | Suelo revuelto con piedras |
| **Apaltun** | Apaltun: between boulders | Soil between boulders | Suelo entre rocas grandes |
| **Chochol lu'um** | Chochol: many small stones | Soil with many small stones | Suelo con muchas piedras pequeñas |
| **Chichiltun** | Chichiltun: very small and loose stones | Very small and loose stones | Piedras muy pequeñas y sueltas |
| **Xmehen tunich** | Xmehen: small<br>Tunich: stone | Small stones | Piedras pequeñas |
| **Nukuch tunich** | Nukuch: big | Big stones | Piedras grandes |
| **Hayil tunich** | Hayil: smooth and soft | Smooth and soft stones | Piedras lisas y suaves |
| **Wola tunich** | Wola: rounded | Rounded stones | Piedras redondas |
| **Tax tunich** | Tax: big, flat and compacted stones | Big, flat and compacted stones | Piedras grandes, planas y compactas |
| **Tok' tunich** | Tok': hard, compact | Hard stones | Piedras duras |
| **Sak-hla tunich** | Sak: white<br>Hla: soft | Soft limestone rocks | Soft limestone rocks |

**Continue Table 12.1 (Continued).** Contemporary Mayan soil nomenclature

| Maya soil terms (Lu'um) | Maya etymology | English terms | Spanish terms |
|---|---|---|---|
| **Relief position** | | | |
| **Ch'om wits lu'um** | Ch'om: at the foot<br>Wits: hill | Soil at the foot of the hill | Suelo al pie del cerro |
| **Lu'um ebek nix** | Ebek nix: gently sloping relief | Soil on gently sloping relief | Suelo en pendiente suave |
| **Haltun ek' lu'um** | Haltun: concave shaped limestone boulder<br>Ek': black | Black soil on a concave limestone boulder | Suelo negro en sarteneja |
| **Chac lu'um Kancab** | Chac: red<br>Kancab: flatland | Red soil on a flatland | Suelo rojo en planada |
| **Kom lu'um** | Kom: concave depression | Soil in a concave depression | Suelo en depresión cóncava |
| **Kekel** | Kekel: undulating relief with flat stone outcroppings and shallow soils | Undulating relief with flat stone outcroppings and shallow soils | Relieve ondulado con lajas aflorando en suelos delgados |
| **K'om** | K'om: depression | Depression | Hondonada, jolla o rejollada |
| **Ak'alche'** | Ak'alche': flooded bottomland | Flooded bottomland soil | Suelo inundable de bajial |
| **Wayaba'** | Wayaba': temporally flooded doline | Temporally flooded doline | Aguada o dolina que se inunda temporalmente |
| **Tsa'ats or Ts'aats** | Tsa'ats: permanently flooded doline | Permanently flooded doline | Aguada o dolina siempre inundada |
| **Ho lu'um** | Ho: hummock | Soil on hummock | Suelo de altillos o montículos |
| **Wits lu'um** | Wits: hill | Soil on hill | Suelo de cerro |
| **Mulu'ch lu'um** | Mulu'ch: hillock | Soil on hillock | Suelo de cerro bajo |
| **Bekab wits lu'um** | Bekab: within<br>Wits: hill | Soil on flatlands within hills | Suelo en planada entre cerros |
| **Soil – relief – vegetation** | | | |
| **Wits 'k'aax** | K'aax: forest<br>Wits: high hill | Forest on high hills | Monte que crece sobre los cerros altos |
| **Mulu'ch k'aax** | Mulu'ch: hummock | Forest hummock | Monte que crece en los altillos o montículos |
| **K'ancabak k'aax** | Kancab: flatland | Forest on flatland | Monte que crece en las planadas |
| **Ich che' k'aax** | Ich: dense<br>Che': tall | Tall and dense forest on Ek' lu'um soils | Monte alto y tupído que crece en suelos Ek' lu'um |
| **Tzekel k'aax** | Tzekel: Flat stony soil | Forest on Tzekel soils | Monte que crece en suelos Tzekel |
| **Bay-hal k'aax** | Bay-hal: sparse | Sparse forest on Tzekel soils | Monte esparcido que crece en los suelos Tzekel |
| **Ya'ax k'aax** | Ya'aax: semi-deciduous | Semi-deciduous forest on flatland with Ek' lu'um soils | Monte semi-deciduo que crece en las planadas con suelos Ek' lu'um |
| **Kan k'aax** | Kan: deciduous | Deciduous forest grown on Tzekel or Tzekel chak lu'um soils | Monte deciduo que crece sobre suelos delgados y con poca retención de Humedad, como los suelos Tzekel o Tzekel chak lu'um |
| **Ka'kab k'aax** | Ka'kab: anthropogenic soil near archaeological sites | Forest on archaeological sites with K'akab lu'um soils | Monte que crece en sitios arqueológicos en suelos K'akab |
| **Kat lu'um Ak'alche'** | Kat: clay<br>Ak'alche': swamp | Upper margins of a swamp having a thin organic top layer over a clayey reddish subsoil; a scarce thorny tropical shrub grows on these lands | Márgenes superiores del pantano cubiertos por una capa superficial de materia orgánica sobre un subsuelo rojizo y muy arcilloso. Aquí crece un matorral tropical espinoso o selva baja espinosa |

**Continue Table 12.1 (Continued).** Contemporary Mayan soil nomenclature

| Maya soil terms (Lu'um) | Maya etymology | English terms | Spanish terms |
|---|---|---|---|
| **Anthropogenic soils** | | | |
| **K'akab lu'um** | K'akab: ridged fertile near an archaeological site | Ridged fertile soil located near an archaeological site | Suelo elevado cerca de sitios arqueológicos |
| **X'tokoy lu'um** | X'tokoy: homegarden | Homegarden soils | Suelo de huerto familiar |
| **Kaanche' lu'um** | Kaanche': Seedling bed | Soil of a seedling bed | Suelo de cama de semillero |

**Sources:** Coronel (1930); Steggerda (1941); Robles-Ramos (1958); Macías-Villada (1954); Hernández-Xolocotzim. (1959); Canul-Peech (1967); Barrera-Marín, et al. (1976); Barrera (1980); Ucán-Ek', et al., (1982); Perez-Pool (1984); Sanabria (1986); Duch (1989); Terán and Rasmussen (1994)

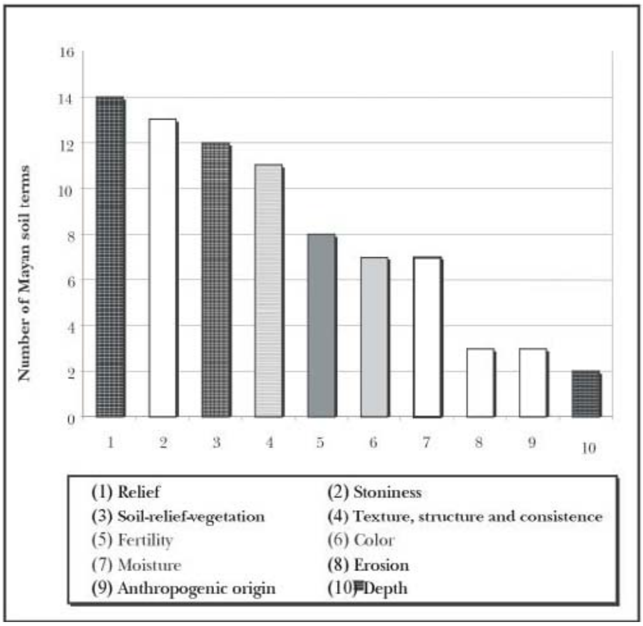



**Figure 12.3.** Frequency of Mayan soil terms related to 10 main soil properties

Mayan knowledge of soil-relief relation as a continuum resembles the concept of soil catena or toposequence coined by Milne (1947) and reflects detailed recognition of the local and micro-local soil heterogeneity and variability.

The Mayan soil nomenclature partially reflects the Mayan ethnopedology as a comprehensive knowledge-based system; its linguistic analysis suggests that soil fertility assessment is very relevant to Mayan farmers. Soil fertility assessment requires a soil classification that clusters limited soil taxa according to specific soil properties and attributes. Ethnopedological research done at regional, local and parcel levels corroborates that Maya farmers mentally organize the soil dominion into a limited group of soil taxa in a hierarchical way.

## 12.4 The Mayan soil taxonomy

Our understanding of the Mayan soil classification system is still limited because of the complexity of the soil distribution in the Yucatán Peninsula (Duch, 1989) and the complexity of the Mayan soil terminology and its many linguistic variations. So far, more interest has been given to the Mayan ethnobotanical classification (Roys, 1931; Barrera et al., 1976).

Ethnopedological research has been conducted mainly with an agronomic approach, focused on the *milpa* shifting cultivation, neglecting the potential contribution of ethnolinguistics and ethnosemantics. This research trend is relevant to regional agricultural development but it limits the integration of the holistic view that the Maya possess about the soil resources (Duch, 1989; Dunning, 1992). Nevertheless, some preliminary conclusions can be made about the Mayan soil taxonomy when comparing local and regional research findings. Maya recognize 30 soil taxa, with their corresponding relief types (see also Table 12.2). Twelve of them can be considered as main soil types:

(1) *Tzekel* (soils with flat stones)
(2) *Chaltun* (stony soils)
(3) *Haltun Ek' lu'um* (black soil pockets on concave limestone outcrops)
(4) *Box lu'um* (light black or gray soils)
(5) *Pus lu'um* (loamy soils)

**Table 12.2.** Soil–relief correlation according to Mayan ethnopedological research

| Maya soil types | Maya soil subtypes | Hernández-X. (1959) | Cortina (1980) | Pérez Pool (1984) | Sanabria (1986) | Duch (1988) | Terán (1994) |
|---|---|---|---|---|---|---|---|
| **(1) Tzekel** | | Hill | Hill | | | Hill, hillock, hummock and flatland | |
| | **Ek' lu'um Tzekel** | Hill and slope | | | | | |
| | **Chak lu'um Tzekel** | Hill and slope | | | | | |
| **(2) Chaltun** | | Hill | | | Hill | Hill, hillock, hummock and flatland | |
| | **Ek' lu'um Chaltun** | | | | Slope | | |
| **(3) Haltun Ek' lu'um or Hoactun pu'uc** | | | | | Slope | | |
| | | | | Flatland | Slope | | |
| **(4) Box lu'um** | | | | | Hillock and slope | Hill, hillock and hummock | Hill, hillocks and hummock |
| **(5) Pus lu'um or Sojo lu'um** | | | Slope | Flatland | Hillock and slope | Hill, hillock and hummock | Hill, hillocks and hummock |
| **(6) Kancab** | | Flatland | | | Flatland | Flatland and hillock | |
| | **Kan lu'um or Chak Kancab** | | | | | | Flatland |
| | | Flatland | Flatland | Flatland | Flatland | Flatland | Flatland |
| | **Ek' lu'um Kancab** | Flatland | | Flatland | Flatland | Flatland | Flatland |
| | **Tzekel Chak lu'um Kancab** | | | | Flatland | | |
| | **Chak' an Kancab** | Flatland | | | | | |
| | **Kancab pu'uc** | | | Flatland | | | |
| | **K'amas lu'um or Chak lu'um** | | | Flatland | | Flatland | |
| **(7) X'tokol lu'um or Laj Kaj** | | | | | Homegarden | | |
| | | | | | | | Homegarden |
| **(8) K'akab** | | Footslope and flatland | Hill and flatland | | Flatland | | Flatland |
| | **Chochol K'akab** | Footslope and flatland | | | | | |
| **(9) Kum lu'um Bekawits or sabana soils** | | Flatland | Swamp, closed depression | | Swamp, closed depression | | |
| **(10) Ya'axhom** | | Flatland | Swamp, closed depression | Flatland | | Flatland and bottom-level flooding land | |
| | **Ya'axhom Ak'alche'** | Flatland | | Flatland | | Bottom-level flooding land | |
| **(11) Ak'alche'** | | Flatland | Flatland, closed depression | Flatland | | Bottom-level flooding land | |
| **(12) Vega** | | Flatland | | | | | |

(6) *Kancab* (reddish yellow soils)
(7) *K'akab* (fertile and ridged soils)
(8) *Ya'axhom* (greenish soils)
(9) *X'tokol lu'um* (homegarden soils)
(10) *Kum lu'um* (savanna soils)
(11) *Ak'alche'* (flooded soils)
(12) *Vega* soils (alluvial soils)

Most of these soil types are well represented in the Yucatán Peninsula and are further clustered into subtypes. This is the case of the *Kancab* and *Tzekel* soils, most important for Maya shifting cultivation and thus well known by the farmers. Some general soil types receive different local names. Such is the case of the *Haltun Ek' lu'um* or *Hoactun pu'uc*, both considered black soil pockets formed on concave limestone relief units. *X-tokol lu'um* and *Laj Kaj soils* are both recognized as anthropogenic soils in the homegardens. Savanna soils and *Kum lu'um* soils appear to be similar, since *kum* means savanna in Mayan language. *K'amas lu'um* is also named *Chak lu'um* according to Terán and Rasmussen (1994), but recognized as a different soil type by Duch (1989). Terán and Rasmussen also identified strong similarities between *Kan lu'um* and *Chak Kancab*.

Contemporary Maya soil taxonomy is a rather simple but hierarchical system, with 12 main soil types and 13 soil subtypes, according to ethnopedological research in different Mayan communities of the Yucatán Peninsula (Pérez-Pool, 1984; Sanabria, 1986, Dunning, 1992; Terán and Rasmussen, 1994). The recognition of a large number of soil properties allows Maya farmers to classify soils by the inclusion of soil descriptors, which are not necessarily used and contrasted among all soil taxa. Table 12.3 shows the Mayan criteria to describe and classify soils in the Ya'axhom community of Oxkcutzcab municipality. Soil classification is based on color, relief position, depth, stoniness, drainage, moisture retention capacity, consistence, texture, fertility and workability of the topsoil. The assessment of the topsoil is critical for Mayan farmers according to the following assumptions:

(1) farmers assume that the topsoil (0-30 cm) is the fundamental soil layer for crop nutrition and performance, because most *milpa* cultivars have short roots;
(2) farmers recognize the topsoil as the soil layer where moisture content and drainage are critical for crop growth and performance;
(3) the topsoil can be easily ameliorated by mixing it, removing it or adding green or chemical fertilizers in the karstic landscapes, and
(4) properties of the topsoil are directly related to relief position, vegetation type and soil depth. Topsoil properties, such as stoniness, structure, texture, consistence, color and organic matter content, are used to classify soils and determine the soil fertility status according to diverse maize cropping systems and the history of land management at each parcel (Hernández-Xolocotzim, 1959, Hernández-Xolocotzim and Padilla y Ortega, 1980).

Contemporary Maya soil taxonomy reflects cultural adaptation to particular environments and flexibility to innovations when people move to other locations. Soil taxonomy and land management are adapted to new environmental characteristics. Carter (1969), Wilk (1981) and Dunning (1992) observed this among the Kekchi-Maya farmers, who recently colonized tropical lowland areas in Guatemala and Belize. In the Alta Verapaz district of the Guatemalan highlands, the Kekchi-Maya soil taxonomy distinguishes first between arable and non-arable land; secondly, between warm and cold arable soils; and thirdly, between various types of warm and cold arable soils. Working among Kekchi-Maya colonists in the vicinity of Lago Izabal in the Guatemalan lowlands, Carter (1969) observed that only the warm soil (*Kixnal choch*) taxa were under use in complex ways.

The Kekchi-Maya soil taxa distinguish variations in texture, color and drainage, the latter specially in the lowlands because of the large extent of hydromorphic soils in the Lago Izabal region. As new arable soil classes were recognized, the "trash land" (*Mu'ru*) category shrinked. Carter (1969) found out that the first

**Table 12.3.** Properties used to classify soil by Mayan farmes from the Ya'axhom community,

| SOIL PROPERTIES | MAYAN SOIL TYPES | | | |
|---|---|---|---|---|
| | **KANCAB LU'UM** | **PUS LU'UM** | **YA'AXHOM LU'UM** | **AK'ALCHE' LU'UM** |
| **Color** | Red or reddish | Grey, black or dark | Yellow, tobacco color | Chocolate color; blackish gray or grayish-brown |
| **Location** | Flatland | Hillocks or slopes | Flatland | Flatland |
| **Depth** | Deep (>2 m) | Shallow (20 to 60 cm) | Deep (>2 m) | Deep (>2m) |
| **Stoniness** | Nil or few | Abundant | Nil | Nil |
| **Drainage** | Good | Excessively drained; more than Kancab lu'um | Good; water expands all over the profile | Deficient; 'water stocks' |
| **Moisture retention capacity** | Moisture retention capacity lower than in Ya'axhom and Ak' alche' soils | Good moisture retention capacity | Very good moisture retention capacity | It saturates easily, thus exposed to flooding; takes a long time to dry |
| **Consistence** | | | | |
| **Moist** | Hard and cracking during the dry season | Not compacted and non cracking | Hard; cracks when drying | Very hard; cracks during the dry season |
| **Dry** | Slightly sticky | Non-sticky | Less sticky than Ak'alche' | Very sticky and gummy |
| **Texture** | Medium-textured to clayey | Fine-textured or Pupuski, loose | Medium-textured to clayey | Very clayey |
| **Fertility** | Low organic matter content; it is fertile but requires chemical fertilizer; less fertile than Ya'axhom | Very fertile, the best soil for rain fed agriculture | The best soil; the most fertile soil | Very fertile if drained; black soil has more vitamins; is strong |
| **Workability** | Easily workable; without problems | The easiest soil to work for rainfed agriculture; with irrigation could be better but is located on hillocks | Good soil for all types of crop; easily workable | Very problematic soil; not easily workable because it floods; Careful crop choice and timing of seedling are needed |

**Source:** Pérez-Pool (1984)

colonists of the community often experimented with modified cultivation techniques on different soils and, thus, helped create new arable classes. A similar process of interpersonal diffusion of soil knowledge and soil taxonomy development was recognized by Wilk (1981) among Kekchi colonists in southern Belize and by Dunning (1992) among Maya in the Pu'uc region of the Yucatán and Campeche states in Mexico.

### 12.5 Correlation between the Mayan and technical soil classifications

There is a moderate correlation between the Mayan soil classification and the FAO/UNESCO/DETENAL soil legend (1970) (Table 12.4). Six out of the 12 Mayan soil types and subtypes correlate with technical soil classes. The regionally well-represented *Kancab* soils show differences within the FAO/UNESCO/DETENAL soil legend. Local Maya soil classification appears to be more detailed than the technical soil classification, with several Maya soil types falling within the same FAO/UNESCO/DETENAL soil class. This is the case of the Rendzina soils, which include *Tzekel, Box lu'um* and *Kancab* soil types and subtypes (Pérez-Pool, 1984; Sanabria, 1986; Terán and Rasmussen, 1994).

**Table 12.4.** Comparison of Maya soil types and subtypes with the FAO/UNESCO/DETENAL soil classes

| Maya soil types | Maya soil subtypes | FAO/UNESCO/DETENAL SOIL CLASSES (1970) | | | | |
|---|---|---|---|---|---|---|
| | | Hernández-X. (1959) | Cortina (1980) | Sanabria (1986) | Duch (1988) | Terán (1994) |
| (1) Tzekel | | Lithosol | Lithosol | | Lithosol | |
| | Ek' lu'um Tzekel | Black Rendzina | Rendzina | | | |
| | Chak lu'um Tzekel | | Rendzina | Red Rendzina | | |
| (2) Chaltun | | Calcic Lithosol | | Lithosol | Lithosol | |
| | Ek' lu'um Chaltun | | | Lithosol | | |
| (3) Haltun Ek' lu'um or Hoactun pu'uc | | | | Lithosol | Lithosol | |
| (4) Box lu'um | | | | Black Rendzina | Black Rendzina | Black Rendzina |
| (5) Pus lu'um or Sojo lu'um | | | Calcic Cambisol | Eutric Cambisol | Black Rendzina | Black Rendzina |
| | | | | | | Organic soil |
| (6) Kancab | | Brown Rendzina | | | Brown Rendzina | Brown Rendzina |
| | Chak Kancab | Chromic Cambisol | Chromic Cambisol | Chromic Cambisol | Chromic Cambisol | Eutric Cambisol |
| | Ek' lu'um Kancab | Black Rendzina | Eutric Nitosol or black Rendzina | | Ferric Luvisol or Eutric Nitosol | Ferric Luvisol |
| | Tzekel Chak lu'um | Red Rendzina | | | | |
| | Chak'an Kancab | Red Rendzina | | | | Red Rendzina |
| | K'amas lu'um | | | | Red Rendzina | |
| | Chak lu'um | | | | Red Rendzina | |
| (7) X-tokol lu'um or Laj Kaj | | Anthropogenic soil | | | | |
| | | | | | Anthropogenic soil | |
| (8) K'akab | | Anthropogenic soil | | Anthropogenic soil | Anthropogenic soil | Rendzina |
| | Chochol K'akab | | | | | Rendzina |
| (9) Kum lu'um or savanna soils | | Gleysol | | | | |
| | | | | | | Vertic Luvisol |
| | Chom- wits lu'um | Gleysol | | | | |
| (10) Ya'axhom | | Vertic Luvisol or Vertisol | | | | |
| | Ya'axhom Ak'alche' | | | | | Pelic Vertisol |
| (11) Ak'alche' | | Vertic Gleysol | | | | Vertic Gleysol |
| (12) Vega | | | | | | Fluvisol |

**Sources:** Hernández-X (1959); Sanabria (1986); Duch (1989); Terán and Rasmussen (1994)

A moderate correlation between the Mayan soil classification and the USDA Soil Taxonomy at suborder level was found by Dunning in the Puuc region of the Yucatán and Campeche states of Mexico (1992) (Table 12.5). Mayan farmers from this region recognize seven main soil types with at least 10 subtypes used for agriculture. Variations in pedogenesis among the seven soil types are the result of local topographic and drainage characteristics.

*Ek lu'um* (dark black soil) is uniformly assigned the attributes of high organic content, clayey texture, firmness, good moisture retention capacity and very dark grey-brown color. *Pus lu'um* (dry soft soil) is also fairly dark in color, but it is distinguished by its silty texture, loose structure, good drainage and easy workability. *Ya'axhom* (green bottom-level soil) is considered to be similar to *Ek' lu'um*, but with olive hue, poorer drainage and gummy consistence when wet. *Kancab* (heavy clay, red-yellowish bottom-level soil) is described as heavy, sticky when wet, firm when moist and with good moisture retention capacity. *Chak lu'um* (red soil) is a shallow, silty, loosely structured, dark red, organic-rich soil found in hillslope pockets, while *K'akab* (sloping soil) occurs in breaks on open slopes and generally has a dark red-brown color. *Tzekel* (soil with flat stones) is also a hillside soil, but found on open steep slopes. The color and organic matter content of *Tzekel* can vary considerably, but this soil is always shallow and very stony. Mayan farmers of the P'uuc region and local farmers of the central Yucatán state use the same attributes to distinguish the same soils (Pérez-Pool, 1984) (see Table 12.4).

**Table 12.5.** Comparison of the Mayan, USDA and FAO SOIL classifications: the case of the P'uuc region

| Mayan soil types | USDA soil taxonomy | FAO/UNESCO/DETENAL |
|---|---|---|
| **Tzekel (stony soil)** | Lithic Ustorthent | Lithosol |
| **Ka'kab (fertile and ridged soil)** | Lithic Ustirendoll | Rendzina |
| **Chak lu'um (red soil)** | Rhodic Ustirendoll | Rendzina |
| **Pus lu'um (dry soft soil)** | Cumulic Ustirendoll | Rendzina |
| **Ek' lu'um (dark black soil)** | Vertic Argiustoll | Vertic Phaeozem |
| **Ya'axhom (green soil)** | Udic Chromustert | Chromic Vertisol |
| **Kancab (reddish-yellow soil)** | Rhodic Paleustalf | Eutric Nitosol |

**Source:** Dunning (1992 and 1993)

Although any comparison between the Mayan and technical soil classifications is preliminary at this stage, the correlation between soil classes of two contrasting systems is striking. Maya farmers classify soils on the basis of a continuous assessment of the topsoil. Soil classes are determined using qualitative properties such as soil fertility, relief, vegetation type and land-use history. Technical soil classifications use measurable properties of the 3-D soil body, supported by laboratory determinations and theories on soil formation. Mayan soil classification is behavioral, relational, diachronic, qualitative, utilitarian and local, while technical soil classification is synchronic, measurable, genetically-oriented and universal. The first one relies on agricultural land-use potential and soil fertility maintenance, while the second one is based on diagnostic properties that are not necessarily utilitarian.

Table 12.6 reports the properties of five Mayan soil types considered at regional and local levels, respectively (Pérez-Pool, 1984; Duch, 1989). Both examples used laboratory determinations to compare the Maya soil taxa with the FAO/UNESCO/DETENAL soil classes. The local analysis used farmers' own soil narrative to describe soil properties, while the regional study used technical terms to determine soil properties. Comparison shows close correlation between measurable and descriptive properties and a moderate correlation between Maya soil classes and FAO/UNESCO/DETENAL soil classes.

Pérez-Pool (1984) compared two local Mayan soil classifications using numerical taxonomic analysis. Distance and similarity matrixes were established and dendrograms were constructed for both taxonomies. Close correlation was found when comparing the dendrograms with local farmers' assessment of soil properties and land productivity for specific crops. Both soil classifications presented more similarities than differences when compared against laboratory determinations, revealing that the Mayan soil taxonomy is technically measurable and scientifically proven. Another main conclusion is that Maya soil taxonomy supports regional land-use evaluation for specific crops.

### 12.6. MAYA KNOWLEDGE OF SOIL-RELIEF-VEGETATION RELATIONSHIPS

Mayan farmers recognize soil heterogeneity and variability even within small parcels. Their recognition of soil-relief patterns generally correlates with the soil toposequences established by soil surveyors at regional level. Ortíz-Monasterio (1950), Robles-Ramos (1958) Aguilera (1959) and Hernández-Xolocotzim (1959) developed a soil catena model, which synthesizes all major soil-relief patterns found in the Yucatán Peninsula, using Maya soil classes and correlating them with technical soil classes. Ortíz-Monasterio (1950) recognized two soil families and four soil series. The two soil families recognized are: (1) the hydromorphic soil sub-order including Vertisols and Gleysols, locally named *aguadas* and *ak'alche'*; and (2) the calcimorphic soil sub-order including black Rendzinas, locally referred to as *k'akab, tzekel* and old *ak'alche'* soils, and red Rendzinas, locally referred to as *kancab* soils.

Soil forming processes are controlled by hydric properties as a function of relief and parent material. The regional soil catena is as follows: *chaltun* and *tzekel* soils (Lithosols), *k'akab* (red Rendzina), *kancab* (red Rendzina) savanna soils (Vertic Luvisol), *aguada* soils (Luvic Vertisol) and *ak'alche'* soils (Vertic Gleysol). These soils have red colors and acid pH when organic matter content is low, but they have black, gray and brown-yellowish colors and a neutral pH when drainage is poor.

**Table 12.6.** Comparison of soil properties of five Maya soil classes at local and regional levels

| Mayan soil classes | LOCAL STUDY | REGIONAL STUDY |
|---|---|---|
| **Pus lu'um (dry soft soil)** | | |
| FAO/UNESCO/DETENAL | Black Rendzina | Black Rendzina |
| Relief | Hillock and sloping land | Hill, hillock, hummock |
| Color | Black or dark gray | Dark brown or black |
| Texture | Fine-textured and loose clay loam | Clay loam |
| Depth | < 60 cm | < 50 cm |
| Stoniness | Abundant | Moderate to abundant |
| Organic matter % | 5 | 15 – 20 |
| Hydromorphism | Absent | Absent to strong |
| PH | 8 | 7 – 8 |
| **Chak' lu'um (red soil)** | | |
| FAO/UNESCO/DETENAL | Chromic Vertisol | Red Rendzina |
| Relief | Flatland | Flatland |
| Color | Red | Red |
| Texture | Clay | Clay loam |
| Depth | < 100 cm | < 50 cm |
| Stoniness | Few | Moderate |
| Organic matter % | 4 | < 6 |
| Hydromorphism | Absent | Absent |
| PH | 7.5 | 7 – 7.5 |
| **Ya'axhom (greenish soil)** | | |
| FAO/UNESCO/DETENAL | Chromic Vertisol | Vertic Luvisol |
| Relief | Flatland | Flatland and flooding bottom–level land |
| Color | Tobacco yellow | Dark grayish-brown |
| Texture | Clay | Clay |
| Depth | > 100 cm | > 100 cm |
| Stoniness | Nil | Nil |
| Organic Matter % | 3 | 5 – 10 |
| Hydromorphism | Absent | Absent |
| pH | 7.5 | 6.5 – 7 |
| **Ya'axhom Ak'alche' (greenish swampy soil)** | | |
| FAO/UNESCO/DETENAL | Pelic Vertisol | Pelic Vertisol |
| Relief | Flatland | Bottom-level land |
| Color | Chocolate or dark grayish brown | Very dark grayish-brown |
| Texture | Clay | Clay |
| Depth | > 100 cm | > 100 cm |
| Stoniness | Nil | Nil |
| Organic matter % | 3 | < 3 |
| Hydromorphism | Strong | Strong |
| PH | 7.5 | 7 – 8 |
| **Ak'alche' (swampy soil)** | | |
| FAO/UNESCO/DETENAL | Vertic Gleysol | Vertic Gleysol |
| Relief | Flooding bottom-level land | Flooding bottom-level land |
| Color | Black or brownish gray | Brownish gray |
| Texture | Clay | Clay |
| Depth | > 100 cm | > 100 cm |
| Stoniness | Nil | Nil |
| Organic matter % | 2.5 | < 3 |
| Hydromorphism | Very strong | Very strong |
| pH | 7.5 | 6.5 – 8 |

**Source:** Pérez-Pool (1984) and Duch (1989)

Hernández-Xolocotzim (1959) proposed two soil series according to soil genesis: (1) soils formed under efficient drainage conditions and (2) soils formed under inefficient drainage conditions. The first soil series is composed of *chaltun* (stony soil), *tzekel* (stony soil), *k'akab* (fertile and ridged soil) and *kancab* soil (reddish-yellow soil), according to the Mayan classification. The second soil series is composed of *ak'alche'* (swampy soil), *ya'axhom ak'alche'* (greenish swampy soil) and *chak'an kancab* (savanna soil). Relief and vegetation types are integrated into the soil descriptions according to the Mayan classification, as shown in table 12.7 and figures 12.4 and 12.5.

### 12.6.1. Soil series formed under efficient drainage conditions

These soil series are located on hills and in non-flooded dolines and depressions. They are mainly Inceptisols and shallow soils formed on limestone with good drainage conditions and under a gradual colluvial accumulation of fine particles. Tropical forest covers the landscape. There, *milpa* soils are the most important in the Yucatán Peninsula. Henequén or *sisal* plantations (*Agave spp.*) are important as well. Citrus trees grow on *kancab* soils.

*Chaltun* are very shallow stony soils, with a thin layer of organic matter in various stages of decomposition. Two *tzekel* soil subtypes are recognized. The shallower one is located on moderately steep slopes covered by tropical deciduous shrub. The deeper subtype occurs on gentle slopes covered by semi-deciduous tropical forest. The humus-rich topsoil is locally named *ek' lu'um* or black topsoil. *K'akab* soils are located on the footslopes of hillocks and hummocks, where colluvial sedimentation had taken place, and border the tzekel soils. *K'akab* soils present a moderately deep humic topsoil over a red-orange mineral subsoil. The presence of small and abundant limestone fragments in any of these soils is referred to as *chochol tzekel*, *chochol k'akab* and *chochol kancab*, *chochol* meaning presence of stones.

Finally, *kancab* soils are located on flatlands or *kancabales*. These are moderately deep soils, formed on colluvial deposits over decomposed limestone. They have a thin grayish humic topsoil, a reddish subsurficial horizon and a yellowish gray subsoil. *Kancab* soils with a humic topsoil are locally called *ek' lu'um kancab*, otherwise they are called *chak lu'um kancab* or reddish *kancab*. These are the only soils having an acid pH in the Yucatán Peninsula. A intermediate-height tropical forest (25–35 m) composed of deciduous and perennial species grows on these soils. Perennial grasses quickly invade *milpa* fields and forest recovers easily after shifting cultivation. Savanna-like vegetation is locally named *chak'an kancab*.

### 12.6.2. Soil series formed by deficient drainage conditions

Soils influenced by permanent to temporal flooding are: *aguada* soils (*tsa'ats lu'um* or permanently flooded soils), *ak'alche'* soils (swampy soils), *ya'axhom ak'alche'* soils (greenish, swampy or humic flooded soils) and *chak'an kancab* soils (savanna soils). All these soils developed from colluvial and alluvial sediments. They are shallow to deep, but without distinct horizonation. Texture is controlled by the speed of sediment deposition under water.

*Aguada* soils are located at the bottom of the permanently flooded depressions, making them non-suitable for agriculture. *Ak'alche'* are temporarily flooded. They are located along the upper margins of the *aguada* soils, have an undulating micro-relief, a well developed A horizon with high organic matter contents, and a dark gray clayey and impermeable B horizon, lying on limestone in various stages of decomposition (dissolution). *Tintal* is the typical forest formation covering these soils. *Tintal* is dominated by a tree species named Palo de Tinte (*Haematoxylon campechianum*). *Milpa* agriculture is unsuitable on these soils, but rice and sugarcane grow well. *Ya'axhom kancab* soils are located along the upper margins of the *ak'alche'* soils and are relatively short flooded during the year. Shifting cultivation performs well during dry years, but produces marginal yields during wet years. *Pukté* forest is the typical vegetation cover, dominated by a tree species locally named *Pukté* (*Bucidas buceras*). Finally, *chak'an kancab* soils or savanna soils are covered by grasses and scattered patches with trees, such as *Byrsonima crassifolia, Crescentia cujete and Psicidia communis.*

The Yucatec-Maya soil catena model proposed by Hernández-Xolocotzim (1959) has been locally corroborated and adjusted by Sanabria (1986). Twelve soil classes were found in Xul, a Mayan community in the Oxkcutzcab municipality. Xul is located near the only important range of the Peninsula, the Ticul Sierra with a maximum elevation of 100 m.a.s.l. in southern Yucatán state. The soil-relief toposequence of Xul shows a pattern similar to the model proposed for the Yucatán Peninsula, although it is more detailed and heterogeneous, because of the proximity of hills (Figure 12.5).

**Table 12.7.** Correlation between the Mayan soil classification and the FAO/UNESCO Soil Legend

| Maya soil classification | English soil terms | FAO/UNESCO |
|---|---|---|
| Chaltun | Stony soil; almost pure limestone outcrop | Calcic Lithosol |
| Tzekel | Stony soil; shallow soil | Lithosol |
| Ek' lu'um Tzekel | Black stony soil; humic topsoil | (black) Rendzina |
| K'akab | Humic soil with red mineral subsoil | Rendzina |
| Chochol K'akab | Humic stony soil with red mineral subsoil | Rendzina |
| Kancab | Deep brown reddish soil | (brown) Rendzina |
| Chak lu'um Kancab | Deep red soil | Chromic Cambisol |
| Ek' lu'um Kancab | Deep black soil | Eutric Nitosol |
| Chak'an Kancab | Savanna-like soil | (red) Rendzina |
| Kom lu'um Kancab | Savanna-like soil | Vertic Luvisol |
| Ak'alche' | Swampy soil | Vertic Gleysol |
| Ya'axhom Ak'alche' | Humic and forested swampy soil | Pelic Vertisol |
| Vega | Fertile plain soil | Fluvisol |

**Source:** Steggerda (1941) Hernández-Xolocotzim (1959)

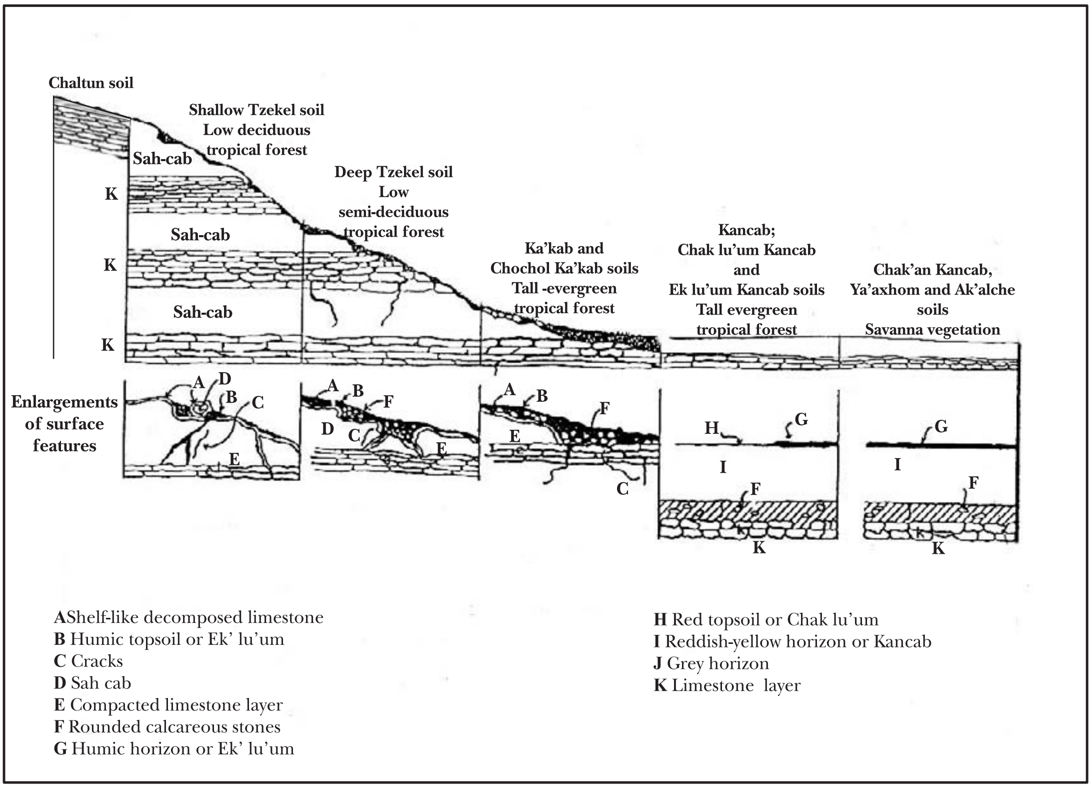



**Figure 12.4.** Mayan soil toposequence model of the Yucatán Peninsula. **Source:** Hernández-Xolocotzim (1959)

Three soil series are recognized in Xul: (1) a calcimorphic soil with good drainage on the hill summits; (2) a calcimorphic soil with moderate drainage on slopes, hillocks and hummocks; and (3) a hydromorphic soil with deficient drainage on flatlands, in poljé or *kancabales*, and on savanna fields. The first soil series is represented by *chaltun* soils (stony soils). The second soil series is represented by *box lu'um* (light black soils) and *pus lu'um* soils (loamy soils), while the third soil series is represented by *kancabal* (reddish-yellow soils), *kom lu'um* (savanna soils) and *chom wits lu'um* (footslope soils). Anthropogenic soils, such as *k'akab* and *x-tokol lu'um* are located on archaeological sites near the present village of Xul and in the homegardens (Table 12.4 and figure 12.5).

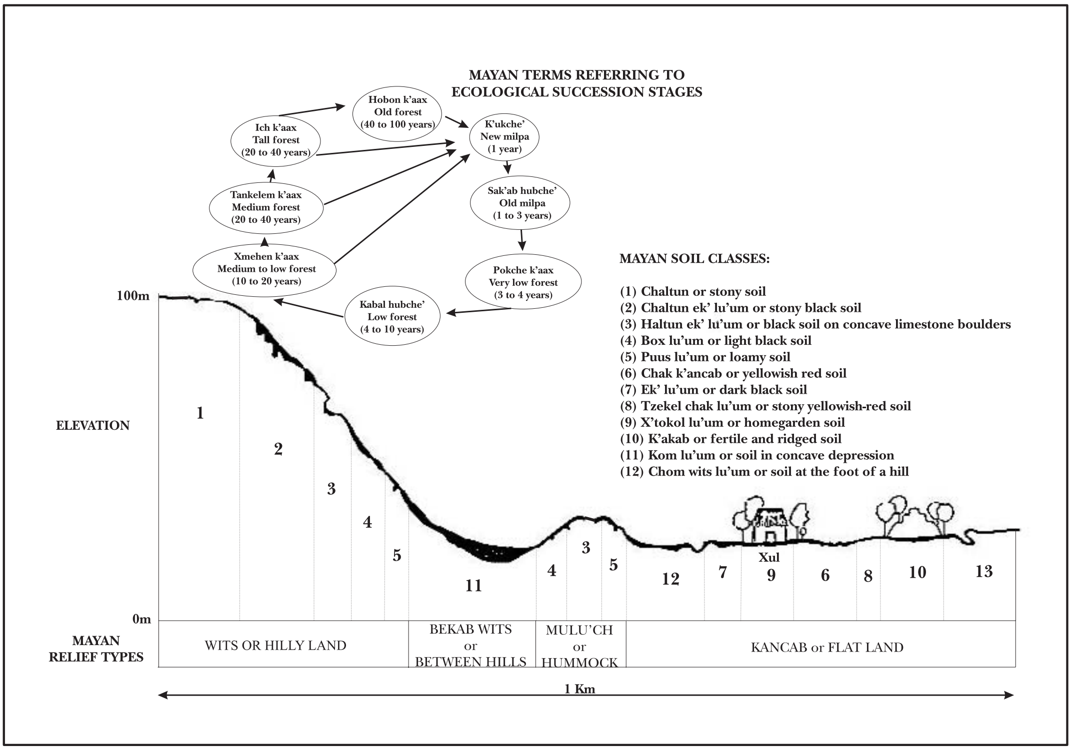



**Figure 12.5.** Mayan soil toposequence, soil-relief types, and ecological succession stages recognized by farmers from Xul. **Source:** Sanabria (1986)

The only main difference found when comparing the general soil toposequence model of the Yucatán Peninsula and the one proposed by Sanabria (1986) is the location of *k'akab*, *box lu'um* and *pus lu'um* soils. Hernández-Xolocotzim refers to *k'akab* soils as being located on slopes and does not recognize the other soil types. For Sanabria (1986) and other authors (Tables 12.2 and 12.3) *k'akab* are anthropogenic soils located near archaeological sites, while *box lu'um* and *pus lu'um* are located on slope sites where Hernández-Xolocotzim (1959) places the *k'akab* soils. According to ethnopedological findings, there is a strong correlation between the Mayan soil classes and their relief location (Table 12.2), confirming the soil toposequence model proposed by Hernández-Xolocotzim (1959).

## 12.7. THE MAYAN-LAND-USE EVALUATION

Mayan farmers apply their ecological knowledge in complex ways for agricultural purposes. Mayan agricultural decision-making involves the assessment of environmental, economic and symbolic factors; thus Mayan soil knowledge plays different roles, depending on practical and symbolic circumstances. Mayan land-use evaluation is based on (1) the assessment of soil-relief-vegetation relationships as a factor of the soil fertility status, land productivity and land management according to specific crops, and (2) the recording of the land-use history at parcel level as a factor of soil fertility maintenance. Mayan *milpa* is managed as an agroforestry continuum, basically depending on the natural replenishment of soil fertility via forest recovery or fallow. Thus the assessment of related soil fertility properties is critical and performed in diverse ways.

Maya farmers assess on-site soil–relief–vegetation relationships to choose their land management units. Each land management unit requires diverse shifting cultivation practices and labor-time allocation during the year and within several years, depending on its biophysical characteristics and dynamics. Pérez-Pool (1984) found a local agricultural land suitability ranking system in the Pu'uc region of southern Yucatán state. Assessment was done according to the natural fertility of the Mayan soil classes, the potential duration (years) of cultivation and the suitability of each crop and multicropping system at each parcel. Mayan farmers from Ya'axhom and Cooperativa communities assess the soil fertility status according to the occurrence of specific weeds in each soil class (Pérez-Pool, 1984).

Mayan farmers cultivate several plots during the same year and allocate labor depending on their biophysical characteristics. Diversity of fields and cultivars allow them to mitigate risks and uncertainties. Faust (1998) found that Maya farmers from the Edzná Valley in the state of Campeche, work on both hilly and flatland plots to compensate for drought and flooding and to prevent crop loss from wind, wild animals, plagues and diseases. According to Cortina (1995) 80% of Mayan farmers from Becanchén in southern Yucatán state crop two or more agricultural fields and manage two to six different Mayan soil classes. Fields are selected according to drainage conditions and moisture retention capacity of each soil class to cope with rainfall irregularity. Becanchén farmers assess the productivity of each soil class on the basis of the amount and timing of rainfall during the year. Hill soils (*tzekel* and *k'akab*) give better maize yields under good rainfall, while bottom-level soils (*ya'axhom* and *ak'alche'*) give better maize yields under scarce rainfall. *Tzekel* and *k'akab* soils are considered by local farmers as having better drainage conditions and better moisture retention capacity than the *ya'axhom* and *ak'alche'* hydromorphic soils (Tables 12.3 and 12.5). Access to site heterogeneity, maintenance of cropping systems and crop diversity are central to the Mayan subsistence strategy, even though these require relatively large areas of land, high labor input and strong communitarian organization based on reciprocity, to achieve an efficient time-labor allocation (Terán and Rasmussen, 1994; Faust, 1998).

Several agricultural practices are performed during the year according to the environmental characteristics of each forest community, fallow land or agricultural parcel. These practices also depend on the number of years that each parcel has been under cultivation, the constant assessment of the soil fertility status and the land-use history of each fallow or forest community (Sanabria, 1986). It takes 15 different agricultural practices to cover a cropping cycle, from the selection of the field to be cultivated until the decision to fallow the parcel (Pérez del Toro, 1942; Hernández-Xolocotzim, 1959; Hernández-Xolocotzim et al., 1980; Varguez-Pasos, 1981; Ucán-Ek', et al., 1982; Ewell and Merrill-Sands, 1987; Zizumbo and Sima, 1988; Terán and Rasmussen, 1994; Remmers and Ucán-Ek', 1996).

Mayan agricultural terminology is rich and complex, reflecting the many ways *milpa* production is performed according to diverse biophysical settings. Soil knowledge and land management practices are reflected in this terminology. Seeding or *pak'al* is conducted after the first rains of the year, during May or June. Three Maya terms specify seeding practices in different soils and relief types: (1) *noria-pak'al* refers to seeding in deep flatland soils; (2) *xkoben-pak'al* refers to seeding practices on stony and shallow hill soils; and, (3) *pach'pak*'al refers to seeding on vegetable furrows in deep flatland soils (Sanabria, 1986).

Sanabria (1986) gives an example of how Maya farmers assess soil–relief–vegetation relationships for choosing land management units or agrohabitats. Maya farmers from the Xul community in the Oxkcutzcab municipality recognize, name and classify agrohabitats according to vegetation type, land-use history, relief type and soil type and subtype. Relief and moisture retention capacity are the main factors used for selecting new agricultural lands. Vegetational characteristics are assessed to evaluate on-site soil fertility status.

Sites with evergreen tropical forest (*ya'axk'aax*) are considered most fertile for agriculture. Vegetables, fruit trees and short-cycle maize varieties are grown after clearing, cutting and burning the vegetation on the new agricultural plot. Forest sites on stony and hilly terrain (*tzekel k'aax*) are suitable for long-cycle maize varieties, while stony and flat forest remains (*tzekel kancab k'aax*) are considered as the low fertility sites for agricultural purposes. Soil fertility replenishment is assessed according to soil type and the speed of recovery of herbs, shrubs and trees, which may take up to 40 years.

Xul farmers recognize 15 vegetation types according to their physiognomy, floristic composition, vegetational succession stage, forest density, and soil-relief position. Complex combination of these factors allows them to classify six different land management units or agrohabitats. A brief description of each land management unit is given according to the local soil fertility and land productivity ranking, using farmers' terminology.

(1) (EK) *Ek' lu'um* developed on *kancabal* (*kancab* black soils developed on flatlands):
These are deep black soils with few stones occurring on poljés, dolines or karstic plains. They are locally considered as the most fertile and always moist soils. A tall and dense tropical forest (*checheh k'aax*) grows on these lands. A forest site 40 years old, with very dense and multiple stories (*ich k'aax*) is considered mature and recognized as the ideal site for shifting agriculture.

(2) (EKWM). *Ek' lu'um* developed on *wits* and/or *mulu'ch* (black soils developed on hills and hummocks):
These black soils are considered less fertile and shallower than EK soils. They are also stonier and retain less moisture than EK soils. Hill forest (*Wits k'aax*) and hummock forest (*Mulu'ch k'aax*) grow on these lands, presenting structural characteristics similar to those of the evergreen tropical forest on EK, but with different species distribution. Soils and forest communities (*k'akab lu'um* and *k'akab k'aax*, respectively) are often associated with ancient human settlements or archaeological sites. Anthropogenic soils on abandoned homegardens (*x-tokoy lu'um* and *x-tokoy k'aax*, respectively) are assessed as very fertile and productive for shifting agriculture.

(3) (PWM) *Pus lu'um* developed on *wits* and *mulu'ch* (loamy soils developed on hills and hummocks):
These are very stony, brownish to black soils. They are the deepest soils occurring on hill slopes. Sites are assessed as fertile, but with less moisture retention capacity than EK and EKWM soils. Vegetation recovery during fallow is slower that of the EK and EKWM vegetation communities. These semi-deciduous tropical forests loose their leaves for a short period (February–May), but leaves sprout again after the first rains (*Ya'aax kan k'aax*). Vegetation cover is less dense than that of the EK and EKWM forests, with less shrubs, lianas and herbs. Old and tall forest communities are locally called dense forest (*Ich che' k'aax*).

(4) (BWM) *Box lu'um* developed on *wits* and *mulu'ch* (black soils developed on hills and hummocks):
These very stony and shallow soils are locally considered less fertile than the EK, EKWM and PWM soils. A semi-deciduous forest (*tzekel k'aax*) grows here. Many tree species loose their leaves during a long period (January–June). Forest density is low, with fewer shrubs, lianas and herbs than in the EK, EKWM and PWM forest communities. The local name is sparse or non dense forest (*bay hal k'aax*).

(5) (CHK) *Chak lu'um* developed on *kancabal* (*kancab* red soils developed on flatlands):
These red, deep and non-stony soils are locally considered less fertile than other land management units. *Kancabal* forest (flatland forest) grows here. It is a sparse deciduous forest (*kan k'aax*) with a long- leaf shading period (January–July) and fewer shrubs, lianas and herbs (*bay hal k'aax*) than in the EK, EKWM, PWM and BWM forest communities.

(6) (TCHB) *Tzekel Chak lu'um* or *tzekel box lu'um* developed on *kancabal* (*kancab* stony red soils or *kancab* stony black soils developed on flatlands):
This land management unit presents the shallowest and stoniest soils of all Xul agrohabitats. Moisture retention capacity and fertility are lower than in other places of the area. A deciduous stony flatland forest (*tzekel k'aax*) grows on these lands. Forest recovery is the slowest of all local forest communities and trees present the longest period without leaves (*kaan k'aax*). Trees loose

their leaves and most herbs die during the short dry hot period within the rainy season (*canícula* in Spanish). It is locally considered as a sparse forest (*bay hal k'aax*), with the lowest density of lianas and herbs.

## 12.8. Land in the contemporary mayan cosmovision

### 12.8.1. Mayan ritual ecology

Contemporary Maya life style is deeply religious and ritualized according to a synchretic cosmological model of the locally observable universe. The Mayan religious cosmology is expressed in a ritualism grounded in both the particular ecology of the Yucatán Peninsula and the Middle American cosmovision (MAC) (see chapter Seven) melded with popular Catholicism. It resembles the complex perception and symbolic representation of the universe by pre-Hispanic Mayan people, but now reorganized by a complex mixing of Mayan and Catholic deities, images and practices. Mayan ritual symbolism reinforces the social organization, emphasizing the systemic properties of the local ecologies (Freidel et al., 1993; Terán and Rasmussen, 1994; Faust, 1998). The conceptual integration of time and space permits mapping the cosmos according to gender, together with their sexual and labor roles, and according to the binary opposition between night and day, left and right, dry season and rainy season, and up and down. This binary opposition is balanced by the sun, human life, and plant cycles, and interactions among them where fertilization permits the return of the holy life cycle. Female represents the forces and deities of the land, left hand, night, the rainy season and the underground world, while male represents the forces and deities of the aboveground world, the right hand and the dry season (Figures 12.6 and 12.7).

High variability of the regional rainfall and the uncertainty that this creates among local farmers appear to be at the base of the Mayan agricultural religious beliefs, sustaining the idea that rain expresses God's willingness to forgive sinners. Drought, scarcity of rains, hurricanes and plagues are considered as God's punishment of humans' sins (Terán and Rasmussen, 1994). Water scarcity, rainfall irregularity, wind forces and marginal soils make swidden agriculture difficult and uncertain, thus creating a tension between human labor and human basic needs procurement in the Yucatán Peninsula. Mayan rituals and traditions have encoded and preserved ancient understanding of local ecologies and climate in an attempt to resolve the tension between giving and receiving.

Embedded in the everyday life, Mayan cosmology is ritualized to dialogue with the supra-natural dimension of the universe and negotiate with the external forces that human beings cannot control. A highly hierarchical and complex pattern of deities plays a central role in balancing the positive and negative natural and supra-natural forces, like during the pre-Hispanic times. Mayan deities can be benevolent or malevolent, and farmers need to negotiate with them during the crucial moments of the cropping cycle. Shifting agricultural practices are embodied in an evolving tradition of Mayan cosmology and adapted to the local ecologies. Shifting farming allows forest recovery to replenish soil fertility, so that land can be used again in a cyclic rotation, resembling the Mayan conception of the universe as a network of connections, cycles and interdependencies.

### 12.8.2. Mayan agricultural ceremonies

Agricultural practices are considered sacred and agricultural ritualism plays an important role during the *milpa* production, so that it is practically impossible to separate technical activities performed on the agricultural plots with their symbolical meanings and representations. Both are inseparable and constitute a monistic worldview. Mayan agricultural cosmology and rituals form a template that guides decisions concerning resource use. Offering, suggesting, praying, convincing and negotiating with supra-natural forces, i.e. the owners of the land, water, wind and forest, are socially conducted throughout the agricultural cycle. Four main ceremonies take place, starting from the selection of the new agricultural plot to be burnt, until the thanksgiving ceremony to acknowledge *milpa* production, which might create temporal abundance and health or cause scarcity and pain. *H'men* (or *Shaman*) are the privileged and knowledgeable persons that conduct

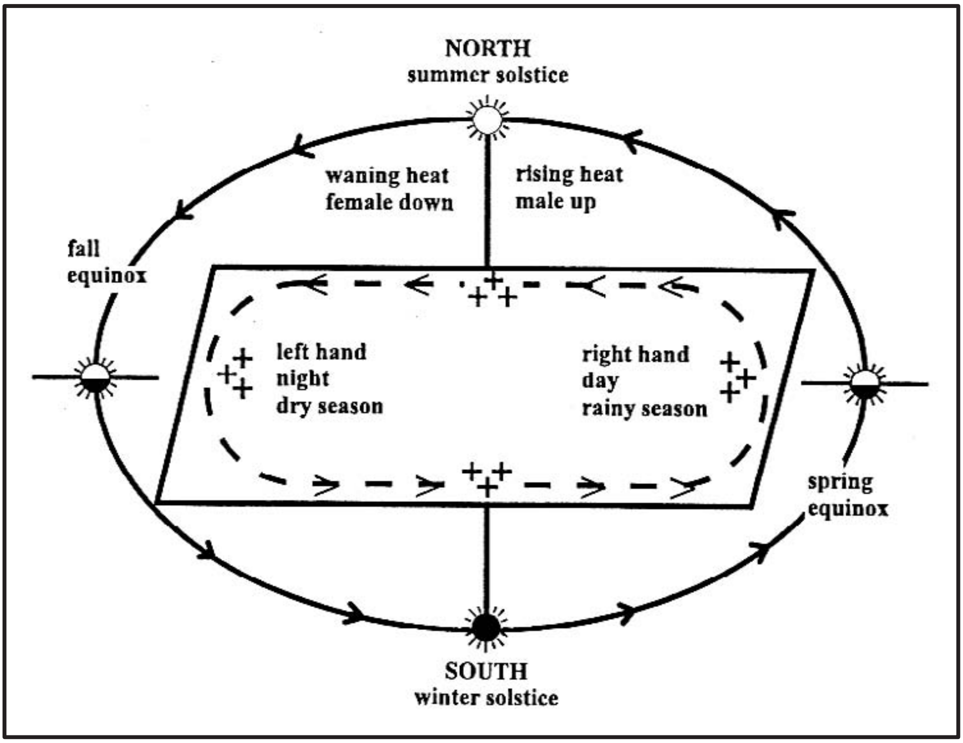



**Figure 12.6.** Life cycle in Campeche Mayan cosmology. **Source:** Faust (1998)

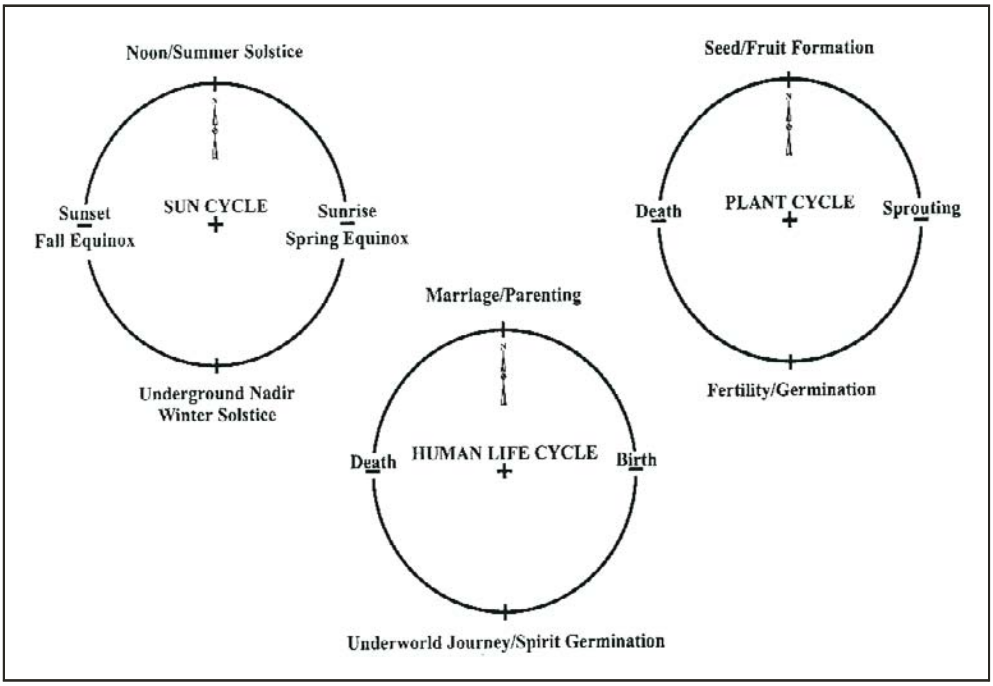



**Figure 12.7.** The Campeche Mayan holy life cycle. ***Source:*** Faust (1998).

ceremonies, as they are the only capable to interact with the supra-natural essences, forces and beings. They are the negotiators and the link between human efforts and divine willingness.

Maya farmers perceive the agricultural parcel as the synthesis of the holy universe. Carefully measured after its selection, the agricultural parcel is oriented according to the fifth cardinals (including center as a cardinal) using sophisticated techniques and tools (Faust, 1998). Parcel orientation is related to the sun appearance on the zenith and its position, during the period of agricultural activities between summer solstice (June 21) and winter solstice (December 21). Typically, a parcel faces the East cardinal, because it is where the rainy winds come from.

A ritual ceremony is conducted after selection and measurement of the new agricultural parcel. This ritual is offered to the eight representatives of *Chak*, the god/goddess of the Holy Rain and Guard of all Cardinals (*Tlaloc* in the Nahua cosmology; see chapter Seven). The *Yum Chako'ob*, or the representatives of *Chak* (or *Tlaloques* in the Nahua cosmology), and the *Yum L'kob* representatives of the four winds allow, or not, the land to be irrigated by rainfall. They play a crucial supra-natural role, as rainfall is critical for Mayan subsistence, and are the terrestrial representatives of the One True God.

The *H'men* conducts another ritual ceremony when the appropriate moment comes to cut the forest on the selected parcel. The ritual is centered on asking permission to the deities, or owners of the forest (*Yum k'aax* or *Kanaan k'aax*), to convert a forest patch into a new agricultural field, transgressing the holy natural cycle. There are thirteen guardians of the forest, as there are thirteen floors of the aboveground world. A ritual ceremony is again conducted to forgive human action and offer sources that initiate the procreative agricultural act, before burning the vegetation and fertilizing the soil with fresh ashes, and before liming the soil with burnt limestone fragments. This ritual is offered to respect the willingness of the deities or owners of the wind (*Yum l'kob*), fire (*Yum k'aak'ob*), land (*Yum Kalan lu'um*) and animals (*Yum winik'ob*).

The most important agricultural ceremony is the *Ch'a aak* or ritual to induce good rain and protect crops and humans from wind damage. This ritual is offered to all principal Mayan and Christian deities and saints to let them know that seeding was completed and that, from now on, rainfall depends on their willingness and intervention for the good performance of the *milpa*. During the ceremony, taking place between May and June, just before the beginning of the rainy season, a small rectangular table is made and placed near the agricultural parcel (Figure 12.8). The table (*Kaanche*) synthesizes the Mayan conception of the universe, with its five cardinals and the thirteen floors of the world. It resembles also the highly productive *K'aan che'* or organic soil-seeding bed, used in homegardens to cultivate vegetables (Vargas-Rivero, 1983). Cardinals represent the pillars that sustain the world and the center represents the Holy Tree that communicates the three main levels of the universe (Figure 12.9; see also chapter Seven). Four *H'men* conducts the ritual during three days. Praying, offering and convincing phrases and songs are socially conducted to negotiate the good performance of rainfall and crops. Among the principal deities that are asked to be benevolent are the holy owners of the land (*Metan lu'um* or *Kalan lu'um*). Without rain, soil would not fertilize and the sterile land would not permit the good performance of crops and the revenue of the holy cycle.

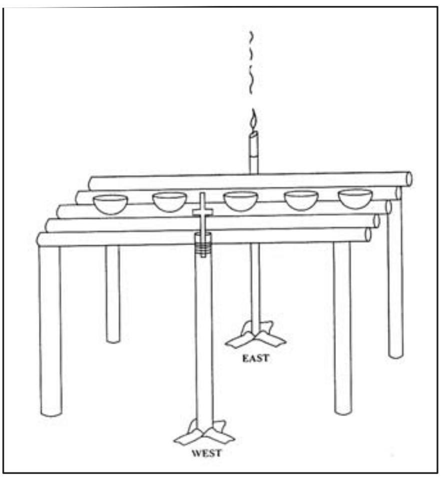



**Figure 12.8.** Kaanche, the seeding bed representing the agricultural parcel and the Mayan universe. **Source:** Faust (1998)

The last main agricultural ritual ceremony conducted during the year is the one called 'thanksgiving action for maize maturation' (*Holche' Yetez Pibil Nal* or *U Janzi Kol*). It consists of offering underground-fumed corncobs (*Pibilnalo'ob*) to all supra-natural deities and Christian saints who allowed maize maturation. Special offerings are dedicated to the owners of the forest (*Kanaan k'aax'ob*), *milpa* (*Kanaan Kool'ob*), cenotes or sinkholes

(*Kanaan sayab'ob*) and rain (*Yum chako'ob*). This ceremony takes place during the days of the Death (October 31 to November 2), highlighting the closure of the past agricultural cycle and the beginning of the next one, as part of the perpetual holy life cycle. The analysis of the ecological and cultural Mayan rationale reveals both continuity with the ancient Maya cosmology and potential for new forms of technology appropriate to the local ecologies of the Yucatán Peninsula. The orientation of the agricultural fields, the way they are laid out in squares, and the association with the sun and the winds, all are congruent with the cosmological system of the ancient Mayan civilization and constitute a technological analogy of the ritual symbolism (Faust, 1998). Practical activities are combined with ceremonial acts during the agricultural cycle and both are seen as sacred because they are essential to human life and sustained through work with the natural world.

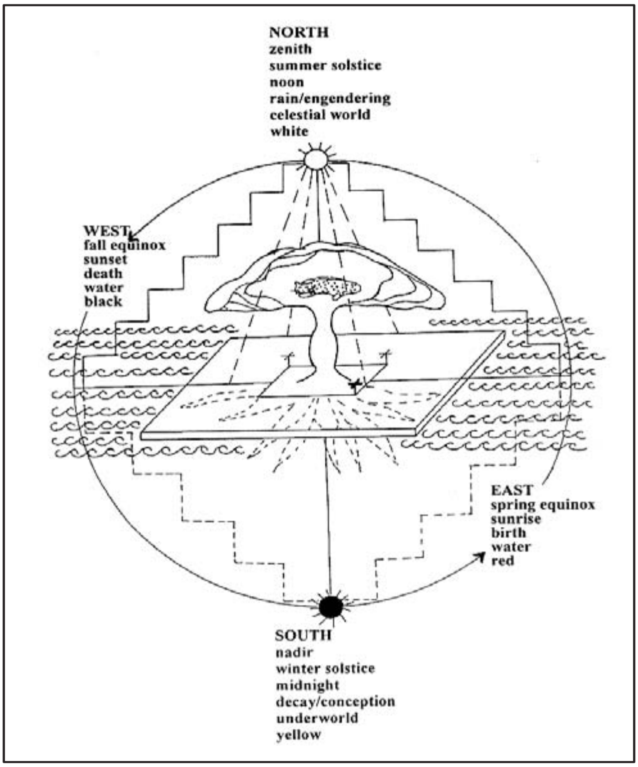



**Figure 12.9.** The Mayan Holy Tree. **Source:** Faust (1998)

## 12.9. CONCLUSION

Contemporary Mayan ethnopedology shows richness and complexity. It also reflects an historical and well-adapted land-use system centered on shifting cultivation, where maize is the most important crop growing on poorly developed and shallow karstic soils. Soil fertility maintenance in marginal environmental conditions has led to a careful recognition of soil-relief-vegetation relationships at micro- and macro-levels. Soil fertility management is linked to the ecological succession of tropical forests, which is highly dynamic and heterogeneous, depending on factors such as land-use history, relief position and soil characteristics. The vast Mayan soil nomenclature takes in account the soil properties and attributes that are directly or indirectly related to soil fertility and productivity. Soil moisture retention capacity, drainage, color, texture, structure, consistence, depth, workability and relief position, are the main soil properties locally assessed for agricultural decision-making. The Mayan soil nomenclature is widely and commonly used by local farmers within all the Yucatán Peninsula, being thus consistent at local and regional levels.

*Lu'um*, or the soil/land Mayan dominion, is recognized and assessed in an integral way. Mayan soil types are linked to relief and vegetation; thus the term *Lu'um* is multidimensional. *Lu'um* refers to soil, land and landscape, and therefore cannot be separated from other environmental factors that are critical for the structure, distribution, dynamic and processes of the karstic tropical ecosystems. In fact, the Mayan ethnopedology mirrors the ecology of the tropical landscapes, as this knowledge-based system is guided by the natural conditions of the landscapes and is well fitted to their dynamics. The Mayan cognitive and practical agricultural systems follow ecological cycles, both at short and long terms, to prevent soil depletion. A synthesis of the Mayan soil knowledge system is shown in figure 12.10.

Soil fertility status is assessed by recognizing the performance of soil-relief-vegetation as a spatial ensemble influenced by climatic conditions. Water is a critical resource for the soil fertility status assessment. Rainfall performance during the year and rainfall variability between years are evaluated for each soil type, as land

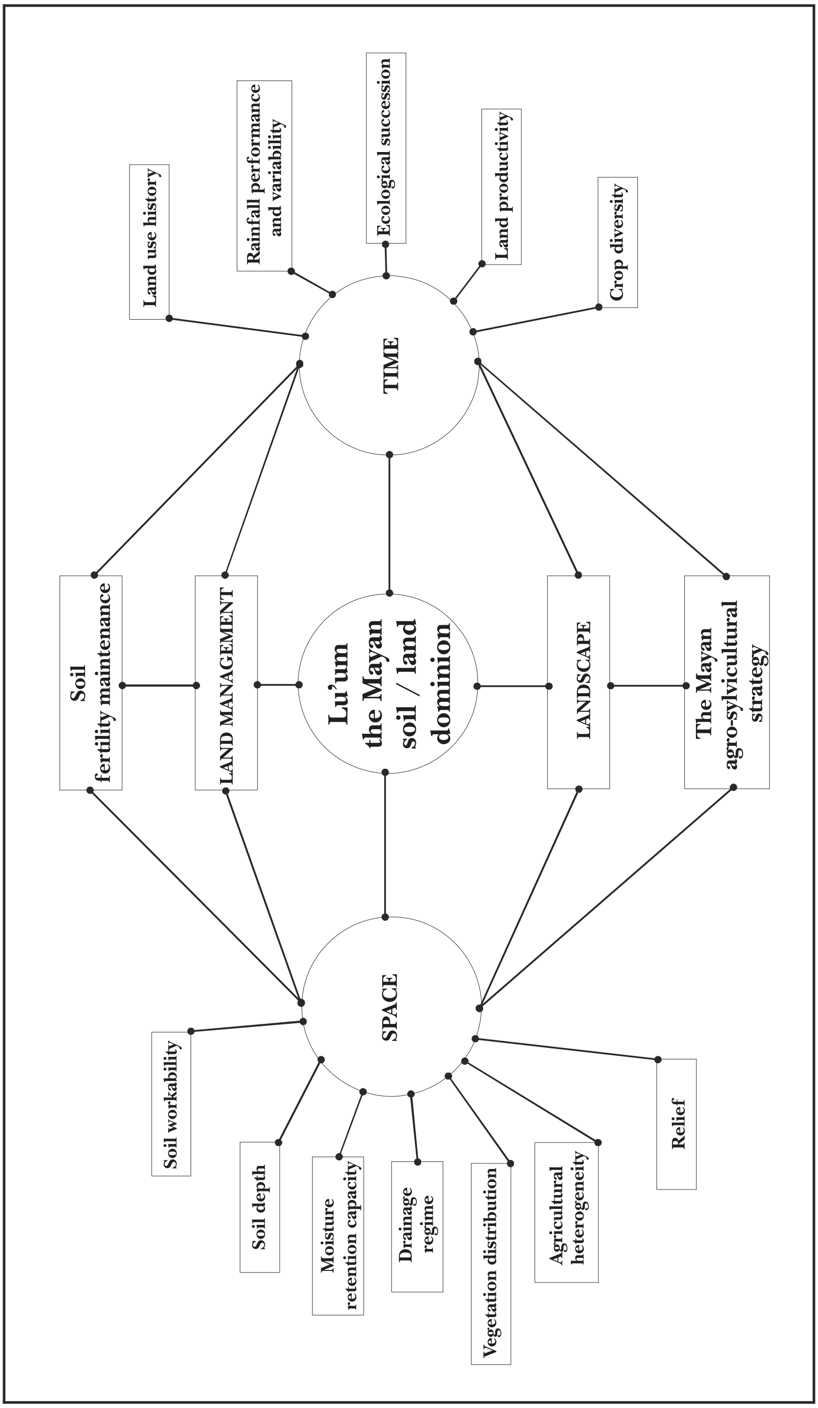



**Figure 12.10.** The Mayan soil knowledge

productivity depends on the soil moisture retention capacity and drainage regime. Mayan farmers assess land productivity according to 'wet' and 'dry' years and according to the soil-relief position. Soil-relief position is recognized in a toposequence controlled by calcimorphic and/or hydromorphic soil formation processes. Sloping and well-drained soils are considered better agricultural soils during 'wet' years while bottom-level and poorly drained soils are considered better agricultural soils during 'dry' years.

The soil toposequence is recognized as controlling forest distribution. Forest age, structure and composition are assessed to determine the soil fertility status. This is done according to the degree, amount and timing of leaves' falling and decomposition. Perennial forests are considered better potential agricultural sites than deciduous forests. Organic littering and decomposition on the topsoil are site-assessed to determine the soil fertility replenishment of a former agricultural plot. Soil fertility replenishment depends on the vegetation succession stage, which is controlled by the land-use history, the former forest type that was cut down, slashed and burned, the relief position and the soil characteristics of the fallow land. Land-use history is recognized as a continuum, which depends on the natural soil fertility replenishment, the potential land productivity and land management over time.

The Mayan soil taxonomy, although not yet well understood by soil surveyors, agronomists and anthropologists, is complex and hierarchical. It is based on a limited set of soil properties and attributes. The Mayan soil taxonomy presents minor differences at regional level and can therefore, be considered as a regional knowledge-based soil system, adapted to the many variations at local level. It serves as a common template that guides soil/land knowledge and management diffusion among farmers from different areas of the Yucatán Peninsula. The same soil classes are named, recognized, classified and managed in similar ways by Mayan farmers from distant areas within the Peninsula, showing a well-established regional indigenous soil culture.

There are similarities between Mayan and technical soil taxonomies. Mayan soil classes correlate in general with the technical ones established according to the FAO/UNESCO/DETENAL soil legend (1979), and the USDA Soil Taxonomy (Soil Survey Staff, 1998). Mayan soil classification can be considered behavioral, relational, diachronic, qualitative, measurable, utilitarian and local, while the technical soil classification can be considered synchronic, measurable, genetically-oriented and universal. The first one relies on agricultural land-use potential and soil fertility maintenance, while the second one is based on diagnostic properties, which are not necessarily utilitarian.

Soil surveyors, agronomists and extensionists are increasingly integrating the Mayan soil taxonomy into their own technical discourse for land-use planning. This common understanding about the regional soils opened a dialogue to evaluate agricultural problems and find alternative solutions according to the local experience and technical expertise. Previously, the widespread opinion that Maya soil and land knowledge and management system are primitive and ill-suited for rural development led to the failure of several attempts to modernize agricultural production in the Yucatán Peninsula (Duch, 1995).

Contemporary Mayan soil knowledge is still linked to the symbolic representations and rituals evolved and adapted since the pre-Hispanic period. The Mayan cosmology is founded on the return of the holy cycle as the only base for the perpetuation of human existence within the natural world. It serves as a guide to control social institutions and economic enterprises, giving meaning to the social perception of the local world. The symbolic and concrete ecological knowledge is systemic and adapted to the local conditions as a risk-avoidance system and as a strategy to cope with uncertainties. Mayan farmers perceive the soil dominion as a subject having forces similar to those possessed by humans and as a resource that can be enhanced by the secular and sacred work. Soil fertility maintenance is critical for the perpetuation of the holy and concrete life cycles. It is carefully assessed and ritualized during the agricultural cycle, playing a central role in the Mayan cosmology and production systems, because soil depletion could break the balance between the sacred and concrete ecologies. Kosmos, Corpus and Praxis are inextricably linked in the contemporary Mayan ethnopedology and cannot be separated when analyzing the ecological and economic rationale of Mayan people.

# Chapter thirteen

# Middle american ethnopedology: A social theory of soil and land resources

## 13.1. Introduction

Chapter Thirteen compares Middle American ethnopedologies analyzed in chapters Eleven and Twelve. The main objective of this chapter is to correlate local ways of perceiving, knowing and managing soil and land resources among small farmers from different ethnic backgrounds but sharing a common history and a common cosmovision. This cross-cultural comparison intends to answer three main questions: (1) Do Middle American ethnopedologies share similar organizing principles constituting a pedologic meta-culture or a single social theory about the soil and land resources? (2) Which are the common elements and principles that frame this pedologic meta-culture? And (3)Which are their main differences and which factors influence these contrasts?

Pedologic meta-culture means a soil and land resources knowledge-based system structured by a set common principles (Kosmos, Corpus and Praxis) shared by local communities from different ethnic backgrounds and ecologies but forming part of the same civilization core. Soil and land resources are locally perceived, symbolized, named, classified and managed in similar ways despite environmental and cultural differences, showing regularities that are the result of a common but multi-ethnic co-evolution between humans, nature and culture. Principles that organize this social theory are considered universal by their producers and constitute a cultural communication and dissemination bridge among ample populations despite linguistic differences, producing a meta-language or a linguistic ecology, showing a unity within diversity (see section 3.3.3 of Chapter Three).

A pedologic meta-culture implies not only an ancient civilization co-evolution between land and people but also its cognitive and practical permanence through time. Change, adaptation, innovation, enrichment and loss make possible the enduring of an ancient social theory about the soil and land resources is continuously hybridizing and is commonly and widely practiced in efficient ways. Syncretism made possible its continuity and future depends on its fully comprehension and adaptation to new circumstances.

## 13.2. The middle american pedologic meta-culture

Middle America, was an area where soil knowledge and management became complex and sophisticated. The evolution of this knowledge-based system was intimately linked to the rise of a civilization core based on plant domestication under heterogeneous ecological conditions. This knowledge-based system presents common organization principles, although it evolved in contrasting cultural and environmental contexts. Local and well-adapted ethnopedologies share the same principles as a result of a complex web of associations organized by agricultural diffusion and exchange and framed within a single cosmovision (see Chapter Seven). The evolution of a common social theory about soil and land resources depended on:

(1) maize domestication and diffusion within the whole civilization core; maize as a main staple crop;
(2) maize as a cultural matrix of Middle American Cosmovision (MAC); maize as a primordial cultural element;

(3) MAC as a polytheistic and animistic religion shared and adapted by different regional cultures; MAC as a common world view, and
(4) land-maize-rain as a symbolic trilogy synthesizing fertilization as the key for the perpetuation of the secular and holy life cycles; maize-land-rain as the *milpa* system (Figure 13.1).

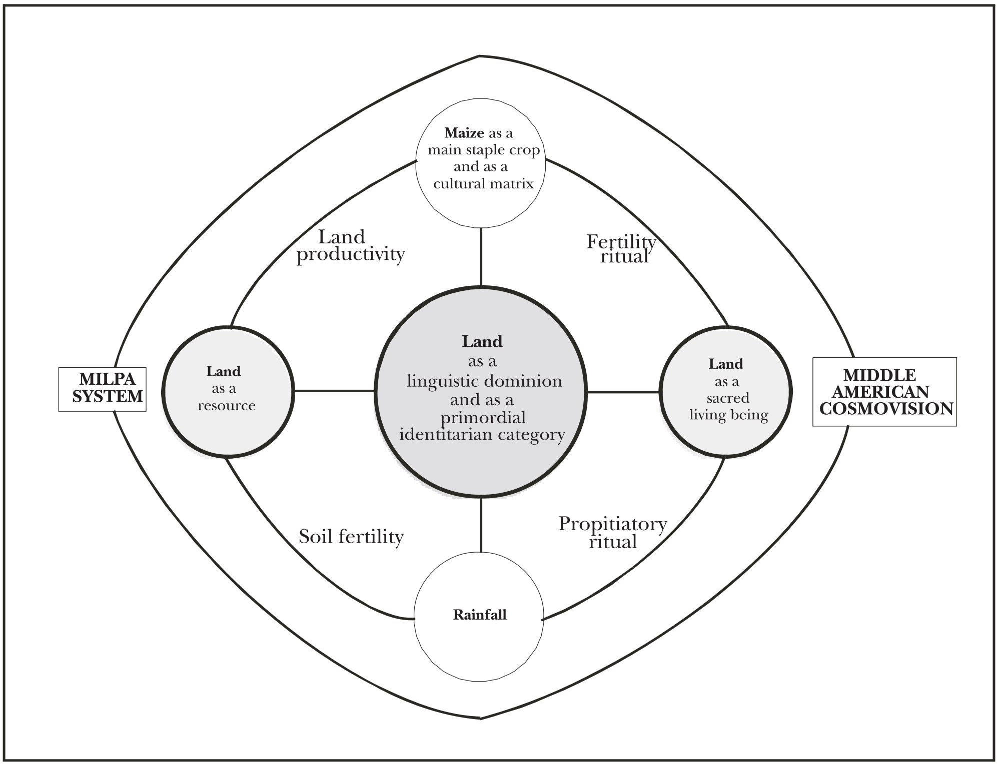



**Figure 13.1.** Land knowledge as a pedologic meta-culture in Middle America

The complexity of the Middle American pedologic meta-culture was based on the integration of the soil classification into a written system, expressed by soil glyphs and pictorial representations (see Chapter Eight). It was rooted on the elaboration of an ample soil and land nomenclature and the recognition of soil-relief-vegetation relationships, consistently applied to assess soil qualities for the *milpa* production requirements (see Chapter Eight). It was also based on the evaluation of soil and land resources applying sophisticated mathematical and land cartography procedures for tributary purposes (see Chapter Eight). Soil and land knowledge was embedded in different environmental conditions and production systems (see Chapter Nine). Land management for *milpa* production included mechanical, biological and agronomic measures, such as the building of anthropogenic soils to fulfill the food demands of 25 to 40 million inhabitants at the eve of the Spanish conquest. Land morpheme emerged as a polysemic dominion (soil, land, terrain, landscape, territory, and the world), as a polyvalent symbol (as a natural object and as a scared living being), and as a multi-purpose natural resource (agricultural, medicinal and construction uses).

The permanence of the Middle American pedologic meta-culture during the last 500 years after the Spanish conquest depended on:

(1) the maintenance of maize production as the main staple crop (see Chapter Ten);
(2) the ability of indigenous and *Mestizo* populations to adapt and innovate their *milpa* systems with the integration of exotic species and agronomic technologies (see Chapter Ten);

(3) the permanence of an important rural population, engaged in small farming oriented towards subsistence and commercial agricultural activities;
(4) the permanence of cohesive political, social and religious local institutions based on the prestige rather than on the economic status of the inhabitants and linked to social landholding regimes (see Chapter Ten), and
(5) the ability of local populations to maintain their ancient cosmovision in syncretic ways, adopting a popular Catholicism that cover Middle American beliefs, rituals and deities linked to the *milpa* agricultural cycle.

Local and regional ethnopedologies from Mexico, Belize and Guatemala show the permanence of rich, complex and diverse soil theories possessed by indigenous and *Mestizo* small farmers living in five agro-ecological zones. Their comparison shows a set of similarities that structure the contemporaneous pedologic meta-culture of this region.

### 13.3 Diagnostic attributes most frequently used to classify soils

Middle American soil nomenclature is rich and complex. Twenty-four soil properties and related attributes are labeled to classify soils, according to the analysis of 28 ethnopedological studies carried out within 11 ethnic groups living in five agro-ecological zones (Table 13.1). The sampled ethnic groups use seven sets of classification criteria. The proportion of the groups implementing a given criterion is indicated as a percentage of the total number of groups. The seven sets are:

(1) color and texture (100%);
(2) consistence and soil moisture (90%);
(3) structure, drainage regime, relief, organic matter content and stoniness (between 68 and 82%);
(4) workability, depth, fertility and ecological succession of vegetation (between 43 and 61%);
(5) vegetation as soil fertility indicator, land-use history, parent material and erosion (between 36 and 43%);
(6) compaction, productivity, hardpan presence, salinity and taste (between 18 and 29%), and
(7) cracking and rooting condition (11%).

Eleven of these properties are used to classify soils by 50% or more of the sampled ethnic groups. The diagnostic attributes most frequently used to label soil taxa are color, texture, consistence, moisture retention capacity and organic matter content. Some other diagnostic attributes are ecological and not properly soil properties. Among these, ecological succession of tropical vegetation, vegetation type, plants as soil fertility indicators and land-use history, which are indirectly implemented, are dynamic and relational attributes permanently assessed to recognize the soil health status. A key feature is that there is no clear-cut distinction between soil and land characteristics.

A comparison of the diagnostic attributes most frequently used to classify soils within the five agro-ecological zones shows that on average, 17 attributes are used per agro-ecological zone (71% of the diagnostic attributes most frequently used to classify soils in Middle America). The average number of diagnostic attributes used to classify soils by 75% or more of the ethnic groups of each agro-ecological zone varies from 10 to 17, and the average number of diagnostic attributes used by all ethnic groups pertaining to each agro-ecological zone is 5.

The comparison of diagnostic attributes used to label soil classes within the five agro-ecological zones shows well-adapted classification systems for agricultural purposes, accordingly to local environmental conditions and dynamics. Ecological succession of tropical vegetation, vegetation types and land-use history are indirectly implemented to evaluate the soil fertility status under shifting cultivation practices. The use of these diagnostic attributes is restricted to the humid tropics of Middle America. Salinization constitutes a main

**Table 13.1.** Diagnostic attributes most frequently used to label soil classes and number of soil taxa per ethnic group of Middle America

| Num. | State | AEZ[1] | Ethnic Group | Color | Texture | Consistence | Moisture | Structure | Drainage | Relief | Organic matter | Stoniness | Workability | Depth | Fertility | Ecological succession | Vegetation | Land use | Parent material | Erosion | Compaction | Productivity | Hardpan | Salinity | Taste | Cracking | Rooting condition | Soil taxa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | GUAT[3] | 1 | Maya | 1[2] | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| 2 | YUC | 1 | Maya | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 14 |
| 3 | YUC | 1 | Maya | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| 4 | YUC | 1 | Maya | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| 5 | YUC | 1 | Maya | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 |
| 6 | YUC | 1 | Maya | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| 7 | VER | 1 | Nahua | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 11 |
| 8 | CHIS | 1 | Tojolabal | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| 9 | VER | 1 | Totonac | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 11 |
| 10 | VER | 1 | Totonac | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 11 |
| 11 | OAX | 2 | Chinantec | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| 12 | OAX | 2 | Chinantec | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 12 |
| 13 | CHIS | 2 | Mestizo | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 5 |
| 14 | OAX | 2 | Mixe | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| 15 | OAX | 3 | Huave | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 11 |
| 16 | VER | 3 | Mestizo | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 11 |
| 17 | VER | 3 | Mestizo | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 10 |
| 18 | GUAT | 4 | Kekchi Maya | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 |
| 19 | GUAT | 4 | Kekchi Maya | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| 20 | GUAT | 4 | Maya Quiche | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 9 |
| 21 | TLAX | 4 | Mestizo | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 9 |
| 22 | MEX | 4 | Mestizo | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 7 |
| 23 | MEX | 4 | Mestizo | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| 24 | DF | 4 | Mestizo | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| 25 | TMPS | 5 | Mestizo | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| 26 | HGO | 5 | Otomi | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 9 |
| 27 | HGO | 5 | Otomi | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 15 |
| 28 | OAX | 5 | Zapotec | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 8 |
| | | | Frequency | 28 | 28 | 25 | 25 | 23 | 22 | 21 | 19 | 19 | 17 | 15 | 13 | 12 | 10 | 10 | 10 | 10 | 8 | 6 | 6 | 5 | 5 | 3 | 3 | 278 |

[1]AEZ= Agro-ecological zone: (1) Humid tropical lowlands; (2) Humid tropical highlands; (3) Sub-humid tropical lands; (4) Sub-humid temperate highlands; (5) Semi-arid lands; [2.] Used diagnostic attribute (1); non-used diagnostic attribute (0); [3]Guatemala

problem in semi-arid lands, sub-humid temperate bottom-level lands and sub-humid tropical coastal lands of Middle America. Small-farmers are well aware of this problem, thus salinity is a restricted diagnostic attribute used to label soil classes in these agro-ecological zones.

## 13.4. Soil classification systems

### 13.4.1. Attributes most frequently used to name soils

Middle American soil classification systems are descriptive, multipurpose, dynamic and utilitarian. A reduced number of the recognized soil attributes are used to name soil classes. Six sets of these attributes are used to name soil classes, according to the comparison of 28 ethnopedological studies. The proportion of the ethnopedological studies recognizing a given criterion is indicated as a percentage of the total number of ethnopedological studies. The six sets are:

(1) color and texture (100%);
(2) stoniness (77%);
(3) structure, drainage and relief (38%);
(4) depth, hardpan presence and chemical composition (23%);
(5) moisture, organic matter content, consistency and salinity (15%), and
(6) vegetation type, parent material and taste (8%).

In total, 16 diagnostic attributes are used to name soil classes, which correspond to 67% of the recognized diagnostic attributes within the five agro-ecological zones of Middle America. The most representative are morphological and are assessed within the topsoil (0-30/45 cm). There are only slight variations between agro-ecological zones. Color, texture, stoniness, relief, structure, drainage and moisture content are the most representative diagnostic attributes used to name soil taxa (Figure 13.3). Although local classifications are apparently rather simple, based on few descriptors, they are flexible and fine-tuned. Soil discontinuities and mixtures are used as modifiers (e. g., reddish yellow soil or slightly salty soil), allowing to account for small soil variations, thus showing complexity.

Considering the 28 studies included in the inventory, the number of soil taxa belonging to the different systems analyzed varies between 4 and 16 (Table 13.1). The average number of soil taxa that are recognized per ethnic group is 10. More than half (68%) of the sampled groups work with 9 to 16 soil taxa. A comparison of the number of soil taxa belonging to the different classification systems recorded by agro-ecological zone shows the following variation, considering:

(1) the 10 studies included in the humid tropical lowlands, the number of soil taxa varies between 9 and 16. The average number of soil taxa that are recognized per ethnic group within this agro-ecological zone is 12, which is the highest in Middle America. Eighty percent of the sampled groups work with 10 to 16 soil taxa;
(2) the three studies included in the sub-humid tropical lands, the number of soil taxa varies between 10 and 12. The average number of soil taxa recognized per ethnic group within this agro-ecological zone is 11, the second highest. All of the sampled groups work with 10 to 11 soil taxa;
(3) the four studies included in the humid tropical highlands, the number of soil taxa varies between 5 and 12. The average number of soil taxa recognized per ethnic group is 10, the third highest. Half of the sampled groups work with 12 soil taxa;
(4) the four studies included in the semi-arid lands, the number of soil taxa varies between 4 and 15. The average number of soil taxa that are recognized per ethnic group is 9. Half of the sampled groups work with 9 to 15 taxa, and

(5) the seven studies included in the sub-humid temperate highlands, the number of soil taxa varies between 5 and 9. The average number of soil taxa that are recognized per ethnic group is 7; the lowest in Middle America. Eighty six percent of the sampled groups work with 7 to 9 soil taxa.

Variations in the number of soil taxa recognized between agro-ecological zones reflect differences in land management strategies, which are discussed in above. Of note is that the tropical zones present the highest average of soil taxa locally recognized, followed by the semi-arid zone, while the sub-humid temperate zone presents the lowest average of soil taxa. Noteworthy is the average number of soil taxa locally managed per ethnic group in all agro-ecological zones.

### 13.4.2. Comparison between indigenous and *Mestizo* soil classifications

Indigenous and *Mestizo* soil classification systems are substantially different. Indigenous systems recognize a higher average number of soil taxa (11) than the *Mestizo* systems (8). Considering the 20 studies carried out in indigenous localities belonging to the five agro-ecological zones, the number of soil taxa varies between 5 and 16. More than a half (60%) of the sampled groups work with 11 to 16 taxa. In contrast, considering the eight studies carried out in *Mestizo* localities from three agro-ecological zones, the number of soil taxa varies between 4 and 11. Only 38% of the sampled groups work with 9 to 11 taxa. Comparison between indigenous and *Mestizo* soil classification systems belonging to four agro-ecological zones gave the following results:

(1) the average number of soil taxa of indigenous systems belonging to the humid tropical highlands is higher (11) than of the *Mestizo* systems (5);
(2) the average number of soil taxa of indigenous and *Mestizo* systems belonging to the sub-humid tropical lands are similar (11 and 10.5, respectively);
(3) the average number of soil taxa of indigenous and *Mestizo* systems belonging to the sub-humid temperate highlands are similar (7.3 and 7.5, respectively), and
(4) the average number of soil taxa of indigenous systems belonging to the semi-arid land is much higher than that of the *Mestizo* systems (10.6 and 4, respectively).

Some conclusions can be drawn from this comparison. Indigenous peoples have lived in the humid tropical highlands since ancient times and developed well-adapted land-use systems centered on shifting cultivation and the management of several agro-ecological belts is controlled by elevation, climate and other ecological factors (vertical zonation). *Mestizo* populations, on the contrary, are historical minorities on these lands where possibilities to expand their local economies were limited. The difference between the average numbers of soil taxa partially reflects historical land management systems and cultural of both ethnic groups. In contrast, indigenous and *Mestizo* populations have lived together in the sub-humid temperate and sub-humid tropical lands, adopting syncretic land-use systems centered on rainfed maize agriculture for subsistence and commercial purposes. The average numbers of soil taxa are similar in both systems, partially reflecting the historical hybridization of land management and socio-cultural preferences of these populations. Finally, although indigenous populations constitute a minority in semi-arid lands, where they were forced to settle down since the colonial times, they adopted rainfed maize systems as a main subsistence strategy. *Mestizo* populations have been historically engaged in cattle ranching on these less favored lands for rainfed cropping. The average numbers of soil taxa in these systems reflect different historical land management strategies.

### 13.4.3. Comparison between indigenous and *Mestizo* soil taxonomies

The comparison of 13 soil taxonomies shows that 54% are hierarchically organized, corresponding to indigenous soil taxonomies, while all *Mestizo* soil taxonomies show non-hierarchical structures. Despite methodological inconsistency among the analyzed studies, making the comparative analysis cumbersome, some general principles can be identified.

(1) Non-hierarchical local soil taxonomies are rather simple at first glance and based on the assessment of few diagnostic attributes. They show flexibility to account for slight soil variations by means of modifiers. Soil discontinuities and mixtures are used as modifiers. Farmers assess soil properties and classify soils on the basis of both inherent and management characteristics of soils. Less suitable agricultural soils are reflected in less detailed soil classification and, vice versa, more suitable agricultural soils are reflected in a more detailed classification. Soil classification emerges as a facet of traditional resource management, matching in complexity the cultural significance of the resources involved.

(2) Hierarchical soil taxonomies, linked to indigenous environmental knowledge-based systems, are complex and based on the assessment of several diagnostic attributes. They cluster soil taxa at different levels of the system. Farmers recognize soil variations and mixtures, and cluster soil types, classes, sub-classes and varieties according to similarities or differences between soil bodies to construct multi-categorical systems. The inclusion or exclusion of given soil classes and their variable positioning in the categories of the system, depend on the classification criteria assigned, which might be ecological, morphological, productive or symbolic.

(3) Hierarchical soil taxonomies show the existence of universal criteria to organize and distribute the soil classes in a multi-level system.

(4) All the hierarchical soil taxonomies start at the higher level of the system with a comprehensive realm concept including all soils, the equivalent to Plantae or Animalae in other natural realms. Of note is that there is no sharp distinction between soil, land, terrain or landscape; thus the 'soil' dominion is multidimensional, resembling the indigenous holistic view of nature. The recognition of differences between the categories depends on the needs to organize and distribute the soil classes for different morphological, utilitarian or symbolic purposes.

(5) All hierarchical soil taxonomies include all or most of the soil classes encountered locally.

(6) The majority of the hierarchical soil taxonomies include from three to five levels.

Some conclusions can be made when comparing the multi-level soil taxonomies analyzed in Chapters Eleven and Twelve, including:

(1) indigenous soil taxonomies belonging to the humid tropical lowlands cluster major soil types in the second level of the system;

(2) indigenous soil taxonomies belonging to the humid tropical highlands cluster main bio-climatic belts at the second level of the system;

(3) indigenous soil taxonomies in areas where not all recognized soils are used for agricultural purpose, cluster agricultural and non-agricultural soils as major soil types at the second level of the system. Finer clustering of soil taxa belonging to the agricultural soil types takes place at the third level of the system, showing an utilitarian classification purpose;

(4) indigenous soil taxonomies belonging to the sub-humid temperate highlands cluster soil according to relief position as major soil types at the second level of the system (hill soils against flatland soils). These soil taxonomies reflect morphological, utilitarian and managerial purposes in areas having high soil variability, and

(5) most non-hierarchical and hierarchical soil taxonomies show linguistic hybridization. *Mestizo* soil taxonomies include colonial Spanish soil terms as well as indigenous soil names. Indigenous soil taxonomies are bilingual and often include colonial Spanish soil terms. Of note is that most of the indigenous soil names included in *Mestizo* soil taxonomies are Nahuatl names, similar to those used by pre-Hispanic Nahua farmers. Some of these terms are also included in non-Nahuatl indigenous soil taxonomies.

## 13.5. Soil quality assessment

### 13.5.1. Farmers assessing soil health

Indigenous and *Mestizo* farmers in Middle America are constantly assessing the soil qualities of their agricultural parcels. The main goal is to maintain soil productivity and soil health over the long-run, as a local food security strategy in conditions where land resources are scarce and economic constraints inhibit the use of high inputs, such as chemical fertilizers, herbicides and machinery. Chemical fertilizers are expensive, herbicides are often avoided in multicropping systems and the sloping landscapes limit the possibilities of using machinery; thus local farmers rely on traditional agricultural strategies based on manual labor to replenish organic fertilizers as a way to restore, maintain or enhance soil fertility. In some cases, high energetic inputs and high yielding crop varieties are used on the most suitable soils. The combination of traditional and modern agricultural strategies takes advantage of the local soil variability and the maintenance of well-adapted local crop landraces. Local management of soil variability and crop diversity permits the integration of subsistence multicropping and cash monocropping as an environmental and economic risk-avoidance strategy.

Farmers commonly use the term soil health, as they perceive the soil body as a living being whose behavior is similar to that of plants, animals and humans. Common terms used by farmers with respect to soil health are caring, protecting, nurturing, feeding and curing. Soils can be thirsty, weak, thin, fat, strong, exhausted, recovered or healthy. Soil health is on-site assessed in a holistic way. Soil and related diagnostic attributes are evaluated to rank soil qualities in relation to crop requirements management practices. The assessment is constantly performed, mainly for properties of the topsoil (0-30/45 cm), to evaluate the soil health status. Diagnostic attributes include not only soil properties (morphological, biological and chemical), but also other ecological factors such as land, climate and vegetation as well as managerial factors.

Management and conservation practices are also included because farmers recognize that the inherent soil properties can be enhanced by labor; thus ameliorating soil qualities is one of their major concerns, but not always reached due to internal and external factors. Soil health assessment is done by observation, touching, smelling, feeling and tasting, together with some other qualitative measurements (topsoil loss, removal, transportation, deposition, crop density, crop growth, soil fauna abundance and rooting conditions). Figure 13.2 synthesizes the most common diagnostic attributes assessed by local farmers in Middle America.

The analysis of ethnopedological findings in chapters Eleven and Twelve shows 22 soil and related diagnostic attributes that are assessed for soil quality ranking in Middle America. Mainly morphological, physical, biological and chemical soil properties are used as of diagnostic attributes. Local farmers belonging to the five agro-ecological zones commonly use 12 of them (in 50 to 100% of the cases). Table 13.2. shows the frequency of recognized indicators of soil condition per agro-ecological zone and the soil quality function according to literature. Although not all the soil condition indicators locally assessed to rank soil quality are similarly perceived by farmers and researchers for obvious reasons, important is to show the complexity of the local soil health assessment. Moreover, both approaches show synergism and complementary and stand for a possible communication bridge between researchers and farmers concerned with soil quality research and application. Romig (1995) has done some attempts in this sense, which have been challenged by other authors (Sojka and Upchurch, 1999).

Although farmers and scientists utilize different tools to assess soil quality, both evaluate similar diagnostic attributes to recognize the ability of the soil, within natural limitations, to perform as a resilient soil ecosystem. Both assess the ability of the soil to support sustained production of plants and animals and to protect environmental quality. Theoretically, they complement one another as both work toward similar goals, specifically productivity and sustainability. Both apply a holistic view for soil quality assessment, that includes not only soil properties but also other environmental and management factors. Practically also, they complement one another. Farmers primarily attend to the local peculiarities of how best to maintain a soil's health, while scientists are more concerned with the definition of soil quality and selection of criteria to quantify it (Romig, 1995; Romig et al., 1995; Lal, 1998; Mausbach and Seybold, 1998).

**Table 13.2.** Indicaitors of soil condition locally assessed to rank soil quality in Middle America and their relation to soil quality and function

| | | AGRO-ECOLOGICAL ZONE | | | | | Freq. | RELATIONSHIP TO SOIL QUALITY AND FUNCTION | Authors |
|---|---|---|---|---|---|---|---|---|---|
| | PROPERTIES | 1 | 2 | 3 | 4 | 5 | | | |
| 1 | COLOR | 1 | 1 | 1 | 1 | 1 | **5** | Reflects organic matter content, drainage regime, salinity, acidity or alkalinity | Zinck, 1986/87 |
| 2 | RELIEF | 1 | 1 | 1 | 1 | 1 | **5** | Influences soil formation, erosion, depth, moisture and drainage conditions; workability | Zinck, 1986/87 |
| 3 | DRAINAGE | 1 | 1 | 1 | 0 | 1 | **4** | Influences leaching, moisture availability, productivity and erosivity | Seybold et al., 1996 |
| 4 | MOISTURE | 1 | 1 | 1 | 0 | 1 | **4** | Influences soil formation, erosion, structure stability and plant growth potential; workability | Zinck, 1986/87 |
| 5 | TEXTURE | 1 | 1 | 1 | 1 | 0 | **4** | Influences soil formation, erosion, structure stability and plant growth condition; workability | Seybold et al., 1996 |
| 6 | DEPTH | 1 | 0 | 1 | 1 | 1 | **4** | Influences productivity potential and erosion; workability | Anderson, 1998 |
| 7 | STONINESS | 1 | 1 | 1 | 0 | 1 | **4** | Influences moisture and nutrient reserve for plants; improves drainage and increases trafficability | Anderson, 1998 |
| 8 | STRUCTURE | 1 | 1 | 0 | 0 | 0 | **2** | Influences soil, water and air movement in the soil profile as well as plant roots and soil fauna | Seybold et al., 1996 |
| 9 | CONSISTENCE | 0 | 1 | 0 | 0 | 0 | **1** | Influences mechanical behavior of soil material according to variable moisture contents | Zinck, 1986/87 |
| | **BIOLOGICAL PROPERTIES** | | | | | | | | |
| 10 | ORGANIC MATTER CONTENT | 1 | 1 | 1 | 1 | 0 | **4** | Influences soil fertility, stability and erosion susceptibility | Seybold et al., 1996 |
| 11 | ECOLOGICAL SUCCESSION | 1 | 1 | 0 | 0 | 0 | **2** | Influences regeneration of soil fertility; maintains biological diversity and prevents erosion | Garrity, 1998 |
| 12 | VEGETATION TYPE | 1 | 1 | 0 | 0 | 0 | **2** | Influences organic matter content in the topsoil; reduces erosion and enhances water infiltration | Garrity, 1998 |
| 13 | PLANT AS SOIL FERTILITY IND. | 0 | 1 | 1 | 0 | 0 | **2** | | |
| 14 | SOIL FAUNA | 1 | 0 | 0 | 1 | 0 | **2** | Influences biological activity, nutrient cycling, filtering and buffering | Karlen et al., 1994 |
| | **LAND MANAGEMENT** | | | | | | | | |
| 15 | LAND USE POTENTIAL | 1 | 1 | 1 | 1 | 1 | **4** | Defines land management and production strategy | |
| 16 | WORKABILITY | 1 | 1 | 0 | 1 | 0 | **3** | Defines the ease with which the soil can be cultivated or tilled depending on specific management practices; it depends on texture/structure/consistence relationships of the topsoil (0-20cm) | FAO, 1983<br>Siderius, 1992 |
| 17 | LAND USE HISTORY | 1 | 1 | 0 | 0 | 0 | **2** | Influences soil health and the capacity of self-organization of the ecosystem | Addiscott, 1995 |
| 18 | FERTILITY | 1 | 1 | 0 | 0 | 0 | **2** | Defines the capacity of the soil to exchange and retain nutrients and the availability of soil nutrients for plant growth | Byrnes, 1998<br>Siderius, 1992 |
| 19 | PRODUCTIVITY | 0 | 0 | 1 | 0 | 1 | **2** | Includes all factors which affect plant growth, including soil fertility, water availability, climate, etc. | Lal, 1998 |
| | **LAND DEGRADATION** | | | | | | | | |
| 20 | WATERLOGGING | 1 | 1 | 1 | 1 | 1 | **5** | Temporary or permanent water saturation up to the surface of the soil | |
| 21 | WATER EROSION | 1 | 1 | 1 | 1 | 1 | **5** | Depends on rainfall, material, position, slope form, land use and time; it includes removal, transport and deposition | Bergsma, 1996 |
| 22 | HARDPAN PRESENCE | 1 | 0 | 1 | 1 | 1 | **4** | Presence of a soil pan that is very hard when dry, caused by cementation of soil particles with organic matter and iron, or with materials such as silica (duripan) | Bergsma, 1996 |
| 23 | SALINITY | 0 | 0 | 1 | 1 | 1 | **3** | Excess of free salts affecting crops through inhibiting the uptake of water by osmosis | FAO, 1983 |
| 24 | CRUSTING | 0 | 0 | 1 | 0 | 1 | **2** | A soil surface layer, from few mm to three cm thick, that is much more compact, hard and brittle when dry, than the material immediately beneath; it always implies a dried out soil | Bergsma, 1996 |
| 25 | WIND EROSION | 0 | 0 | 1 | 0 | 0 | **1** | Soil loss by wind, specially in semi-arid lands or in the tropics with rainfall less than 700mm/y | FAO, 1983 |
| 26 | ALKALINITY (SODICITY) | 0 | 0 | 0 | 0 | 1 | **1** | Affects crops through toxicity of the sodium ion and gives rise to massive or coarse columnar structure and low permeability | FAO, 1983 |

[1]Agro-ecological zones: (1) Humid tropical lowlands; (2) Humid tropical highlands; (3) Sub-humid tropical lands; (4) Sub-humid temperate highlands; and (5) Semi-arid lands. Assessed soil condition (1); non-assessed soil condition (0)

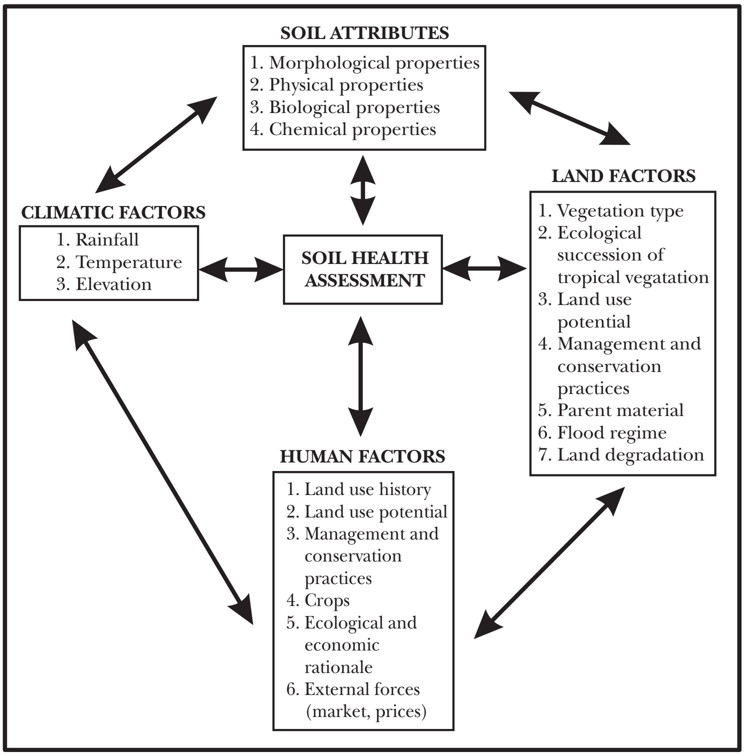



**Figure 13.2.** Diagnostic attributes most frequently used for soil health assessment in Middle America

### 13.5.2. Comparison of the diagnostic attributes used to assess soil quality per agro-ecological zone

Comparison of the diagnostic attributes used to assess soil health in Middle America shows commonalties and differences. Seven morphological properties (color, relief, drainage, moisture, texture, depth and stoniness), one biological property (organic matter), one land management factor (land-use potential) and three land degradation indicators (waterlogging, rain erosion and hardpan presence) are commonly used in the five agro-ecological zones, showing a structured soil quality assessment system linked to *milpa* cultivation. The graphical comparison of the distribution of soil and related diagnostic attributes per agro-ecological zone shows remarkable similarities. The number of diagnostic attributes varies between 15 and 17 (64 to 77% with respect to the overall assessed diagnostic attributes). Some differences are recognized as well, showing soil quality assessment adaptations to local environmental and management factors, but always linked to the *milpa* production. The differences are:

(1) farmers from the humid tropical lands assess a higher number of diagnostic attributes (13 to 16) than farmers from other agro-ecological zones (5 to 7);

(2) the higher number of diagnostic attributes assessed in the humid tropical lands resembles the complexity of the ecosystems being managed under shifting cultivation. Ecological succession of tropical vegetation, vegetation types and land-use history are diagnostic attributes specific to these lands. All of them are linked to the maintenance and restoration of soil fertility and productivity by the replenishment of organic matter, controlled by the ecological succession of tropical vegetation. Knowledge of possible sequences of secondary forests in the long term is a very important factor for soil quality assessment under shifting cultivation, and

(3) farmers from the semi-arid lands, sub-humid temperate highlands and sub-humid tropical lands are aware of soil erosion susceptibility, salinity and hardpan presence, as highly dynamic land degradation indicators affecting the soil health and agricultural productivity over short-term periods. Soil-water conservation practices are constantly performed in these areas where the replenishment of organic matter is not controlled by the ecological succession of the vegetation cover.

Probably, the most important commonality among small farmers in Middle America when assessing a soil's health is the well-fitted knowledge of the soil toposequence where the slight distinctions of soil moisture, drainage, depth and vegetation cover organize land management strategies, soil fertility maintenance and soil-water conservation practices for *milpa* production. Small farmers assess soil health for maize production under variable environmental, economic and cultural circumstances.

## 13.6. Soil knowledge for land management

### 13.6.1. Main similarities

Rural activities carried out by indigenous and *Mestizo* small farmers in Middle America are rooted in ethnoecological knowledge and manual labor to guarantee a constant flow of goods and services. Lack of economic opportunities forces them to rely on local human and natural capitals and adopt relatively high self-sufficiency strategies, while being open to knowledge, labor and good exchanges. They operate in open and hybrid multi-purpose natural resource systems, addressed toward maximizing the variety of goods and services locally needed throughout the year. Often, environmental heterogeneity and patchiness and biological and genetic diversity are locally maintained and favored as part of ecological and economic rationale.

Local soil knowledge plays an important role for the maintenance of this rationale. Sustained land management partially relies on the ability to apply soil knowledge where the land resource is limited and often marginal for agricultural purposes. Complex local soil knowledge systems were evolved, hybridized and are still maintained to overcome resource limitations. Local soil knowledge for land management in Middle America shows similarities, although it has evolved in contrasting agro-ecological, economic and cultural contexts. Among the most important similarities are:

(1) farmers take advantage of their local soil variability knowledge to maintain and improve land management in a patchwork-like pattern.

The number of local land management units is remarkably high, varying between two and six. The average number of land management units recognized in 13 case studies is four (Table 13.3). The number of local soil taxa shows the detailed recognition of soil discontinuities and mixtures. Local soil taxa vary between 5 and 12 and the average number of taxa locally recognized is 10. Soil micro-variability is carefully assessed for land-use evaluation. Soil-relief position and soil quality assessments are the most important local procedures for land-use decision-making (Table 13.3). Local farmers assess on-site soil properties and conditions to rank soil qualities for specific crop requirements and assess on-site soil performance during the agricultural cycle and between several agricultural cycles to determine the soil health status. Constant assessment of the soil condition is critical for land-use decision-making where soil health mainly depends on the natural or induced replenishment of organic matter. Cropping systems are adapted to small soil variations and mixtures in a single agricultural parcel, land management unit or between all local land management units, according to soil-crop requirements and limitations. Soil amelioration can overcome agricultural restrictions and enhance inherent soil properties; thus land management practices are not separated from soil knowledge. This complex combination of knowledge and practice allows a fine-tuned management of micro-environmental variations in reduced areas or within a single agricultural parcel.

**Table 13.3.** Land management units, number of soil taxa and maize landraces per ethnic group and agro-ecological zone

| ETHNIC GROUP | AEZ[1] | LAND MANAGEMENT UNITS | SOIL CATENA ASSESS. | SOIL QUALITY ASSESSMENT | SOIL TAXA | MAIZE LANDRACES | SUBSISTENCE AGRICULTURE | COMMERCIAL AGRICULTURE | MULTI-CROPPING | MONO-CROPPING |
|---|---|---|---|---|---|---|---|---|---|---|
| **Totonac** | 1 | 6 | X | X | 11 | 3 | X | X | X | X |
| **Nahua** | 1 | 5 | X | X | 11 | 15 | X | X | X | X |
| **Tojolabal** | 1 | 4 | X | X | 6 | 5 | X | X | X | X |
| **Maya** | 1 | 6 | X | X | 12 | 14 | X | X | X | X |
| **Chinantec** | 2 | 5 | X | X | 12 | 5 | X | X | X | X |
| **Mixe** | 2 | 3 | X | X | 9 | 5 | X | X | X | X |
| **Mestizo** | 2 | 2 | X | X | 5 | 15 | X | X | X | X |
| **Mestizo** | 3 | 5 | X | X | 10 | Diverse | X | X | X | X |
| **Huave** | 3 | 4 | X | X | 11 | 4 | X |  | X |  |
| **Mestizo** | 4 | 3 | X | X | 9 | 4 | X | X | X | X |
| **Quiche-Maya** | 4 | 3 | X | X | 9 | 4 | X | X | X | X |
| **Otomi** | 5 | 4 | X | X | 13 | 4 | X |  | X | X |
| **Zapotec** | 5 | 4 | X | X | 8 | 4 | X | X | X | X |
| **Frequency** |  | **13** | **13** | **13** | **13** | **13** | **13** | **11** | **13** | **12** |
| **Average** |  | **4** |  |  | **9.6** | **6.8** |  |  |  |  |

[1]Agro-ecological zones (AEZ): (1) humid tropical lowlands; (2) humid tropical highlands; (3) sub-humid tropical lands; (4) sub-humid temperate highlands; and (5) semi-arid lands

**Table 13.4.** Farming systems per ethnic group and agro-ecological zone

| ETHNIC GROUP | AEZ[1] | SHIFTING CULTIVATION | RAINFED AGRICULTURE | AGROFORESTRY | HOMEGARDEN | MILPA | TROPICAL PLANTATIONS | VEGETABLES | GRAZING |
|---|---|---|---|---|---|---|---|---|---|
| **Totonac** | 1 | X |  | X | X | X | X |  | X |
| **Nahua** | 1 | X | X | X | X | X | X |  | X |
| **Tojolabal** | 1 | X | X | X | X | X | X |  | X |
| **Maya** | 1 | X |  | X | X | X | X | X | X |
| **Chinantec** | 2 | X | X | X | X | X | X | X | X |
| **Mixe** | 2 | X | X | X | X | X | X | X | X |
| **Mestizo** | 2 | X | X |  |  | X |  |  |  |
| **Mestizo** | 3 | X | X |  |  | X | X |  | X |
| **Huave** | 3 |  | X |  |  | X |  |  |  |
| **Mestizo** | 4 |  | X |  |  | X |  | X |  |
| **Quiche-Maya** | 4 |  | X |  |  | X |  | X |  |
| **Otomi** | 5 |  | X |  |  | X |  |  | X |
| **Zapotec** | 5 |  | X |  |  | X |  | X | X |
| **Frequency** |  | **8** | **11** | **6** | **6** | **13** | **7** | **6** | **9** |

[1]Agro-ecological zones (AEZ): (1) humid tropical lowlands; (2) humid tropical highlands; (3) sub-humid tropical lands; (4) sub-humid temperate highlands; and (5) semi-arid lands

(2) Local soil knowledge and land management are intimately linked to maize production. All local ethnopedologies analyzed in chapters Eleven and Twelve are specialized in *milpa* production, showing high diversity of maize landraces (Table 13.3).

Soil variability recognition, land management diversity and the number of local maize landraces show an agricultural strategy based on the adaptation of maize to environmental heterogeneity. The number of maize landraces varies between 4 and 15 and the average number of maize landraces locally grown is remarkably high (7). The adoption of high yielding maize varieties partially competes with the local maize landraces. Local maize landraces are well adapted to sloping lands and marginally suitable agricultural soils, and are preferred for local consumption. High yielding maize varieties are adapted to flat lands and good agricultural soils, and are basically sold on local and regional markets.

(3) The great majority of Middle American small farmers is engaged in both subsistence and commercial agricultural activities; thus their local ethnopedologies are adapted to partial technological adoptions (Table 13.3).

The partial technological adoption, which combines traditional strategies (multicropping, organic fertilizers, green manuring, mulching, local maize landraces, etc.) with modern strategies (monocropping, chemical fertilizers, herbicides, pesticides, plaguicides, high yielding maize varieties, etc.), is implemented to buffer economic uncertainties and avoid ecological risks. It enhances the multi-purpose land management strategy and maintains biological and genetic diversity, taking advantage of the local environmental heterogeneity and soil variability. Detailed soil knowledge of more favorable agricultural lands allows intensification in some cases, but intensification depends on economic accessibility and cultural preferences in other cases. In any case, the average number of soil classes that a farmer handles simultaneously, varies between 2 and 6, reflecting the multi-purpose strategy displayed by Middle American farmers (Table 13.3).

### 13.6.2. Main differences between agro-ecological zones

Land management is culturally, economically and environmentally adapted, and is reflected in the local ethnopedologies. Differences in the ways soil knowledge is applied under contrasting agro-ecological conditions can be inferred from the comparison of (1) the average numbers of land management units; (2) the average numbers of local soil taxa; and (3) the average numbers of maize varieties grown per agro-ecological zone. This comparison is complemented with an account of the specific soil and water conservation practices implemented in the five agro-ecological zones. Comparison shows 4 land management strategies ranging from intensive to extensive systems, although the limited information and the methodological inconsistency of the analyzed studies make the comparison cumbersome (Figure 13.3 and tables 13.3; 13.4 and 13.5).

(1) Comparison shows a detailed micro-level assessment of soil properties under homogeneous agro-ecological conditions and intensive land management in the humid tropical lowlands and the semi-arid lands (horizontal zonation). It also reveals a patchwork-like pattern distribution of land-use systems in relatively small areas with less than 2,000 hectares, in these agro-ecological zones.

The average number of land management units in the humid tropical lowlands is 5, the highest for Middle America. Eight production practices are carried out, expressing a multi-purpose land management strategy. This strategy includes subsistence and commercial production activities, and multicropping and monocropping systems as well. An average number of 10 soil taxa and an average number of 9 maize landraces show adaptation of maize to soil variability. Land management is dynamic, resembling the complexity of the ecosystems involved and the fine-tuned ethnoecological knowledge. Shifting cultivation practices are locally performed as an agroforestry continuum where *milpa* production constitutes just one but crucial stage of the land-use system and the ecological succession

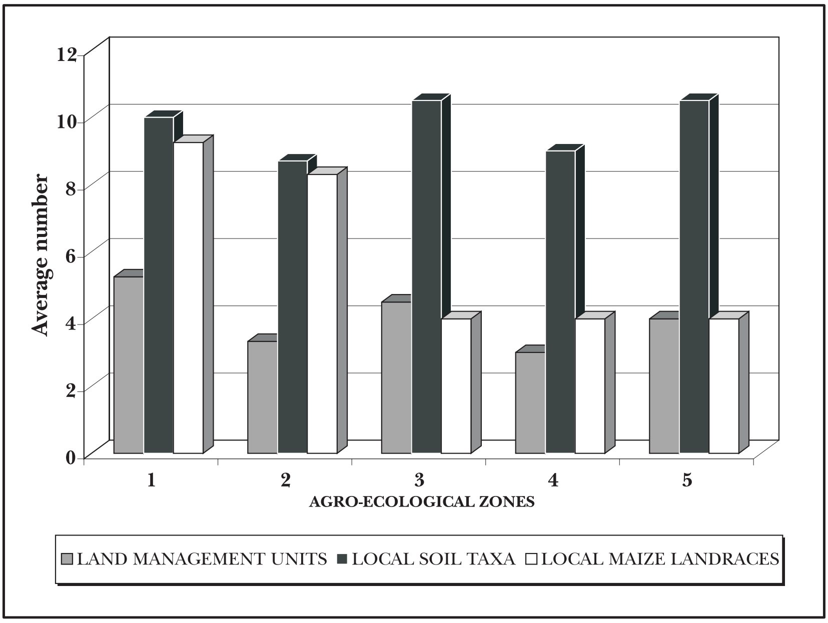



**Figure 13.3.** Average numbers of land management units, soil taxa and maize landraces per agro-ecological zone. Agro-ecological zones: (1) humid tropical lowlands; (2) humid tropical highlands; (3) sub-humid tropical lands; (4) sub-humid temperate highlands; and (5) semi-arid lands

of tropical vegetation. Non-tillage, mulching, green manuring and land fallow constitute the main soil and water conservation practices. Anthropogenic soils are built in homegardens and household backyards to maintain limited vegetable production for subsistence purpose.

The average number of land management units in semi-arid lands is 4. Subsistence multicropping and sheep grazing are the most important production activities. Although land management is more specialized than in the humid tropical lands due to the harsh environmental conditions, a detailed micro-level assessment of soil properties and conditions is shown by the average number of soil taxa (11), the highest of Middle America. Only a few maize landraces are cultivated because of the low and uncertain rainfall, which limits the possibilities of maize production. Soil and water conservation practices are oriented toward the maintenance or amelioration of soil moisture retention and sediment trapping to enhance or restore soil fertility. Careful measures are applied to reduce salinization, one of the major land degradation risks, and soil erosion is managed and even induced for sediment trapping. Construction of agricultural terraces, check dams, micro-catchments, ridged fields, and the amelioration of surface or sub-surface soil hardpan, by breaking them up, are the most important soil and water conservation practices. The building of anthropogenic soils is central to the maintenance of intensive agricultural systems.

(2) Compound assessment of soil properties under heterogeneous agro-ecological conditions aimed to combine non-intensified and intensified agricultural systems. Detailed micro-level assessment of soil properties and conditions is performed on the best agricultural soils (footslopes and bottom-level lands), while less detailed micro-level assessment of soil properties and conditions is performed on marginal agricultural soils (backslopes). Generally, the more favorable agricultural soils are managed for cash cropping, while the marginal soils are managed for subsistence purpose. This is the case in the sub-humid temperate highlands.

The average number of land management units in the sub-humid temperate highlands is 3, the lowest for Middle America. Small-scale irrigation, terracing and sloping rainfed agricultural systems are distributed within

**Table 13.5.** Soil and water conservation practices per ethnic group and agro-ecological zone

| ETHNIC GROUP | AEZ | NON-TILLAGE | MULCHING | FALLOW | TERRACES | CHECK DAMS | RIDGED FIELDS | SEDIMENT TRAPPING | CHANNELING | RUNOFF | SOIL HARDPAN AMELIORATION | ANTHROP. SOILS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Totonac** | 1 | X | X | X | | | | | | | X | |
| **Nahua** | 1 | X | X | X | | | | | | | | |
| **Tojolabal** | 1 | X | X | X | | | | | | | | |
| **Maya** | 1 | X | X | X | | | X | | | | | X |
| **Chinantec** | 2 | X | X | X | | | | | | | | |
| **Mixe** | 2 | X | X | X | | | | | | | | |
| **Mestizo** | 2 | | | X | | | | | | | | |
| **Mestizo** | 3 | | | X | | | | | | | | |
| **Huave** | 3 | | X | X | | | | X | | | | |
| **Mestizo** | 4 | | | X | X | X | X | X | X | X | X | X |
| **Quiche-Maya** | 4 | | | X | X | | X | X | X | X | X | X |
| **Otomi** | 5 | | | X | X | X | X | X | X | X | X | X |
| **Zapotec** | 5 | | | X | X | | X | X | X | X | | X |
| **Frequency** | | **6** | **7** | **13** | **4** | **2** | **5** | **5** | **4** | **4** | **4** | **5** |

[1]Agro-ecological zones (AEZ): (1) humid tropical lowlands; (2) humid tropical highlands; (3) sub-humid tropical lands; (4) sub-humid temperate highlands; and (5) semi-arid lands

these land management units in a gradient ranging from monocropping to intercropping and to multicropping, and from bottom-level to steep hill lands. The average number of soil taxa is high (9), but the average number of maize landraces is relatively low (4). Short-cycle maize varieties are adapted to the bottom-level lands for commercial purpose, while the long-cycle maize landraces are cropped in sloping lands, accounting for most landraces locally consumed. This hybrid technological adoption requires the building of anthropogenic soils. Agricultural terraces, check dams, sediment trapping and soil surface and sub-surface amelioration are conservation practices performed on the footslopes, while the construction of ridged fields and channels are soil conservation practices performed on the bottom-level lands. Non-intensive rainfed agricultural systems are located on the backslopes. Detailed micro-level assessment of soil properties and conditions supports intensive cash cropping, using chemical fertilizers, herbicides and, in some cases, machinery on the bottom-level and footslope lands. Less detailed micro-level assessment of soil properties and conditions is performed to maintain the productivity of the less suitable backslope soils. Traditional agricultural methods are used to fulfill local self-sufficiency.

(3) Less detailed micro-level assessment of soil properties under highly heterogeneous agro-ecological conditions and under less intensive land management. A patchwork-like pattern of land-use systems controlled by bio-climatic belts in relatively ample areas is characteristic of the humid tropical highlands (vertical zonation).

The average number of land management units in the humid tropical highlands is 3. Eight production activities are carried out within these units, expressing the multi-purpose land management strategy controlled by elevation and climate. Land management is dynamic and complex, but less intensive than in the humid tropical lowlands and the sub-humid temperate highlands. This production strategy requires great mobilization of the farmers throughout the year to maintain different agricultural systems in an ample distance range; thus distance and labor allocation limit agricultural intensification. As a consequence, assessment of the land resources is less detailed. Nevertheless, the average numbers of soil taxa locally recognized (9) and maize landraces locally grown (8) reflect good adaptation to environmental heterogeneity. Mountain landscapes are managed as overlapping patchworks because of their high variability and low predictability. The ever-changing economic and environmental factors require the adoption of a dynamic subsistence strategy aimed to reduce risks and uncertainties. Subsistence and commercial agricultures overlap with other production activities; thus agro-ecological zones are not managed as separate and uniform land management units. Much probably ethnopedological information does not reflect the land management complexity in mountain landscapes, limiting the understanding of soil and land resources knowledge.

(4) Very detailed micro-level assessment of soil properties is often restricted to the best agricultural soils under harsh agro-ecological conditions and under non-intensive land management. Locally,

agriculture plays a subsistence role and is restricted to areas having the most favorable soils in the sub-humid tropical lands.

The average number of land management units in the sub-humid tropical lands is 5. Land management is restricted to agricultural activities and grazing. The average number of soil taxa (11) is the highest for Middle America, but the average number of maize landraces is relatively low (4). Unfavorable and scarce agricultural soils and rainfall variability require a micro-level assessment of soil properties and conditions as a risk-avoidance strategy. The recognition of slight variations in soils and soil mixtures in reduced areas is critical for agricultural success, and multicropping reduces failure. This detailed assessment of soil variability permits the adaptation of diverse agro-habitats according to soil–relief position, moisture retention capacity and erosion susceptibility. Non-tillage, mulching, green manuring, live fences and land fallow are main land conservation practices adopted to maintain and restore soil fertility and to reduce soil erosion. The use of chemical fertilizers is reduced and herbicides are avoided to maintain multicropping.

### 13.7. Land as a symbolic dominion

Land is strongly symbolized and ritualized in contemporaneous Middle America. The sacred meaning of land gives cohesiveness to the whole social theory about nature and the soil and land resources. Its sacred condition is embodied and embedded in almost every aspect of land management decision-making among indigenous peoples and, to some extent, among *Mestizo* small farmers.

Land is considered having visible and invisible attributes and forces; some are natural and others are considered supra-natural. The land body has four dimensions of which three are visible (extent, depth and volume) and the fourth is invisible, corresponding to the sacred quality of the land. The recognition of the invisible dimension is crucial to understand Middle American farmers' attitude toward land: it serves as a principle that guides human engagement with the land resources. Land is revered and respected, and its inalienable condition is reflected in the local worldviews. More than an economic resource, land is perceived and treated as a primary source of life that nourishes, supports and teaches. Land as a polysemic dominion is considered as the center of the universe, the primordial territory, the agricultural parcel and the origin of ethnic identity. That is why every land practice is negotiated with the supra-natural forces to balance reciprocity between the secular and the holy lives, thus allowing perpetuation. Agrarian and propitiatory rituals, shamanic acts, offerings and prays are common dialogical mechanisms used by farmers to convince and compensate land behavior and production.

The symbolic dominion is widely forgotten in ethnopedological research, more oriented towards the analysis of knowledge (Corpus) and management (Praxis) using cognitive and productivist approaches. Ethnopedologists have been more concerned by the understanding of the local soil taxonomies and land management practices when seeking sustainable production systems, without recognizing that land symbolism governs major parts of the local ecological and economic rationale. In Middle America, self-sufficiency and sustained land management systems are often promoted by highly ritualized and institutionalized local cosmovisions where sacred pedologies play critical roles. Perceptions, beliefs and attitudes show no clear-cut distinctions between soil and land as natural objects, cognitive dominions and sacred beings, because production is seen as an engagement with the natural and supra-natural worlds. Kosmos, Corpus and Praxis are not separated, but constitute a complex web of associations, which as a whole structure the social theory about soil and land.

Local symbolic meanings and representations about land as perceived and practiced in Middle America show the permanence of sacred pedologies. The latter are framed by the syncretic popular Catholicism and expressed in the communion between religious and agricultural calendars, organized as part of the multi-purpose land management strategy and influenced by local and external political, economic and social contexts. There are regularities in the ways land is symbolized and represented, despite the variety of local sacred pedologies.

(1) Land-maize-rain is perceived as the symbolic trilogy that synthesizes fertilization as a vital act that perpetuates the secular and the holy life cycles. They cannot be separated when understanding local attitudes toward soil and land resources (Principles of relatedness and connectedness).

(2) Maize, the staple food and cultural matrix of Middle America, requires the intercourse between land (female) and rainfall (male), to be fertilized and grown with human aid, otherwise life would not exist. Land and rainfall are considered scarce and uncertain. Supra-natural forces control uncertainty and scarcity; thus humans must engage with the land and convince that they are doing whatever is in their dominion. Land management is required to enhance, maintain or restore the inherent sacred and non-sacred qualities of land according to rainfall and maize performance. Humans intend to balance these opposite forces and, when it succeeds, it is compensated with maize, the vegetal milk and meat (Principle of reciprocity).

(3) Land is considered a sacred living being. Its qualities are variable and dynamic, depending on human labor and the willingness of the supra-natural forces. Land has to be fed, nourished and cured, the same as any other living being, because land health is central to the success of fertilization and continuation of life. Land dies when it is not fed, nourished and cured, thus becoming thirsty, weak, white and unfertile. Land must be fed with ashes, fresh sediments or decomposed matter from plants, animals and humans to restore its black color and strength. Land life can be maintained or can be reborn with labor and rainfall (Principle of renewability).

(4) The color of the land reflects non-sacred and sacred land qualities. Color is assessed to evaluate the shape of the land and represents its sacred universality. Black, white, red, yellow and green are sacred colors representing the five cardinal points, the four corners, territories, winds and clouds of the universe. All of these colors are used to name soil classes and all of them represent the center of the universe (Principle of universality)

These are 4 of the most important cosmological principles that guide the Middle American pedologic meta-culture. All of them are perceived and vividly represented by indigenous peoples as part of the local sacred pedologies, but they are not equally recognized among *Mestizo* small farmers. *Mestizo* small farmers, some of them being acculturated Indians, lost part of these perceptions and attitudes or maintain some of them as part of their local traditions without explicitly recognizing their sacred meanings. Nevertheless, millions of them still rely on the communion of agricultural and religious calendars, perceive land as a behavioral living being, work in communion and maintain a multi-purpose land management strategy. Local symbolic systems toward land are complex and diverse, but are shared as linguistic ecologies throughout Middle America, presenting more commonalities than differences. These systems are shared by millions of indigenous or non-indigenous small farmers, but are rapidly shifting; therefore, the study of this cosmological dominion requires more attention from ethnopedologists seeking for sustainable land management systems.

## 13.8. Comparison of worldwide and middle american ethnopedological findings

Worldwide and Middle American local ethnopedologies share similarities, showing the existence of universal criteria to name, classify and use soil and land resources, applied by indigenous and small-scale farmers from different cultural and contrasting environmental contexts. Local ethnopedologies show complexity in the organization of the soil mantle. This complexity is based on the recognition and implementation of morphological, biological, ecological and managerial attributes for soil classification. Local soil classifications are at the same time dynamic, utilitarian, symbolic, and often constructed as multi-categorical systems (see Chapter Six).

### 13.8.1. Similarities in the classification criteria used to label soil taxa

Worldwide analysis shows 15 soil attributes commonly used by the sampled ethnic groups (62 ethnic groups located of 25 countries in Africa, America and Asia), while the Middle American analysis shows 24 soil attributes commonly used by the sampled ethnic groups (28 ethnic groups in Mexico, Belize and Guatemala). Fourteen of these attributes are commonly used at global and regional scales. Table 13.6 shows the proportion of the groups implementing a given soil attribute. The proportion is indicated as a percentage of the total number of groups in both cases.

Of note is the difference between the number of soil attributes used by more than 50% of both sampled groups. Four soil attributes are commonly recognized worldwide against 11 soil attributes commonly recognized regionally. Both inventories show that the diagnostic attributes most frequently used to label soil classes are morphological ones. Color and texture are the most representative worldwide. Color, texture, consistence, moisture, structure, drainage and relief are used by 75% or more of the Middle American sampled ethnic groups.

### 13.8.2. Similarities in the numbers of soil taxa recognized

Considering all studies included in both inventories, the number of soil taxa (soil classes) belonging to the different systems recorded varies between 3 and 24 at worldwide level and between 4 and 16 at regional level. The average number of taxa recognized per ethnic group is 12 at worldwide level and 10 at regional level; more than 50% of the sampled groups in both inventories work with 8 to 14 (worldwide level)and 9 to 16 soil taxa (regional level). Comparison shows detailed soil taxa recognition at local level as well as complex management of soil variability.

### 13.8.3. Similarities in land management strategies per agro-ecological zone

Comparison of local land management strategies per agro-ecological zone shows commonalities between the global and regional scales (Table 13.7). Similar soil and water conservation strategies are performed to maintain, restore or enhance soil and land qualities, especially in the humid tropical and semi-arid tropical lowlands. These are also similarities between the cold and dry highlands and the sub-humid highlands at global and regional scales. This is remarkable when considering that soil and water conservation and land management are performed for different crop requirements (maize, wheat, cassava, rice and other tuber crops) in highly diverse cultural and economic contexts. Multi-purpose land management appears to be a worldwide risk-avoidance strategy applied under complex and diverse land-use systems, where the detailed micro-level assessment of soil variability plays a critical role.

### 13.8.4. Other ethnopedological similarities

Small farmers from Middle America and those from the rest of the world, according to the comparison of both inventories, share some other ethnopedological similarities:

- Although local knowledge about soil and land resources is widely shared by all members of a community, there are differences in wisdom among individuals according to age, gender, social and economic status and experience;
- unlike the ethnobotanical and ethnozoological classifications, the multi-level ethnopedological classifications generally start, at the higher level of the system, with a comprehensive realm concept including all 'soils', the equivalent of Plantae and Animalae in the other natural realms; and
- unlike the ethnobotanical taxonomic systems, which cluster only selected species occurring locally, the ethnopedological classifications generally include all or most of the soil classes encountered locally.

Middle America could be considered as a world-system from an ethnopedological perspective. Soil and land resource knowledge-based systems have historically evolved in diverse biologic, linguistic and agricultural settings and adapted to environmental heterogeneity and cultural particularities, but share similar principles

**Table 13.6.** Comparison of soil attributes commonly used to classify soils at global and regional scales

| GLOBAL SCALE | | | REGIONAL SCALE | | |
|---|---|---|---|---|---|
| **Ranking** | **Soil attribute** | % | **Ranking** | **Soil attribute** | % |
| **1** | Color | **100** | **1** | Color | **100** |
| **2** | Texture | **98** | **2** | Texture | **100** |
| **3** | Consistence | **56** | **3** | Consistence | **90** |
| **4** | Moisture | **55** | **4** | Moisture | **90** |
| **5** | Organic matter | **48** | **5** | Structure | **82** |
| **6** | Stoniness | **47** | **6** | Drainage | **79** |
| **7** | Relief | **44** | **7** | Relief | **75** |
| **8** | Land use | **37** | **8** | Organic matter | **68** |
| **9** | Drainage | **34** | **9** | Stoniness | **68** |
| **10** | Fertility | **26** | **10** | Workability | **61** |
| **11** | Productivity | **24** | **11** | Depth | **54** |
| **12** | Workability | **19** | **12** | Fertility | **46** |
| **13** | Structure | **18** | **13** | Productivity | **36** |
| **14** | Depth | **10** | **14** | Land use | **36** |

to organize the soil mantle. These similarities are also shared globally, among other indigenous and small-scale rural populations of the world. What makes the difference between the Middle American pedologic meta-culture and other social theories about soil and land resources is its specialization for *milpa* production and the specific cosmovision that embraces the social behavior with respect to these resources.

## 13.9. Conclusion

Comparison of contemporaneous local ethnopedologies from Middle America shows commonalities in the ways soil and land resources are recognized, named, classified, managed and symbolized. Comparison also reveals the existence of a set of common principles organizing the soil mantle. These principles are shared by millions of small farmers belonging to different cultural and environmental contexts, thus constituting a single social theory about soil and land resources. Specialization of the soil knowledge-based system on (a) *milpa* production, (b) a multi-purpose land management strategy, and (c) a similar cosmovision, reveals the existence of a Middle American pedologic meta-culture. This singular soil culture is based on a complex web of associations between Kosmos, Corpus and Praxis.

### 13.9.1. Kosmos

- Land is strongly symbolized and ritualized in contemporaneous Middle America. The sacred meaning of land gives cohesiveness to the whole social theory about nature and the soil and land resources. Its sacred condition is embodied and embedded in almost every aspect of land management decision-making among indigenous peoples and, at some extent, among *Mestizo* small farmers.
- Land is conceived as a sacred living being. Its qualities are variable and dynamic, depending on human labor and the willingness of the supra-natural forces.
- Land is considered having visible and invisible attributes and forces; some are natural and others are considered supra-natural. Thus the land body has four dimensions of which three are visible (extent, depth and volume) and the fourth is invisible (sacred quality of the land).
- Land has to be fed, nourished and cured, the same as any other living being, because land health is central to the success of fertilization and the continuation of life.

**Table 13.7.** Similarities of land management strategies per agro-ecological zones at global and regional scales

| WORLDWIDE | MIDDLE AMERICA |
|---|---|
| **Humid tropical lowlands** | |
| • Fertility conservation or restoration using complex agro-ecological systems | • Soil fertility conservation and restoration using complex agro-ecological systems |
| • Micro-local soil conditions to select a variety of adapted crop associations | • Detailed micro-level assessment of soil properties and conditions for selecting a wide array of multicropping systems |
| • Agricultural fields are densely covered with plants to maintain soil productivity | • Multicropping, mulching, non-tilth, green manure used to maintain soil productivity |
| • Changes in the topsoil are used to monitor the fertility status | • Topsoil (0-30/45 cm) is constantly assessed to maintain the soil health status |
| **Semi-arid tropical lands** | |
| • Water harvesting and soil moisture conservation | • Soil and water conservation practices to enhance soil fertility and maintain soil moisture |
| • Soil protection from erosion and salinity | • Soil erosion management and salinization control |
| • Terraces, check-dams and channeling to enhance soil moisture | • Terraces, check-dams and channeling to enhance soil moisture |
| | • Sediment trapping systems and runoff agriculture |
| • Disposal of sediments | |

- Land-maize-rain is perceived as the symbolic trilogy that synthesizes fertilization as a vital act that perpetuates the secular and the holy life cycles.

### 13.9.2. Corpus

- Similar properties are used to classify soils.
- Selected soil and related attributes are assessed according to specific agro-ecological conditions.
- Similar sets of soil diagnostic attributes are used to name soil classes.
- Local soil classifications are complex, multipurpose, dynamic and utilitarian.
- The majority of local taxonomies is hierarchical and presents similar structure.
- Local soil taxonomies show the existence of universal criteria to organize and distribute soil classes.
- Similar soil diagnostic attributes and conditions are assessed to rank soil qualities.

### 13.9.3 Praxis

- Farmers take advantage of their local soil variability knowledge to maintain and improve land management in a patchwork-like pattern.
- Local soil knowledge and land management are intimately linked to maize production.
- The greatest majority of Middle American farmers is engaged in both subsistence and commercial agricultural activities; thus their local ethnopedologies are adapted to partial technological adoption.

The comparison between worldwide and Middle American ethnopedological findings shows similarities in:

- The classification criteria assigned to label soil taxa.
- The numbers of soil taxa locally recognized.

- Land management strategies per agro-ecological zone.
- Unlike the ethnobotanical and ethnozoological classifications, the multi-level ethnopedological classifications generally start at the higher level of the system, with a comprehensive realm concept including all 'soils', the equivalent of Plantae and Animalae in other natural realms;
- Unlike the ethnobotanical taxonomic systems, which cluster only selected species occurring locally, the ethnopedological classifications generally include all or most of the soil classes encountered locally.
- Although local knowledge about soil and land resources is widely shared by all members of a community, there are differences in wisdom among individuals according to age, gender, social and economic status and experience.

What makes the difference between the Middle American pedologic meta-culture and other social theories about soil and land resources is its specialization for *milpa* production and the specific cosmovision that embraces the social behavior with respect to these resources.

# Part Three

# The indigenous community of San Francisco Pichátaro, Mexico: a local perspective

# CHAPTER FOURTEEN

## RESEARCH FRAMEWORK AND METHODS AT LOCAL LEVEL

### 14.1. INTRODUCTION

This chapter is dedicated to the research framework and methods applied at local level. It offers insights into the empirical foundations on which the analysis of Part Three of this thesis, from chapters Fifteen to Twenty three, is based. This chapter helps understand how data were acquired and analyzed at local level, taking into account that Part Three is mainly based on fieldwork information and other primary data handled through the application of GIS techniques. However, Part Three also includes data acquired from secondary sources, such as archival documents, bibliographic references, and previously published and unpublished information from the author of this thesis and others, covering the last 20 years.

The term 'local' is used to differentiate this approach from the worldwide ethnopedological analysis at global scale, presented in Part One, and from the Middle American ethnopedological analysis at regional scale, carried out in Part Two of the thesis. Chapters Fifteen to Seventeen deal with the Pátzcuaro Lake Basin, the natural and cultural territory where San Francisco Pichátaro, the village study area, is located and interacts with. Chapters Eighteen to Twenty Two offer a comprehensive analysis at village level, including ethnopedological findings, while chapter Twenty three links the current status of perception, knowledge and management about soil and land resources (the K-C-P- complex) with the political ecology of the community and its surroundings.

This link helps understand why, how and by which ecological, economic, socio-cultural and political processes, the local theory of soil and land resources has been readapted by gain-loss circumstances, during the last 20 years. A multi-scale and multi-temporal analysis is required to frame contextual studies, such as the one offered here. A more comprehensive theoretical and conceptual research framework is offered in Chapter Five.

Chapter Fourteen is divided into nine sections. Section 14.2 presents the research framework adopted to structure the ethnopedological analysis at local level. It explains how a multi-scale and multi-temporal analysis was carried out to contextualize the local theory about soil and land resources. Research was integrated through landscape analysis, using the K-C-P complex (see Chapter Five) with an actor-perspective approach. Section 14.3 discusses the selection of the local study area. Section 14.4 offers insights about the applied research approaches. Section 14.5 explains the ethnographic techniques applied to acquire, systematize and assess the local theory about nature and about soil and land resources. Sections 14.6 and 14.7 explain how the socio-economic and agronomic surveys were conducted, and which field-based techniques were applied. Section 14.8 describes techniques used for time-series and spatial analysis. Finally, section 14.9 concludes this chapter by highlighting the importance of applying an integrated and interpretive approach when analyzing social theories about soil and land resources, with the active participation of the local actors.

### 14.2. RESEARCH FRAMEWORK

The design and implementation of the research framework at local level seek linking theoretical, conceptual and methodological tools offered by political ecology and grounded theory for the assessment of ethnopedological findings that should be considered in local endogenous development. Theoretical and methodological conceptualization of political ecology, grounded theory and endogenous development was already discussed in Chapter Five, but insights on how and by which techniques empirical data were acquired are explained in this section. This includes the description of four research sets of elements (landscape, pepole and social institutions, local environmental knowledge and management practices, and worldview) and their interaction patterns, that allows explaining the local adoption of natural resource strategies over time and under the influence of processes at various scales (Figure 14.1). This research framework helps explain how, when and why local soil and land resources' symbolism, knowledge and management were put into practice in the past, and which are the current limitations and potential possibilities for integrating ethnopedological findings into the development process, according to prevalent circumstances. Figure 14.1 represents embedded relations between the four sets of elements, which can be analyzed to explain the co-evolution of socio-ecological systems. In this context, the analysis of interaction patterns (feedbacks) between the four sets of elements is crucial for assessing adaptive management systems at local level. The framework is meant to help focus on key interactions that result in adaptive management outcomes. It mainly helps think about phenomena ordering data and revealing patterns, as pattern recognition leads to models and theories (Rapaport, 1985; Berkes et al., 1998, 2000). The four sets of elements are described hereafter.

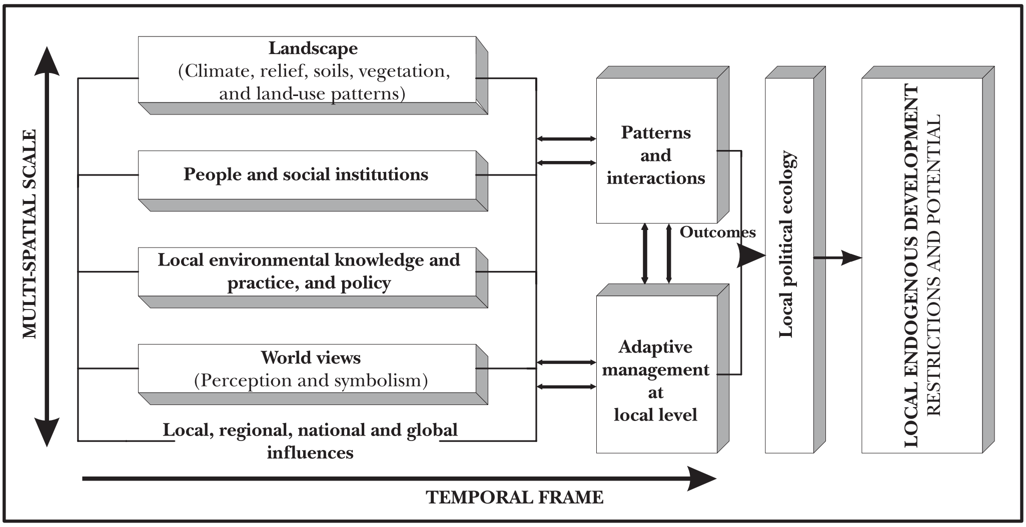



**Figure 14.1**. The research framework model. **Adapted from:** Berkes and Folke (1998; 2000)

### 14.2.1 Landscape

Landscape analysis in this thesis focuses on the human-environment connection, thus it uses a variety of epistemologies seeking to integrate physical and social sciences. In this context, landscape is considered as an inclusive and holistic concept, including humans, their anthropogenic ecosystems, and the way space is symbolized, conceptualized and experienced (ethnoscape). From a natural point of view, landscapes are analyzed as dynamic entities that are constantly fluctuating through dramatic changes, such as volcanism, tectonics, climate change and lake fluctuations. Thus, landscapes are essentially fragile, complex, non-static, non-linear and with an inherently unpredictable nature, sometimes tending towards chaos (Zimmerer, 1994a).

Landscape changes alter parameters governing land stability, productivity and potential. Thus, landscapes are historically contingent entities and should be analyzed as palimpsests possessing their own structure and functioning. From a social point of view, landscapes are analyzed as units of human occupation or inclusive totalities. Landscape is then an "amalgam of humans, their anthropogenic environment, and natural processes outside human control- all undergoing the work of the other" (Fisher and Thurston, 1999). As palimpsests, landscapes are diachronic and multi-scalar documents encoding accretionary strategies of environtmental manipulation; thus, landscape analysis decodes these 'texts', determining how humans affect and are affected by the world they create. Key to this conception is the analysis of human-nature or culture-nature connection, relation or interactions. The anthropogenic landscape (or ethnoscape), always fransient and never static, results from the manner in which socio-cultural systems interact with, and are the result of intentional or forced strategies of landscape manipulation. In the process of engaging with nature, humans construct their own niche, adapting the environment in pursuit of socio-political and socio-economic goals. However, changes outside human control still affect societies thrugh processes such as climate change and lake-level fluctuations, presenting a range of choices to mitigate unpredictable natural disturbances. In this instance, culture serves and operates as a landscape modifier to adapt the human-nature connection. This may lead to unintended environmental disturbances or adaptive management systems, depending on the type, duration and intensity, causing landscape modifications.

### 14.2.2. People and social institutions

In principle, analysis of this set of elements focuses on the entire social group or the indigenous community, rather than on individuals, households or wards. However, the latter are scrutinized for recognizing socio-cultural, political and economic internal differences to distinguish user communities and the sustainability of their practices. A social biography allows understanding the complexity, dynamics and openness of the entire social system and the varied ways socio-political and socio-economic goals are pursued. Central to this is the assessment of the local socio-ecological metabolism and rationale. It also includes the rules that sanction collective and individual use of the local natural resources. Focusing on user communities helps reveal internal cohesion and conflicts over resources and allows assessing environmental trends, such as deforestation, land degradation or the maintenance of adaptive management systems through local multi-purpose resource strategy. The analysis includes the ways property rights are conducted and sanctioned.

### 14.2.3. Local environmental knowledge and management practices

A rigorous scrutiny of the ways nature is perceived, known, classified and managed at local level helps understand interactions between humans and landscapes. Starting from the point of view that any resource user embodies certain amount of local environmental knowledge, that may allow him/her to carry out a particular activity, analysis at this level offers insights about how local knowledge is applied. Again, analysis focuses on the whole user community as it reveals the strength and weakness of the local environmental knowledge system that is being applied, and how and by which means it is applied and restricted or limited. However, scrutiny at individual, household and ward levels helps assess knowledge differences and particularities, taking into account age, gender, experience, production specialization, political and economic status, and social prestige. At the end, what matters is assessing the social theory about nature and the ways it is applied for the maintenance of adaptive management systems. More important than recognizing internal knowledge differences is assessing the cohesion and robustness of the local epistemology and practices. That may lead to reinforce land management sustainability or revert environmental degradation processes. Especially important for this thesis is to analyze the maintenance of landscape resilience. Analysis at this level uses the K-C-P complex to explore how landscape is perceived (mindscape) and known (knownscape), and how it is managed, transformed and readapted (technoscape) to meet environmental and socio-economic changes.

### 14.2.4. Worldview

Analysis of the set of four elements helps organize and understand cultural elements, that appear to be symbolic engines maintaining the local social identity, cohesion and adaptive natural resource management. Religion, ideology and customs induce social behavior towards nature, although cannot be formally separated from the local environmental knowledge and social institutions. This also does not imply that the various elements in the overall system (Figure 14.1) are discrete boxes; they rather operate as fuzzy elements in the overall human-nature experience. However, their artificial separation is suitable for research convenience. The analysis of the local worldview helps understand the sacred dimension of the management of resilience. This implies that, at local level, processes not controlled by humans are derived from natural and supra-natural forces. In this context, landscape adaptation relies not just on the recognition of unpredictable natural processes but also on the inseparable sacred forces governing nature. This means that adaptive management systems rely on the worldview and world life spheres, both conducting human behavior through secular and sacred experience. Appadurai (1995) rightly affirms that "much that has been considered 'local' knowledge is actually knowledge of how to produce and reproduce locality under conditions of anxiety and entropy, social wear and flux, ecological uncertainty and cosmic volatility, and the always present quirkiness of kinsmen, enemies, spirits and quakes of all sorts". Cultural identity, religion, ritual and custom are inextricably linked to natural resource user communities at local level in no-western societies, such as the Purhépecha from San Francisco Pichátaro, and elsewhere in the rural landscapes of Middle America.

### 14.2.5. Patterns of interaction and outcomes

Patterns of interaction (Figure 14.1) result from the complex and varied interrelations between the four sets of elements, and are influenced by processes driven at local, regional, national and global scales. Patterns of interaction result from local dynamic change; thus, their understanding requires an evolutionary focus, as both social and ecological systems have an evolutionary character. The recognition of patterns of interaction helps assess how the local social system has developed management practices based on environmental knowledge for dealing with the dynamics of landscapes in which it is located, and the social mechanisms behind these management practices (Berkes and Folke, 1998).

Contextual studies recognize that local patterns of interaction vary according to specific influences triggered by internal and external forces; thus, interactions at each locality may be different and may produce positive or negative disturbances. Positive disturbance (i.e. successful adaptation schemes) may be triggered by feedback mechanisms, such as the social capability to aconvert adverse or new conditions into a favorable land management strategy, which relies on previous decision-making, knowledge adoption and adaptation to the local context. On the contrary, negative disturbance may be the outcome of the loss of cultural control or the lack of feedback mechanisms to adapt according to new circumstances. Factors that obliterate feedbacks may result in loss of cultural adaptations and knowledge loss, triggering environmental degradation, migration, internal conflict and social disarray. The central question here is to find the key factors of interaction patterns that may result in the maintenance or not of adaptive natural resource management schemes at local level; thus, the analysis requires to focus on social-ecological linkages.

Patterns of interaction produce certain key outcomes. Sustainable land-use, environmental degradation, social inequality, inequitable property rights are possible outcomes showing the type of performance in natural resource management that rural localities may take. Assessing the type of performance in natural resource management, or the socio-ecological strategy, is critical to evaluate local sustainability. Maintenance of genetic, biological and agricultural diversity, food security, social equity, production efficiency, and cultural control may lead to sustainable land management schemes; thus, these key outcomes must be evaluated to assess the level of sustainability that a locality may hold (Toledo, 1996b). To do so, another key outcome to be evaluated is the level of territorial, ecological, political, social and economic control held by the users community. Evaluation of these outcomes may also be critical in the search of mechanisms for the resilience of the integrated socio-ecological system. The overall evaluation of local patterns of interaction and their key outcomes offers insights of the local and regional political ecologies.

### 14.2.6. Local endogenous development: restrictions and potential

Adaptation of the research framework proposed by Berkes and Folke (1998 and 2000) aims to pursue an integrated analysis, focusing on the links between local soil and land resources symbolism, knowledge and management (the K-C-P complex) and landscape analysis, using a multi-temporal and multi-scale approach founded on an actors' perspective and a field-based survey. It seeks for a contextual analysis. The framework can be used as a guide for identifying social practices based on local environmental knowledge and the social mechanisms behind these practices. It also can assist in identifying similarities, general patterns and principles that can be drawn from several case studies, and lessons to be learned in assisting the design of sustainable adaptive management systems at local level.

This framework may also be used as a policy guide for designing local endogenous development. Evaluation could help adapt the interaction between ecological and social systems, as both modify one another over a period of time. The understanding of how adaptiveness and resilience may contribute to institutional enhancement, so that the local social system would be capable of responding to the processes that contribute to landscape resilience, lies at the center of this research framework. Endogenous local development acknowledges that interaction of social and natural systems may be modified through adaptations for maintaining resilience, so that successful knowledge and resource management systems will allow disturbances to enter at a level which does not disrupt the structure and functional performance of landscapes and the services they provide. Adaptive resource management leaded by an endogenous development process may need to recognize the feedbacks that signal disturbance and recreate mechanisms by which information from the environment may be received, processed and interpreted. A key question to be answered is how social mechanisms that lie behind management practices, based on local environmental knowledge, evidence a co-evolutionary relationship between institutions and the landscapes in which the former are located and performed.

## 14.3. Selection of the local study area

### 14.3.1. Research criteria and questions

San Francisco Picháraro, a mountain Purhépecha community located within the Pátzcuaro Lake Basin, Michoacán, in central western Mexico, was selected as the local research area based on the following criteria:

(1) the indigenous community pertains to a wider Purhépecha territory maintaining a vivid cultural heritage since pre-Hispanic times, based on Middle American agrarian tradition and centered on maize production, a communal institutional regime and landholding, a multi-purpose natural resource management, and fervent religious practice;

(2) the local study village is located at the center of the pre-Hispanic Purhépecha territory, that was dissolved after the Spanish conquest during the 16th century, but remained as an indigenous settlement despite acute socio-cultural and economic changes occurred since then;

(3) ethnohistorical data suggest that Pichatáro remained as an agricultural enclave since at least 3,500 years ago, based on *milpa* production, forest exploitation and wooden handicraft manufacturing. Archaeological, palinological, ethnohistorical and anthropological information revealed a long-standing engagement of the local populations with soil and land resources through agricultural activities, thus suggesting the permanence of an adapted environmental knowledge system through thousands of years;

(4) ethnohistorical, historical, agronomic and sociological data assert that populations adapted their natural resource management strategy through adoption, adaptation and innovation of crops, agricultural systems and related technology and know-how, as in most of the indigenous localities and territories of Middle America, without loosing their cultural grassroots. Cultural and economic exchanges since pre-Hispanic period were driving factors for hybridization of the local values, symbolic representations, cognition, practice and livelihood;

*(5) Pichatareños* have maintained a diversified agricultural strategy and food security, and communal organization and political power to defend their local territory, despite efforts to dissolve their

social conquests, thus representing the historical struggle for land of thousands of indigenous communities in Middle America to counteract their subordinated role in the process of modernization;

(6) Pichátaro's landscapes show no evidence of acute land degradation despite being located in a fragile and steep endorreic mountainous basin and despite being cultivated since at least 2,000 years, according to previous research findings from the author of this thesis and others. This contrasts with research findings intending to demonstrate severe land degradation in the Pátzcuaro Lake Basin since much before the Spanish conquest, blaming farmers and suggesting not to support traditional systems to counteract the acute environmental degradation that the basin is facing nowadays, and

(7) the local research area has been well studied. Previous information gave the possibility to broaden new inquiries, test previous results and reconstructs the land management history and related knowledge systems through the implementation of grounded theory methodology.

Four research questions guided inquiries at local level:

(1) How soils and land resources were historically perceived, symbolized, known and managed by *Pichatareños* and how this knowledge is currently implemented?

(2) How do people go about conserving soil and land resources, and which other ecological and agronomic information is acquired and implemented for conserving land, water and crops?

(3) What evidence is there of land degradation and how is it locally perceived and counteracted?

(4) Which are the driving factors that impede the full use of the local soil and land resources knowledge nowadays?

### 14.3.2. Research strategy and design

A case study was conducted giving insights of how soil and land resources are currently recognized, symbolized and managed in an indigenous village of Middle America. This supposes that San Francisco Pichátaro is not the only indigenous community in Middle America implementing a social theory about natural resources. Thus, research at this level intends to confirm that there is an ample repertory of knowledge, skills and practices among hundreds, if not thousands of localities that should be taken into consideration for endogenous development with active local participation. Examples of local ethnopedologies were presented in the previous two parts of this thesis at worldwide and regional levels. However, findings from the local case study also revealed the need to frame ethnopedological studies in a contextual way, acknowledging that social theories about nature are locally framed by diverse and complex factors; thus, these theories are somehow unique but repeatable through communication exchange.

The case study is the principal research strategy at this level, while a diversity of methods has been used to guide it (Yin, 1994). The conjunction of qualitative and quantitative research findings allowed broadening inquiries and research questions during the whole research process, giving at the end a better comprehension of the main topic of this thesis and of the local actors that are the main knowledge producers of this topic. The case study integrates different kinds of data, as case studies are fundamental in transcending the division bwtween natural and social science methodologies (Reenberg, 1997).

Qualitative methods included environmental research on ethnohistorical and archival documents, and anthropologic work using ethnographic techniques. Quantitative methods were implemented in socio-economic and geopedologic surveys were conducted using standard statistical analysis, while land-use changes and spatial correlation analysis used a variety of statistical analysis in a GIS environment. From the conjunction of qualitative and quantitative information it was possible to link aspects such as technical soil maps with indigenous soil maps, local demographic trends with land-use and livelihood changes, and technical soil observations and laboratory determinations with participatory soil profile descriptions and soil property determinations.

Findings from the implementation of quantitative methods were discussed with the local actors to assess local perceptions about factors, processes and phenomena, such as impact of development programs, production budget trends, maize price fluctuations, meteorological phenomena, rainfall variability, maize yield fluctuations, deforestation and forest fire occurrence. The combination of qualitative and quantitative methods allowed to recognize and assess the variety of perceived realities about the studied topics thanks to the interdisciplinary and interpretive nature of the study.

### 14.3.3. Inquiries at two geographical scales

Research strategy included inquiries at two main geographic scales. The Pátzcuaro Lake Basin was taken as the territory that frames the historical development of San Francisco Pichátaro, one of the 25 Purhépecha communities that are located within the basin since pre-Hispanic times. Three main research analyses were undertaken at this geographical scale, using information provided by the author of this thesis and other authors: (1) a discussion about the natural history of the basin and its lake; (2) an analysis of the main land-use changes over the last 3,500 years resulting from the implementation of land management policies since the pre-Hispanic period until the eve of the 20$^{th}$ century; and (3) a discussion about contrasting historical land degradation and ethnoecological findings within the basin to frame the current debate about to the active participation of farmers and other stakeholders in causing land degradation and/or promoting environmental preservation of the Pátzcuaro Lake Basin.

Research conducted at the second geographical scale in the village of San Francisco Pichátaro itself, was based on primary data gathered during an extensive fieldwork covering a full maize production cycle (1996-1997) and two short visits in 1999 and 2001. Four different surveys were carried out during this period: (1) a semi-detailed geopedological survey, (2) an ethnopedological and ethnoecological survey, (3) a socio-economic survey, and (4) an agronomic survey. Qualitative and quantitative methods were combined to link anthropological work with technical soil analysis. Description of the implemented research approaches and techniques is provided hereafter.

## 14.4. APPLIED RESEARCH APPROACHES

### 14.4.1. Geopedologic approach

Geopedologic approach is based on a strong integration of geomorphology and pedology, using geomorphology as a tool to enhance and speed up the soil survey. Geomorphic units were delineated using a hierarchical classification system of geoforms comprising six categoric levels, each defined by a specific concept as indicated in table 14.1 (Zinck, 1988/1989). A local geopedologic study was conducted using aerial photo-interpretation (API), field observations, soil sampling, laboratory determinations, soil classification and mapping. Color aerial-photo pairs (1:25,000) were used to delineate geopedologic units and to plot 29 sampled soil profiles, using a GPS Garmin 12XL. Geopedologic mapping covers the entire territory of San Francisco Pichátaro (100 $km^2$). A topographic map of the study area was digitized using ILWIS version 2.4, which served to delineate geopedologic units. A digital terrain model (DTM) was constructed, using the digitized topographic map, and was used to adequate geopedologic unit boundaries.

(1) Field observations and profile descriptions

Over 50 soil observations were done to cover the local area, using minipits, profile pits, road cuts and augerings. ITC field recording data cards were used to describe soils, according to FAO guidelines for soil profile description (Farshad, 1985; FAO, 1990b). In a reconnaissance survey that covered the whole study area, using a preliminary aerial-photo interpretation map, soil profile sampling sites were selected to cover all landscapes and relief units. Three cross-sections were selected to do so (Figure 14.2). In total, 29 soil profiles were sampled, giving 189 soil samples. All soil profiles were examined for horizon depth and designation, structure, color, texture, stoniness, porosity, root condition and biological features, according to the FAO guidelines for soil profile description (FAO, 1990b). Additional data about soil surface features, such as water erosion features (rills, gullies, overland flow) and degree (slight, moderate, severe), coverage percentage of surface rock fragments, and vegetation type and land-use cover percentage, were recorded. The software PEDON (PDP Beta Version 1.0, 1988) was used to store and manipulate soil profile information from field observations. PEDON includes input, edit, print, selection, and file creation facilities. Soil profile information is stored via a relational database so that the data may be easily accessed for future use. Selected soil profile descriptions are shown in Appendix 1.

**Table 14.1.** Synopsis of the geoform classification system

| Level | Category | Generic concept | Short definition |
|---|---|---|---|
| **6** | Order | **Geostructure** | Large continental portion characterized by a specific geological structure. Relationship with plate tectonics (i.e. cordillera, geosyncline basin). |
| **5** | Suborder | **Morphogenetic environment** | Broad type of biophysical medium fundamentally originated and controlled by a given style of geodynamics, either internal or external or a combination of them (i.e. structural, depositional, erosional). |
| **4** | Group | **Landscape** | Large portion of land characterized either by a repetition of similar relief types or an association of dissimilar relief types (i.e. valley, piedmont, mountain) |
| **3** | Subgroup | **Relief/molding** | • Relief as determined by a given combination of topography and geologic structure (i.e. mesa, hill, vale); • Molding as determined by specific morphoclimatic conditions or morphogenetic processes (i.e. glacis, terrace, delta). |
| **2** | Family | **Substratum** | Petrographic nature of hard rocks (i.e. basalt, andesite, limestone, etc.) or origin/nature of soft cover formations (i.e. lacustrine, alluvial, etc.). |
| **1** | Subfamily | **Landform** | Conspicuous basic geoform type, characterized by a unique combination of geometry, dynamics and history (i.e. backslope, toeslope, crest, etc.). |

**Source:** Zinck (1988/89)

(2) Laboratory determinations

The following determinations were carried out: (1) soil reaction (pH); (2) bulk density; (3) organic carbon content (OC); (4) percentage of phosphorous retention (P-ret); (5) available phosphorous (P); (6) particle size distribution; (7) nitrogen (N); (8) extractable aluminum (Alo); (9) extractable iron (Feo); (10) extractable silica (Sio); (11) exchangeable sodium (Na); (12) exhangeable calcium (Ca); (13) exchangeable magnesium (Mg); (14) exchangeable potassium (K); (15) water retention at field capacity (33 kla); (16) water retention at wilting point (1500 kla); (17) cation exchange capacity (CEC); (18) base saturation (BS); and (19) clay mineralogy. Table 14.2 summarizes the laboratory techniques implemented for soil determinations. Soil properties from 1 to 14 were determined at the Instituto de Ecología, A.C., in Xalapa, Mexico, while soil properties 15 to 19 were determined at ISRIC, in the Netherlands. Clay mineralogy (kaolinite, mica/ illite, smectite and quartz) of selected surface and subsurface soil samples was determined at ISRIC to understand the formation of the local soils developed from volcanic material. Extractable aluminum, silica and iron were determined at the Instituto de Ecología, A.C., together with phosphorous retention and bulk density. All laboratory results were used to determine andic properties, according to Mizota and van Reeuwijk (1989) and the USDA Soil Taxonomy (Soil Survey Staff, 1996). Appendix 2 shows laboratory determinations of selected soil profiles.

To frame the local landscape and soilscape evolution under Plio-Quaternary volcanism, a buried soil located at the bottom of a fluvio-volcanic valley was sampled for $^{14}C$ determination. Carbon-14 is useful to date materials directly or indirectly involved in the Earth's carbon cycle during the last 50,000 years. Carbon dating determines the age of a sample in years, by measuring the concentration of $^{14}C$ remaining in the organic material, formerly living matter (Bates and Jackson, 1987). $^{14}C$ is measured from radioactive decay. However, variations in the atmospheric $^{14}C$ content due to changes of the Earth's magnetic field, known as long-term trends or solar fluctuations, determining medium-term variations, complicate the conversion of conventional BP ages (i.e. years before AD 1950), into real calendar ages (AD/BC) (van der Plicht and Mook, 1989). Carbon-14 determination was carried out at the Laboratory for Isotope Research, University of Groningen, The Netherlands. The resulting radiocarbon age was calibrated to correct errors due to natural variations of the $^{14}C$ content in the atmosphere, using the Seattle/Groningen method described by van der Plicht and Mook (1989). Carbon-14 determination is discussed in Chapter Eighteen.

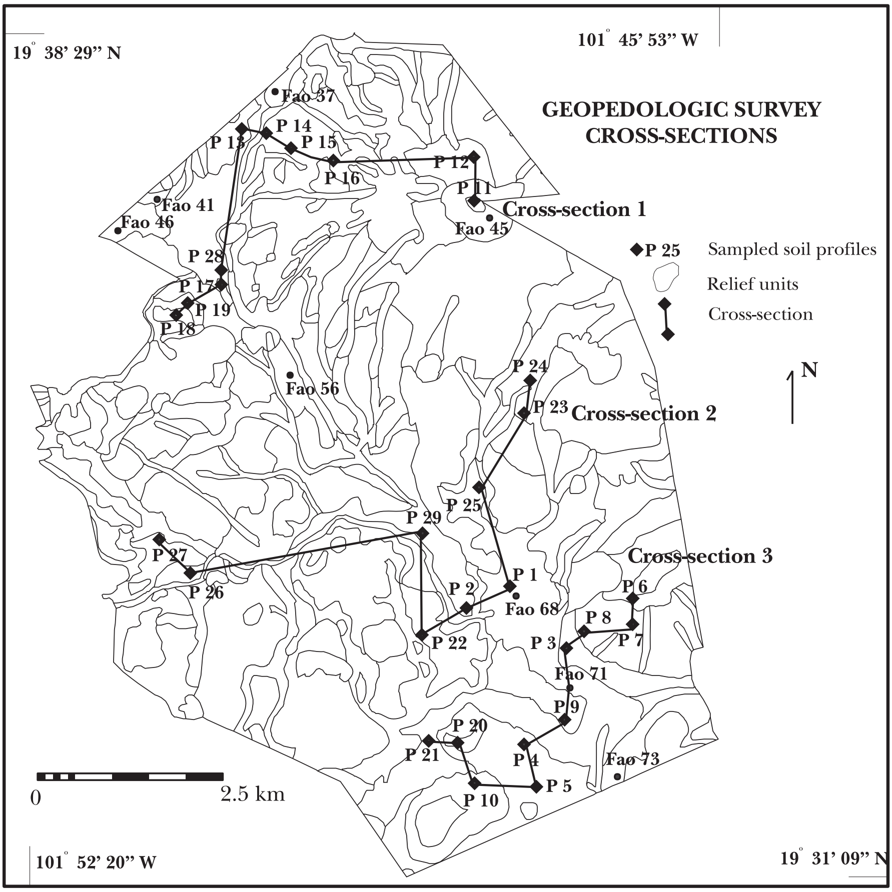



**Figure 14.2.** Geopedologic survey cross-sections

(3) Soil classification

Field observations of 29 soil profiles and laboratory determinations were used to classify the local soils according to the USDA Soil Taxonomy (Soil Survey Staff, 1996). Soils were classified at suborder level due to the lack of laboratory determinations of particle size classes for Andisols, the most common local soil classes, which is a requirement to soils classify at family level according to the USDA Soil Taxonomy. A soil database was built using Excel software to store, retrieve and manipulate field descriptions and laboratory determinations. The soil horizon was used as the basic unit for data capture. Field descriptions and determinations were aggregated at horizon level, coded according to the FAO Guidelines for soil profile description (FAO, 1990b). The soil database was structured according to the soil classification system and geomorphic units (Zinck, 1988/1989). Geomorphic units were used to link the stored semantic data with spatial data, creating a relational soil database, further exported to ILWIS for mapping manipulations. The combination of a basic geomorphic unit with its associated soil information results in a soilscape unit. Figure 14.3 shows the soil database design for GIS manipulation, according to previous database model design proposals (Zinck and Valenzuela, 1990; Metternicht, 1996).

**Table 14.2.** Laboratory determinations

| LABORATORY DETERMINATIONS | | | | | |
|---|---|---|---|---|---|
| **Num.** | **Soil property** | **Units** | **Samples analyzed** | **Technique** | **Lab.[1, 2]** |
| **1** | pH | | 189 | Determined according to Jackson (1976) and Schlichting et al. (1995). Soils $H_2O$ (1:2.5). Potentionametrically determined in $H_2O$ and KCL (1:2.5) (Also Soil Conservation Service, 1973) | IE[1] |
| **2** | Bulk Density | g/cc | 189 | Coated-clod procedure (Soil Conservation Service, 1973; Leamy, 1983) | IE |
| **3** | Organic Matter content | % | 189 | Determined according to Walkley and Black (Jackson, 1976) and Blackmore (1977) | IE |
| **4** | Organic Carbon content | % | 189 | Determined dividing the amount of organic matter by 1.724 | IE |
| **5** | Phosphorus Retention | % | 189 | Determined according to Jackson (1958) and Blackmore (1982) | IE |
| **6** | Available P | ppm | 189 | P-Bray-1 determination. Bray et al. (1965) | IE |
| **7** | Particle size distribution | % | 189 | Determined according to Bouyoucos (1951) | IE |
| **8** | Nitrogen | % | 189 | Determined according to Kjeldahl (1958). See also ISRIC (1992) | IE |
| **9** | Extractable Aluminum | % | 189 | Determined according to Blackmore (1977), using oxalate acid | IE |
| **10** | Extractable Silica | % | 189 | Determined according to Blackmore (1977), using oxalate acid | IE |
| **11** | Extractable Iron | % | 189 | Determined according to Blackmore (1977), using oxalate acid | IE |
| **12** | Interchangeable Sodium | Meq/100 gm | 189 | Determined in $CH_3COONH_4$pH 7 1N | IE |
| **13** | Interchangeable Calcium | Meq/100 gm | 189 | Determined using the Spectrophotometry Atomic Adsorption method. Ca was determined in $CH_3COONH_4$pH 7 1N | IE |
| **14** | Interchangeable Magnesium | Meq/100 gm | 189 | Determined using the Spectrophotometry Atomic Adsorption method. Mg was determined in $CH_3COONH_4$pH 7 1N | IE |
| **15** | Interchangeable Potassium | Meq/100 gm | 189 | K was determined in $CH_3COONH_4$pH 7 1N | IE |
| **16** | Water Retention Capacity. Field Capacity at 1/3 atm. | atm | 13 | Coated-clod procedure | ISRIC[2] |
| **17** | Water Retention Capacity. Wilting point at 1500 mlg. (15bars) | bar | 13 | Coated-clod procedure | ISRIC |
| **18** | Cation Exchange Capacity | cmol/kg | 14 | Percolation with Ammonium Acetate at pH 7 | ISRIC |
| **19** | Base saturation | % | 14 | | ISRIC |
| **20** | Clay Mineralogy | % | 14 | X-ray diffractometry | ISRIC |

[1]IE: Instituto de Ecologia, A.C., Xalapa, Mexico.
[2]ISRIC: International Soil Reference and Information Centre, Wageningen, The Netherlands.

(4) Soil mapping

The geopedologic map was digitized in ILWIS version 2.4 (ITC, 1993), using a digitized topographic map and a digitized map of the territorial boundaries of San Francisco Pichátaro. The geopedologic map was derived from the interpretation of aerial photographs at scale 1:25,000. It was used as basis for the location of the sample sites and for data extrapolation, applying the geopedologic approach (Zinck, 1988/1989). The soil

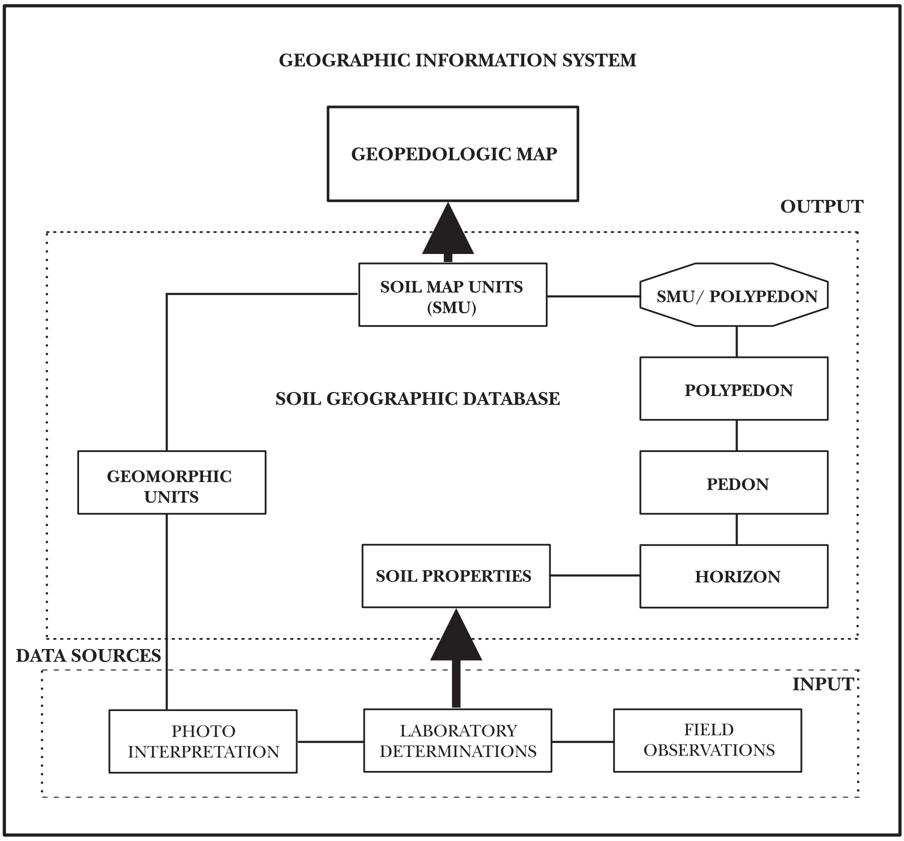



**Figure 14.3.** Soil database design. **Modified from:** Zinck and Valenzuela (1990)

relational database was imported to ILWIS, giving the possibility to produce several attribute maps from the polygon map, that were used to correlate the geopedologic map (technical map) with the ethnopedologic map (local soil knowledge map), applying spatial correlation and correlation matrix analyses at various levels in ILWIS version 3.1. Section 14.8 describes this procedure.

A geomorphic map was also digitized applying the same procedure as for the geopedologic map. Geomorphic units were characterized using the procedure and nomenclature for volcanic features proposed by Verstappen (1977), Verstappen and van Zuidam (1991), and van Zuidam (1985/1986). The local geomorphic map was also correlated with a relief map based on local geomorphic knowledge.

14.4.2. Ethnopedologic approach

An ethnopedologic survey was conducted applying ethnographic (Yin, 1994), participatory (Idris et al.,, 1998; Norton et al., 1998; Pretty et al., 1995; Pretty, 2001), socio-economic, and agronomic techniques and surveys (Conway, 1993). The main objective was to acquire local soil and land data and information, including spatial and temporal information at various scales and levels. Ethnopedologic survey also consisted in analyzing the local theory about soil and land resources, using the K-C-P complex derived from the ethnoecological systemic research framework (Chapter Five). Ethnopedologic information included also environmental and agronomic knowledge, such as the hydrological cycle, ethno-meteorology, ethno-climatology, and knowledge about the moon cycle, relief, vegetation, crop phenology and spatial distribution, and the local agricultural systems. It also included the acquisition and interpretation of symbolic meanings, rituals and religious ceremonies related to the water cycle, soil and land resources, and agricultural activities. The main goal was to unfold and interpret the many relationships of soil and land resources with other ecological and agronomic information as perceived by the local population.

Acquisition of ethnopedologic information *stricto sensu* included knowledge about soil components, properties and related features, soil nomenclature, soil profile descriptions, soil taxonomy, spatial distribution of soil classes, soil behavior, soil quality assessment, soil fertility cycle, soil erosion recognition, and soil and water conservation measures. It also included knowledge about land-use, land-use restrictions and potential, land-crop suitability and limitations, and land management practices. The main objective was to acknowledge the manifold ways that perception and knowledge about soil and land resources are applied as part of a multi-purpose natural resource management strategy.

Ethnopedologic (and ethnoecological) data gathering paralleled the acquisition of scientific (technical) soil information to avoid 'knowledge contamination', that is the misinterpretation of local environmental knowledge when *a priori* comparing it with technical knowledge. Ethnopedological research was conducted after recognizing basic technical soil information. From the beginning, technical survey and local knowledge understanding about soil and land resources were conducted independently, to give sense to the different ways of comprehending the soil and land worldviews, that is the researcher's cognition about such resources and the local perception and knowledge of the same resources. This disciplinary separation of both knowledge systems served to construct a dialogue between the author of this thesis and the local population. A similar research approach was conducted by Oudwater and Martin (2003), calling it a 'critical approach'. These authors highlight the risk that an uncritical approach to local knowledge may lead to misunderstandings and misconceptions that are not apparent until detailed research is conducted. Several ethnopedological techniques were developed to acquire soil and land perception, symbolism, knowledge and management. These techniques are described hereafter.

(1) Participatory profile descriptions

**Figure 14.4.** Participatory soil profile description

The soil profiles sampled for conducting the geopedologic survey served as natural objects to establish a dialogue among farmers and between farmers and the author of this thesis, concerning soil nomenclature, characteristics, properties and related features, such as horizon and layer identification and characterization, water holding capacity, internal drainage condition, stoniness, root condition, and biological features. Farmers, who showed a deep understanding of the local soilscape and soil distribution pattern, were selected to conduct participatory soil profile descriptions (Figure 14.4). A group of three to five farmers was invited to explain and discuss their findings at each soil profile. Explanations about land-use restrictions and potential and land management practices were also encouraged. In total, 15 participatory soil descriptions were conducted with the active participation of 45 farmers. Farmers previously selected the soil profiles to be described and then highlighted the heterogeneity and distribution pattern of local soil classes. Farmers touched, felt, smelled and tasted specific soil layers. Each individual repeated this procedure until reaching a group consensus about soil profile characterization and classification. The author of this thesis had minor interaction with the farmers, but conducted the procedure. Participatory soil profile descriptions were audio-recorded and latter transcribed, and analyzed using contrastive textual techniques aided by the software HyperRESEARCH™ (1997) (i.e. recognition of keywords and discursive differences).

Explanations and discussions at soil profiles took several hours until reaching an agreement. Knowledge differences and consistency were tested by this procedure. In general, farmers that describing a soil profile located on their own agricultural parcel or forest plot were carefully listened by the other individuals that attended the exercise. After some hesitation, individuals possessing parcels and plots with similar soil characteristics initiated their own tasting, description and discussion. This shows that soil knowledge is diffuse, and soil knowledge specialization is driven by land tenure and personal experience. However, explanations and discussions revealed a common knowledge background and nomenclature, thus showing the grassroots of the local theory of soil and land resources.

(2) Soil correlation boxes

Soil correlation boxes were used to contrast ethnopedological information gathered in an open environment (the soil profile and/or soilscape) with information acquired at a closed and distant place (i.e. the household compound). Correlation boxes simulated soil profiles selected by farmers, to open a dialogue between the author of this thesis and local individuals about the same topics discussed during the participatory soil profile descriptions. In this case, selected individuals were visited at their own household compounds and, by applying open-ended controlled interviews, they were invited to touch, feel, smell and taste samples from diverse soil profiles, organized by horizons according to the technical soil description. Soil correlation boxes are wood-made boxes with mobile divisions, allowing to store soil samples from each horizon, thus simulating a soil profile (Figure 14.5). These boxes are easily movable, light and can be easily handled, as they can be locked to prevent soil samples from contamination. The boxes were locally built and were costless. They resemble a mobile soil museum and they served as artificial objects to test soil knowledge consistency and diversity among farmers (Figure 14.6).

Interviewed individuals tended to be more talkative and confident during this procedure, although explanations about characteristics and properties of simulated soil profile horizons initiated after recognizing possible areas where similar soils could be found in the Pichátaro landscape. Insights about local soil and land resources knowledge, gained by the application of the soil correlation boxes technique, revealed that individual skills and experience are at the base of the local theory about these resources and that individual knowledge is eminently situated or site-specific. However, farmers were able to distinguish and characterize soils separately from their location. Birmingham (1996, 1998) applied a similar technique, but using transparent plastic bags in an ethnopedologic survey carried out in Ivory Coast, West Africa. Findings were similar to those of this thesis.

(3) Participatory cross-sections

Participatory cross-sections were aimed at understanding the different microenvironments and their transition zones within the local territory. Figure 14.7 shows the location of the participatory cross-sections. The objective of this procedure was threefold: (1) it aimed to elicit soil-relief distribution patterns according to local farmers' knowledge and experience; (2) it also aimed to elicit local knowledge of the agricultural lands and forest plots, and identify problems and potentials with special reference to land, crops and water related issues; and (3) special attention was given to soil-relief boundaries. Groups of three to seven farmers were invited to walk along a previously identified transect. Farmers were selected according to their experience and deep knowledge of the selected cross-sections; thus, most of them had agricultural parcels or forest plots adjacent to the transects. Technicians and extensionists were also invited to join transect walk groups, during the two participatory workshops held at the end of the fieldwork activities. Agronomists, geographers, biologists, foresters, anthropologists, and extensionists had then the opportunity to discuss about local environmental, production and socio-economic issues with farmers of different age, gender, occupation and prestige. The main objective was to establish an on-site dialogue between different experts about the environmental characteristics of the visited landscapes. Discussions about land-use, land-use history, micro-climatic characteristics, relief, soils,


**Figure 14.5.** Correlation boxes from selected soil profile samples

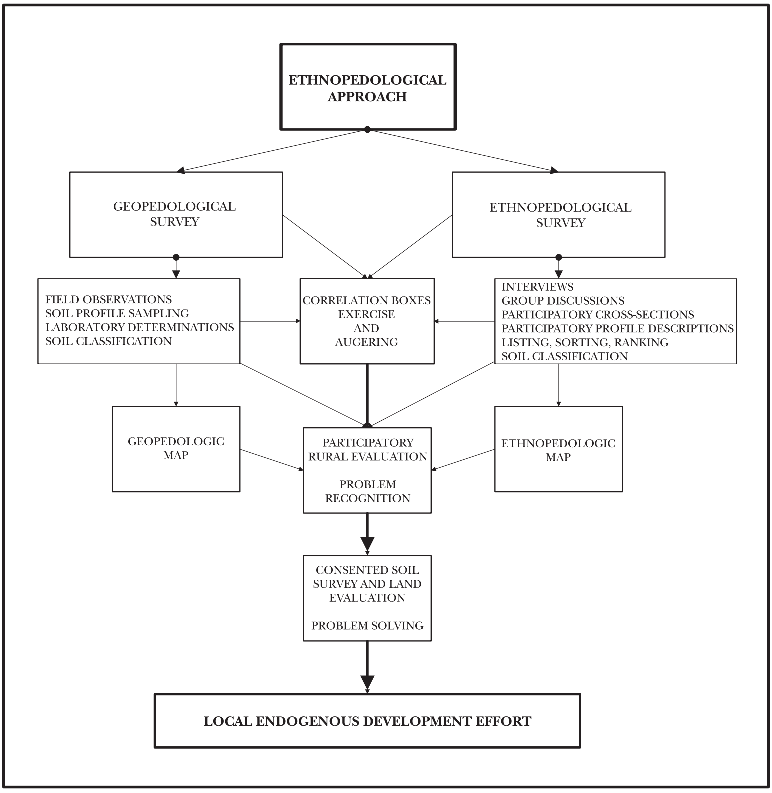



**Figure 14.6**. The ethnopedological approach and correlation boxes exercises

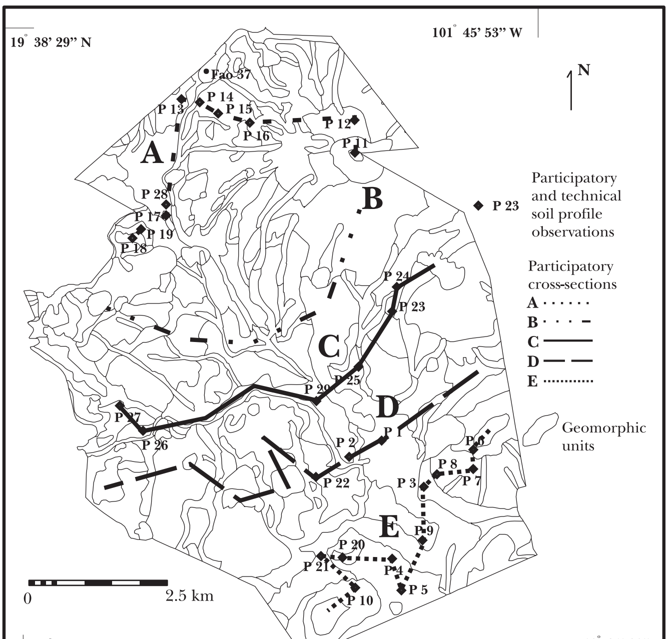



**Figure 14.7.** Location of participatory cross-sections

vegetation, water resources, infrastructure, farming practices, crop adaptation and phenology, soil erosion and land degradation, soil and water conservation measures, and related environmental issues, problems and potentials took place while walking along transects. Discussions were audio-recorded and latter transcribed and analyzed, using the software HyperRESEARCH™. Information gathered at each participatory cross-section exercise was later discussed among all transect walk groups during workshop sessions, including external experts. Relevant and consensual data was transcribed into a correlation matrix, including information of all cross-sections. Group discussions aimed to offer insights at local level and generate an overview of the local environmental and production problems, potentials and possible solutions.

(4) Workshops

Two participatory workshops were held at the end of the author's fieldwork, once the bulk of the ethnoecological and ethnopedological information was collected along a 12-month field survey. In total, 50 local individuals of different age, gender, ward, social status and experience intervened in the workshops. External technicians, the local Catholic priest, local, state and federal authorities, local teachers, and members of regional NGO's also actively participated during this process. The main objective was threefold: (1) to socialize information gathered by the author of this thesis aimed to crosscheck and test its consistency, pertinence and cohesion; (2) to promote a multi-stakeholder discussion focused on environmental, production and economic problem-solving; and (3) to generate a consensual local planning program according to local, regional and national needs and demands. Discussions also came about the success and failure of past and ongoing governmental projects and programs, and about local conflicts and dissent over land-use and natural resource management. Specialized staff members of CESE, A.C. (Centro de Estudios Sociales y Ecológicos, Asociación Civil, or Social and Ecological Studies Centre, Civil Association), a nationally prestigious NGO that has been working with the indigenous and Mestizo communities of the Pátzcuaro Lake Basin, conducted the two workshops using participatory rural appraisal techniques (PRA). Several participatory techniques applied during the workshops are described in section 14.5.

The first participatory workshop included the active intervention of 30 individuals from San Francisco Pichátaro, 12 external technicians, governmental officials, and extensionists. The meeting was conducted during a five-day period from the 23$^{th}$ to 27$^{th}$ of September 1997, in a room located next to the main local church. Local participation included authorities, farmers, artisans, resin extractors and teachers, from different wards, from both sexes and from different ages. The average age of local participants was 40 years. The main objectives of this workshop were: (1) to analyze the current political, economic, production and environmental conditions of the locality and its lands; (2) to integrate the social, economic and political problematic into the analysis of the local natural resource management, seeking to define a general strategy for an alternative endogenous development process; and (3) to promote, among local and external participants, the importance of planning as a self-centered and conservative process of empowerment and as a key instrument for local development at short-, intermediate- and long–term perspectives. The aim was to develop a general and consensual planning framework with the participation of different stakeholders, by finding possible solutions to the current local problems.

Activities carried out during this process were group meetings, participatory cross-sections, guided visits and interviews at schools, the local health center, handicraft and wooden furniture workshops, bakeries, butcheries, grocery shops, household compounds, and homegarden plots. An inventory of the local urban infrastructure and services was also carried out, including data collection from various sources (census, written documents and interviews with key informants). Individuals were chosen according to production specialization (farmers, artisans, carpenters, resin collectors, cattle raisers, etc.) to form transect walk groups, including external technicians. The heterogeneous composition of these groups made possible to contrast views about land-use, land degradation and related environmental issues of the visited landscapes.

Two main products derived were derived from the workshop. An extensive document consisting of 85 pages, including maps, figures and tables, was compiled under the title "General Framework for Indigenous Development at Short, Intermediate and Large Perspectives: Indigenous Community of San Francisco Pichátaro. Tingambato Municipality, Michoacán (Marco General para el Desarrollo Indígena a Corto, Mediano y Largo Plazo: Comunidad Indígena de Pichátaro, Municipio de Tingambato, Michoacán)”. This document was officially promoted as the local development program and was submitted to the Ministry of Natural Environment, Natural Resources and Fishery (SEMARNAP), the Ministry of Social Development (SEDESOL) and the Secretary of Agricultural and Forest Development of Michoacán in a ceremony held in December 1997. The three state ministers signed the receipt of this document and, since then, it has been used as an official ruling document for community development (Figure 14.8).


JEFATURA DE TENENCIA PICHATARO MICH

MARCO GENERAL PARA EL DESARROLLO INDIGENA
A CORTO, MEDIANO Y LARGO PLAZO

COMUNIDAD INDIGENA DE PICHATARO
MPIO. DE TINGAMBATO, MICHOACAN

*- VERSION PRELIMINAR -*

PICHATARO MICH. DICIEMBRE DE 1997.

**Figure 14.8.** Cover of the local development planning document after officially received by three federal ministers.

The second product consisted in a 45 min video-documentary (VHS format), that synthesizes internal and external perceptions about the local environmental and production problems and their possible solutions. The document focuses on forest exploitation, agricultural diversity, handicraft manufacturing, urban infrastructure and services. This video-documentary was produced, edited and formatted by professional staff, using main findings from the workshop and interviews to key individuals, such as elders, youngsters, women, teachers, local authorities, external and local technicians, the priest and the physician in charge of the local health clinic. Several copies of this document were delivered to the local authorities and population at large. The main objective was to socialize, as much as possible, the local challenges and possible solutions in San Francisco Pichátaro and the neighboring localities from the Pátzcuaro Lake Basin. This thesis includes a copy of this video-documentary.

The second participatory workshop took place from the 21st to the 24th of April 2000. It was held at the same place as the first participatory workshop was conducted, with the active participation of 27 local individuals and 7 external technicians, governmental officers and extensionists. The local participants were mainly agriculturalists as the workshop focused on the local agricultural systems, with a special effort to link soil, land and water problematic into the current agricultural crisis. The average age of the local participants was 45 years and the majority of individuals were men from all the local wards and the authorities.

This workshop was held in accordance with the findings and conclusions made during the first workshop, that is the environmental, socio-economic and political factors affecting agricultural activities at local, regional and national levels. Discussion topics were the potential loss of local agrodiversity, tensions created by forest overexploitation and land-use changes, land management, land degradation, agricultural practices, and the local perceptions about the rural policies implemented by national and international agencies, that have been weakening the local control of the agricultural process. Participatory cross-sections, inventory of local maize landraces, correlation and ranking matrices, seasonal calendars, time lines and trend changes analysis, and participatory mapping, were used as analytical procedures to elucidate the strength and weakness of maintaining local agricultural diversity. Current challenges and potential solutions for maintaining local food security and environmental services provided by soil and water conservation measures were also discussed among the local and external participants. PRA specialists and the author of this thesis organized individual tasks, group sessions and a general assembly. A small group of farmers, local authorities, governmental officials and external technicians were selected by the general assembly to elaborate a technical report, including findings, proposals and programmatic activities to convert local agricultural challenges into opportunities, after reconciling different views and perceptions about the future of the local agricultural production. This endogenous development program was presented to local, state and federal governmental authorities and to the local population at large in a general assembly.

(5) Participatory mapping

Information gathered from the above-mentioned approaches and activities was used to construct socially consented maps. This participatory mapping procedure integrates guided walk transect data, workshop information, ranking, sorting and correlation matrices, soil correlation boxes exercises, individual and group interviews, questionnaires and census information. Information acquired from participatory-guided techniques was geographically positioned using a GPS device and later digitized using the ILWIS software (ITC, 1993, 1998, 2002). The main objective was to organize the local environmental knowledge data as accurately as possible, from spatial and temporal perspectives. This includes the author's findings and interpretation, which are discussed in the following chapters. Participatory mapping was conducted using an amplified topographic map of the local territory, which was exposed on a wall during assembly meetings and after group sessions were finished. A member of each group presented conclusions in a diagrammatic form (correlation matrices), which were discussed by the general audience and geographically localized on the map. Iterations made possible to construct a final consented map and a related matrix-built legend (Figures 14.9 and 14.10). The aim was to socialize, as much as possible, all the environmental data gathered during the whole process, to finally present socially consented information. Participatory mapping produced the following information:

(1) Toponymy map
(2) Bioclimatic map
(3) Ethnogeomorphologic map
(4) Ethnopedological and soil properties maps
(5) Natural hazards map
(6) Local maize landraces distribution map
(7) Agricultural systems map
(8) Forest restoration measures map

However, the analysis and interpretation of the local information, which is discussed in the following chapters, are the only responsibility of the author of this thesis, as the author used an interpretive anthropological research method. Discursive translation included, therefore, the perception and findings of an external agent that is the ethnoecologist. Important is to note that PRA techniques were combined with conventional ethnographic techniques (Bernard, 1994), which allowed to reveal the local environmental knowledge through a 'long conversation' with the local actors, but including the author's own views. Interpretive anthropology requires heuristic and hermeneutic inquiry from all agents involved in the analyzed issues and problems. Ethnographic techniques applied during the whole process are described hereafter.

### 14.5. Ethnographic techniques

Several ethnographic techniques were applied during fieldwork to elicit the local environmental knowledge and related issues, with special reference to interpreting the social theory about soil and land resources that *Pichatareños* maintain and apply in their natural resource management strategy. Triangulation of data sources derived from each ethnographic technique permitted an in-depth analysis of the social theory about the local soil and land resources, giving accuracy and credibility to the conclusions that are drawn in the following chapters. Data crosschecking allowed understanding the local concepts, explanations and discourses coming from different sources at various moments and places during fieldwork, and from different individuals and observed activities.

**Figure 14.9.** Group discussion after the participatory cross-section exercise

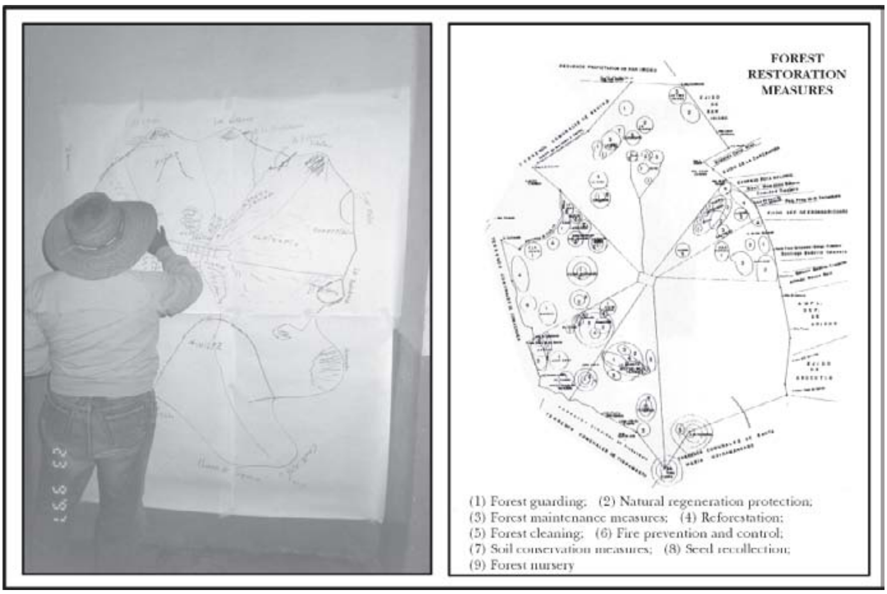



**Figure 14.10.** Participatory mapping for forest restoration measures

Data crosschecking also allowed to link conceptual thinking with practical knowledge, assuming that local knowledge is not homogenous but shared through individual experience and according to the individual's social status. Not all members of the local study area possess the same stock of information. Knowledge differences are derived from gender, age, skills and abilities, social prestige and production specialization. However, common conceptualization and practice schemata shared and negotiated among individuals constitute a sort of theoretical background, that irrigates the everyday communication among all community members. This is called a social theory, which involves all aspects of the K-C-P complex as a logic and indivisible unit of world life and worldview. Data triangulation and crosschecking constituted an appropriated research strategy for understanding subtle yet important knowledge-practice differences, because it allowed focusing on the circumstances leading to individual actions. Data triangulation and crosschecking also helped integrating qualitative and quantitative information gathered through different research approaches.

### 14.5.1. Individual interviews

Throughout fieldwork, intensive use was made of individual and group interviews and conversations. Individual interviews were of two kinds: (1) semi-open structured interviews and (2) open-ended interviews and conversations. Semi-open interviews focused on a particular topic in a formal and individual way, including an appointment set-up with some specific questions prepared beforehand and others coming up during the interview. A total of 37 interviews of this kind was recorded, including information provded by women and men from different ages, production specialization, social status and village wards. Interviews were audio-recorded and later transcribed and analyzed, using the software Hyper RESEARCH™. Interviewers were selected depending on the topic and according to individual experience (Figure 14.11). Interviewers' names were modified to preserve anonymity and avoid possible social dissent. The checklist used for conducting semi-open interviews covered a wide array of issues, including physical, biological and socio-economic aspects.

Open-ended individual interviews were conducted to gather additional and more detailed information from key informants. These interviews had the objective to fill some data gaps and corroborate information not widely acquired. Open-ended interviews were also applied to external actors, such as extensionists, NGO staff members involved in development projects, and governmental officials and technicians. Interviews mainly focused on policy-related topics.

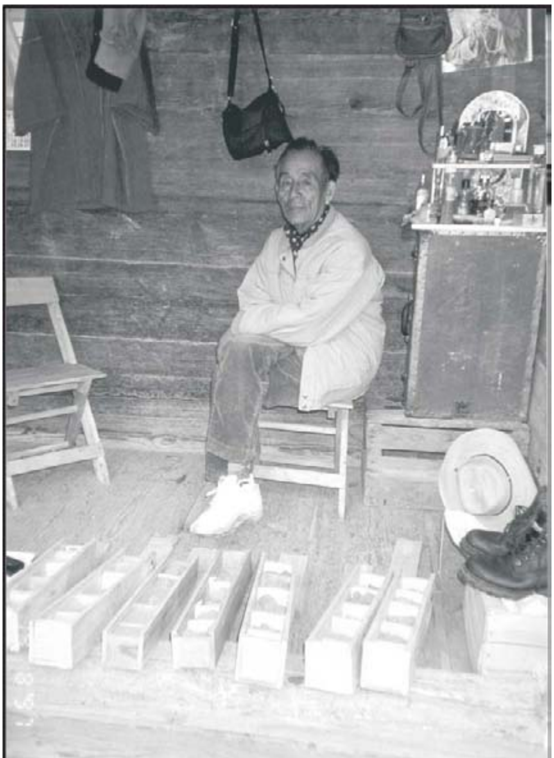


**Figure 14.11.** A correlation boxes exercise during an individual interview

Conversations were informal and about any topic rised by the researcher or informant. They were conducted during household visits, guided transect walks and production activities at field, parcel or handicraft workshops. Informal conversations had the advantage of recognizing new topics or relevant information that was not thought about beforehand. Such issues could then become at a later time topics for individual interviews.

### 14.5.2. Group interviews

Group interviews were conducted during guided transect walks, group meetings, participatory workshops and production activities at field, parcel or handicraft workshops. Most groups consisted of 3-7 individuals. The group size was never so large as to preclude adequate participation nor was it so small that it failed to provide greater coverage than that of an individual interview. Group interviews had the advantage of comparing and contrasting individual tacit knowledge and experience, knowledge cohesion, consistency, heterogeneity and relevance. They were aimed to understand knowledge fuzziness and knowledge communication among individuals from different age, gender and production specialization.

Other applied techniques used during group meetings were sorting, labeling and rating procedures. Oral history interviews were used to collect historical information related to environmental issues and changing livelihood patterns at village and regional levels. No statistical procedure was predetermined to guide data acquisition by individual and group interviews. These ethnographic techniques were conducted until no new relevant information was acquired. Most interviewees were previously selected according to topic, individual experience and skills, but some interviews were not predetermined and interviewees were not previously chosen.

### 14.5.3. Listing, sorting and ranking

Ethnopedological and ethnoecological data acquisition also consisted in nomenclature listing, sorting, rating and ranking. Eliciting soil, relief and crop names, and related issues was based on a free-listing technique, which consists in the creation of an extensive inventory of names and concepts during individual and group interviews. Characterization of soil types, for example, helped understand the local concepts concerning soils, their problems and their uses.

Pile sorting and triad test techniques were applied among individuals and groups once an extensive nomenclature inventory was acquired. These techniques allowed getting insight about soil, relief and crop characteristics and the taxonomic order of different soil and crop types. Pile sorting and triad tests were done with index cards stating soil, relief and crop names. Pile sorting consisted in organizing index cards according to similarities or affinities, thus creating several card piles from the original ones. Triad tests consisted in discriminating the degree of affinity or difference (brotherhood or similarity) among items previously organized in several card piles. Over a large number of trios, the number of times any two soil types were paired together versus the number of times the pairs were separated gave an index of their degree of similarity. Ranking consisted in organizing the card piles with similar soil classes (soil groups and sub-groups) in a tree-like chart, thus representing the hierarchical organization of the soil world according to the local soil grouping (for details of these methods see Berlin et al., 1974; Furbee, 1989; Bernard, 1994; Sandor and Furbee, 1996).

Ranking and rating were also used to obtain and compare information about choices made and their reasons, and to identify decision-making procedures. It helped identify criteria used to rank soil quality, for example. In this case, individual and group ranking tasks aimed to recognize soil quality factors and indicators according to inherent properties of each soil class, soil behavior, relief position land-use, soil-crop relationships and soil fertility maintenance. Ranking and rating procedures were established using correlation matrices and creating a ranking index (see chapter Twenty One). All local participants built up the ranking index during a general meeting, after discussing individual and group findings.

### 14.5.4 Ethnopedological questionnaire

Twenty-seven ethnopedological questionnaires were applied to a similar number of individuals. The questionnaire was divided into two sections (see Appendix 3). The first section consisted in a list of questions aimed to elicit ethnopedological information at local level (the whole village territory), while the second section was aimed to acquire ethnopedological information at parcel level. Both sections were further subdivided into two sets of specific questions. The first one consisted in questions related to the recognized soil types or classes, their properties and distribution pattern, while the second one consisted in a list of questions linking land-use and land management per each soil type or class.

Questionnaire application took several hours in an open place and at the parcel(s) cultivated or forest plot(s) exploited by each interviewed. Augering, soil profile descriptions and transect walks were conducted while applying each questionnaire. Informants were selected according to the location of their agricultural parcel or forest plot and using a predetermined cross-section. Cross-sections were chosen to cover the vast majority of soil classes and relief types, according to preliminary findings from the geopedologic survey. Figure 14.12 shows the cross-section matrix model with main discussed factors. Discussions were also audio-recorded and later transcribed. Ethnopedological data derived from questionnaires was later discussed during the soil correlation boxes exercises held at the household compound of each individual. This crosschecking procedure was aimed to qualify the degree of cohesion and accuracy of each individual's knowledge and to find new relevant information and topics. The ethnopedological questionnaire was a useful tool for integrating information derived from the researcher's observations and fieldwork notes with data acquired from the application of PRA and ethnographic techniques.

### 14.6. Socio-economic survey

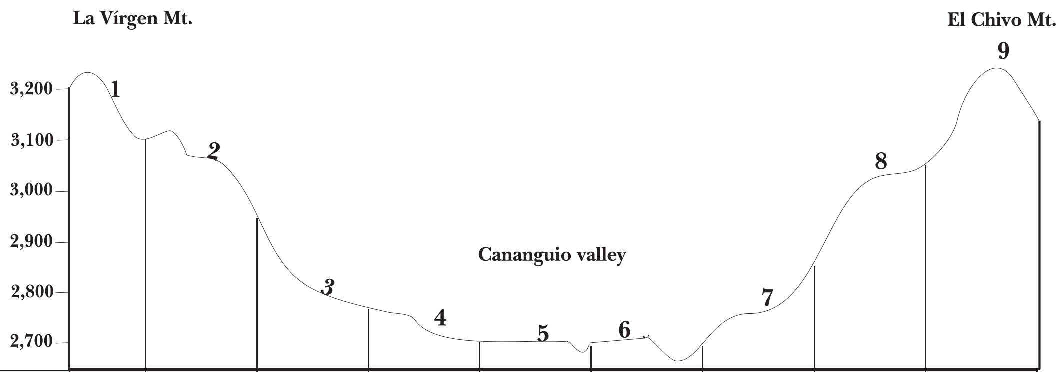
A village census and a comparison of socio-economic covering a period of 20 years, using previous census information, were carried out to analyze current demographic, educational, economic and migration characteristics of San Francisco Pichátaro and changes occurred during the 1977-1997 period. Additional information about land-use, land property and production activities, with special reference to agriculture, forest exploitation and resin extraction was also acquired. Village census was conducted during a three-day period in July 1997 with support from the local authorities and teachers, a research assistant (a Dutch student in anthropology from the University of Utrecht, the Netherlands), and 60 students from the 3rd year of the local secondary school.

The census questionnaire was adapted from previous census carried out by the author of this thesis in 1983 (Toledo and Barrera-Bassols, 1984) and by Clay-Young and Garro (1994) in 1977 (see Appendix 4). The main objective was to cover the same fields for a timeline and trend change analysis. The questionnaire also included an agronomic area, specially focusing on maize production and commercialization. The questionnaire was applied in 397 households (approximately 52% of the local households) and later transcribed as a database, using the software DBase™, and imported to the SPSS v9 software package. The census survey was conducted with random selection of households from all the seven wards, using a urban cadastral map. Questionnaire application also included the 57 households of the selected individuals directly and actively participating in the research project. The main objective was to compare demographic structure, educational level, spoken language, production activities and economic strategy of the informants' households, including migration, production specialization, location of agricultural parcels and agricultural activities carried out during the 1996-1997 cycle. The socio-economic survey also included official statistical data acquired at various governmental agencies, the local health clinic, and archival and bibliographic information, which is discussed in Chapter Nineteen.

### 14.7. Agronomic survey

A local agronomic survey was conducted during fieldwork. Archival, bibliographic and statistical analyses were also carried out. This survey consisted in several research activities, such as agricultural systems characterization, questionnaire application, participant observation along a full agricultural cycle (1996-1997), including all agricultural commercialization activities, and participatory workshops, guided transect walks, maize landraces collection and inventory, and participatory mapping. Qualitative and quantitative techniques were applied during the survey. Qualitative techniques were discussed in previous sections of this chapter, while quantitative techniques included budget analysis for maize production under various environmental contexts and technological characteristics, GIS techniques applied for land-use changes analysis, and participatory rating and ranking procedures. The main goal was to analyze the diversity of the local agricultural systems, generate a farmers' typology according to household size, number of production activities carried out per each household, landholding size and geographical location, maize production volume per hectare per household, and subsistence and commercial strategies. Special effort was made to recognize and analyze crop diversity at parcel, landscape and local levels, natural hazard mapping according to local perception and experience, and the collection, inventory and spatial distribution of local maize landraces. Information of production calendars per agricultural system, phenological cycle of the local varieties of maize, beans, oats,

**PARTICIPATORY CROSS-SECTION 'A'**




| OBSERVATION NUMBER | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
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| PLACE NAME | | | | | | | | | |
| OWNER | | | | | | | | | |
| LOCATION (GPS) | | | | | | | | | |
| VEGETATION TYPE | | | | | | | | | |
| USEFUL SPECIES | | | | | | | | | |
| TYPE(S) OF FOREST EXPLOITATION | | | | | | | | | |
| TYPE(S) OF FOREST DEGRADATION | | | | | | | | | |
| RELIEF TYPE | | | | | | | | | |
| SOIL TYPE(S) | | | | | | | | | |
| SOIL CHARACTERISTICS | | | | | | | | | |
| LIMITING FACTORS | | | | | | | | | |
| LAND-USE | | | | | | | | | |
| AGRICULTURAL SYSTEM | | | | | | | | | |
| CROP ROTATION | | | | | | | | | |
| WATER AND SOIL CONSERVATION MEASURES | | | | | | | | | |
| LAND MANAGEMENT PROBLEMS | | | | | | | | | |
| LAND-USE HISTORY | | | | | | | | | |
| OTHER OBSERVATIONS | | | | | | | | | |

**Figure 14.12.** The participatory cross-section matrix model

several fruit trees, and wheat, and agronomic rituals and religious ceremonies was also acquired with special reference to soil-water-crop relation.

The second part of the census questionnaire was applied to acquire agronomic and land-use information per household, with special reference to maize production and commercialization (see Appendix 4). Selected informants with the technical support of a local agronomist conducted maize landraces collection and inventory. Maize landraces classification was done using technical taxonomic keys with the aid of specialists from the Faculty of Agronomy of the UMSNH (Michoacán University of San Nicolás de Hidalgo), the INIFAP (National Research Institute for Forest, Agriculture and Cattle Raising Development), and bibliographic research.

The local maize landraces classification was conducted during a special session of the second participatory workshop. This workshop focused on characterizing the local agricultural systems, land-use change trends during the 20$^{th}$ century, participatory mapping of maize landraces and agricultural systems distribution. The main goal was to discuss among farmers and technicians the links between socio-economic, environmental and agricultural problems and possible solutions, using the local environmental and agronomic knowledge as a guideline for an endogenous local development program. Special effort was made to link soil and land resources knowledge in the local agronomic context. This workshop was held at the end of the research fieldwork, thus after acquiring a great bulk of information. The purpose was to compare, co-validate and confront agronomic data with local farmers and internal and external technicians.

Agricultural calendars and the types, spatial distribution, periodicity, intensity, prediction, assessment and prevention of natural hazards in agriculture were characterized and mapped during parcel visits, transect walks, interviews and participatory surveys. Stereoscopic photo pairs, topographic maps and satellite images were used to plot the acquired information, using a GPS device. Information on agricultural budget analysis, soil-water conservation measures, recognition and assessment of the severity of agricultural plagues and diseases was also acquired during fieldwork and discussed during the second participatory workshop. Several individual and group interviews focused on cultivation history as part of the agronomic survey. These interviews were held during guided transect walks, at agricultural parcels and household compounds, and in a special session of the already mentioned workshop. Qualitative and quantitative agronomic information is discussed in chapters Nineteen, Twenty, Twenty One and Twenty Two.

## 14.8. Time series and spatial analysis

Integration of qualitative and quantitative information was conducted using various research techniques. Figure 14.13 shows a diagrammatic model of data integration, comparison and correlation. The main objective was to evaluate the local environmental and the technical knowledge systems using a co-validation analysis, that assumes both knowledge systems as synergetic and valuable for local endogenous development. Time series and spatial analysis are described hereafter.

### 14.8.1. Time series analysis

Time series analysis was used for human and livestock populations, climatic data, land-use changes, number of wooden-furniture workshops and estimated volume of wood extraction. It was also used for comparing maize production budgets and yield trends during a 20-year period (1977-1997). The understanding of the historical display and multiple perceptions of these factors plays an important role in the discussion of the local natural resource management strategy and, therefore, in the practice, maintenance and change of the local environmental knowledge at individual and local levels. Archival, official statistics and bibliographic research was conducted for this purpose. Findings were presented to the workshop participants and during individual and group interviews. In some cases, it was possible to compare and correlate technical with local information. That was the case, for example, of climatic data collected at the nearest station to San Francisco Pichátaro, covering a 40-year period. Technical climatic data was discussed with local individuals and correlated with the local ethno-climatologic information (see Chapter Twenty).

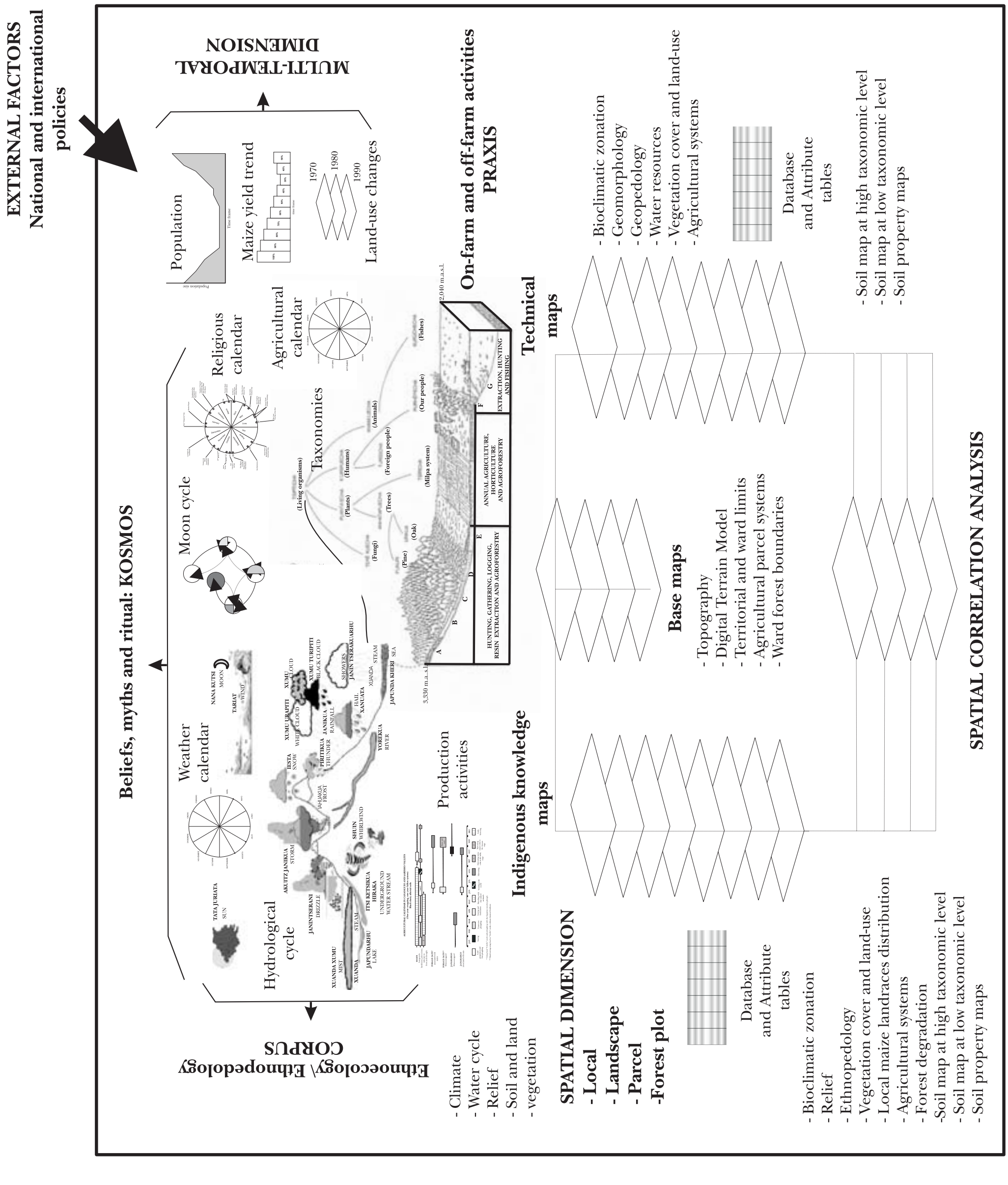



**Figure 14.13.** Data integration model

### 14.8.2 Multi-temporal spatial analysis

Multi-temporal spatial analysis was carried out for assessing the local land-use changes during a 6-year period (1986-1992), using the ILWIS 2.4 version software (1993). Two geo-referenced cloud-free TM Landsat images taken during the month of February of 1986 and 1992 were used for a supervised NDVI (Normalized Difference Vegetation Index) classification. NDVI values are a measure of the presence and condition of green vegetation using TM Landsat bands 3 and 4. Vegetated areas generally yield high values because of their relatively high near–infrared reflectance and low visible reflectance, while water, clouds and snow have larger visible reflectance than near-infrared reflectance, thus yielding negative values. Rock and bare soil areas have similar reflectance in the two bands and result in vegetation indices near zero . It is also recognized that well-preserved and densely forested areas yield higher values than less preserved or disturbed and not densely forested areas, with the last ones yielding the lowest values among vegetated areas (Schmidt and Karnieli, 2000). Therefore, NDVI can be used in the evaluation of land cover and land-use changes, deforestation, forest fire monitoring and plant growing seasons (Tucker et al., 1985; Liu et al., 2001).

Two basic sources were used for this analysis (Figure 14.14). The local territorial limits and ward boundaries map (1:25,000) was used to calculate land cover and land use-changes derived from the NDVI maps, within the local study area and ward territories. A vegetation cover and land-use map (1:25,000), that was interpreted using color aerial photographs from 1992 (Caballero et al., 1993), and a related attribute table storing field samples information, were also used for supervising the NDVI classification. A GPS device was used for sample point location. The attribute table included point information concerning vegetation type, vegetation association, geographical location, slope gradient, aspect, relief type, soil type according to the USDA Soil Taxonomy, vegetation structure and composition, dominant species, and other environmental factors, such as the degree and cause of disturbance. Vegetation cover and land-use sample points were used for supervising the 1992 NDVI TM Landsat image and then compared against the 1986 NDVI TM Landsat image. A NDVI value comparison table per sample point was created to assess the degree of disturbance and/or land-use change occurred during the 6-year period. Findings from this analysis are discussed in chapter Nineteen.

### 14.8.3. Spatial correlation analysis

Spatial correlation analysis consisted in comparing technical and local soil knowledge systems, using GIS techniques to cross the soil maps resulting from the geopedological and ethnopedological surveys. Though limited, the spatial comparison reveals similarities and differences between technical and local soil knowledge systems and might result in synergies aimed to resolve land management problems at local level. It also shows the consistency of each approach and the differences in perceiving, knowing and assessing soil and land resources between farmers and soil surveyors. Since farmers have a profound soil-landscape understanding, spatial analysis in a GIS environment was preferred to the multivariate statistical approach to compare both knowledge systems. This procedure consisted in several steps using the ILWIS 3.1 version software (1998).

Spatial comparison provides information from two different approaches developed for soil mapping. The geopedological semi-detailed survey (Zinck, 1988/89) allowed to map soils at sub-group level of the USDA Soil Taxonomy (Soil Survey Staff, 1998), based on technical profile descriptions and laboratory determinations (quantitative approach). The ethnopedological survey consisted in farmers' profile descriptions, participatory cross-sections and characterization of soil properties, mainly based on topsoil (0-40 cm) assessment and using qualitative criteria evolved from farmers' experience of the soil body behavior and land management. The ethnopedological survey mapped soil at 'variety' level, the lower hierarchical level of the local soil classification (chapter Twenty). Both soil maps are based on relief units according to scientific and local criteria, allowing also to assess similarities and differences between relief map units, which in both cases are basic factors for understanding soil distribution patterns, soil forming processes and soil behavior. The spatial correlation was carried out at three levels, which are described hereafter (Figure 14.15):

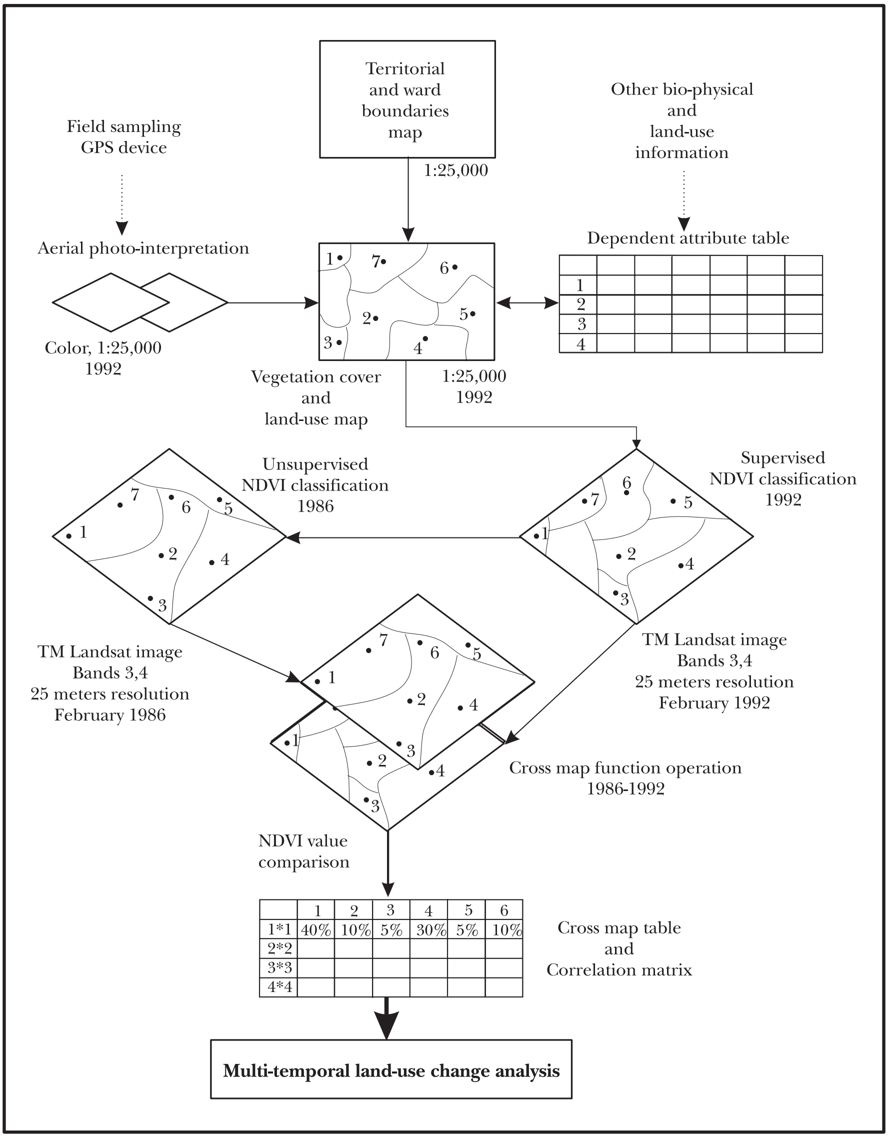



**Figure 14.14.** Land-use changes analysis model

(1) spatial correlation analysis at high taxonomic level to compare soil map units composed of taxa at order level according to the USDA Soil Taxonomy with soil map units based on the main soil groups according to the Purhépecha classification;

(2) a spatial correlation analysis at low taxonomic level to compare soil map units composed of taxa at subgroup level according to the USDA Soil Taxonomy with soil map units based on soil varieties according to the Purhépecha soil classification, and

(3) a spatial correlation analysis at soil property level, including: (1) texture, (2) moist color, (3) organic matter content, (5) consistence (dry, moist, wet), (6) internal drainage condition, (7) stoniness, and (8) rooting condition. Soil properties were chosen according to the importance given by farmers for agricultural purpose and soil quality assessment. Profile observations and

laboratory determinations were adjusted to 0-40 cm depth, hereafter named as topsoil, as farmers assess and classify the above properties within this soil depth.

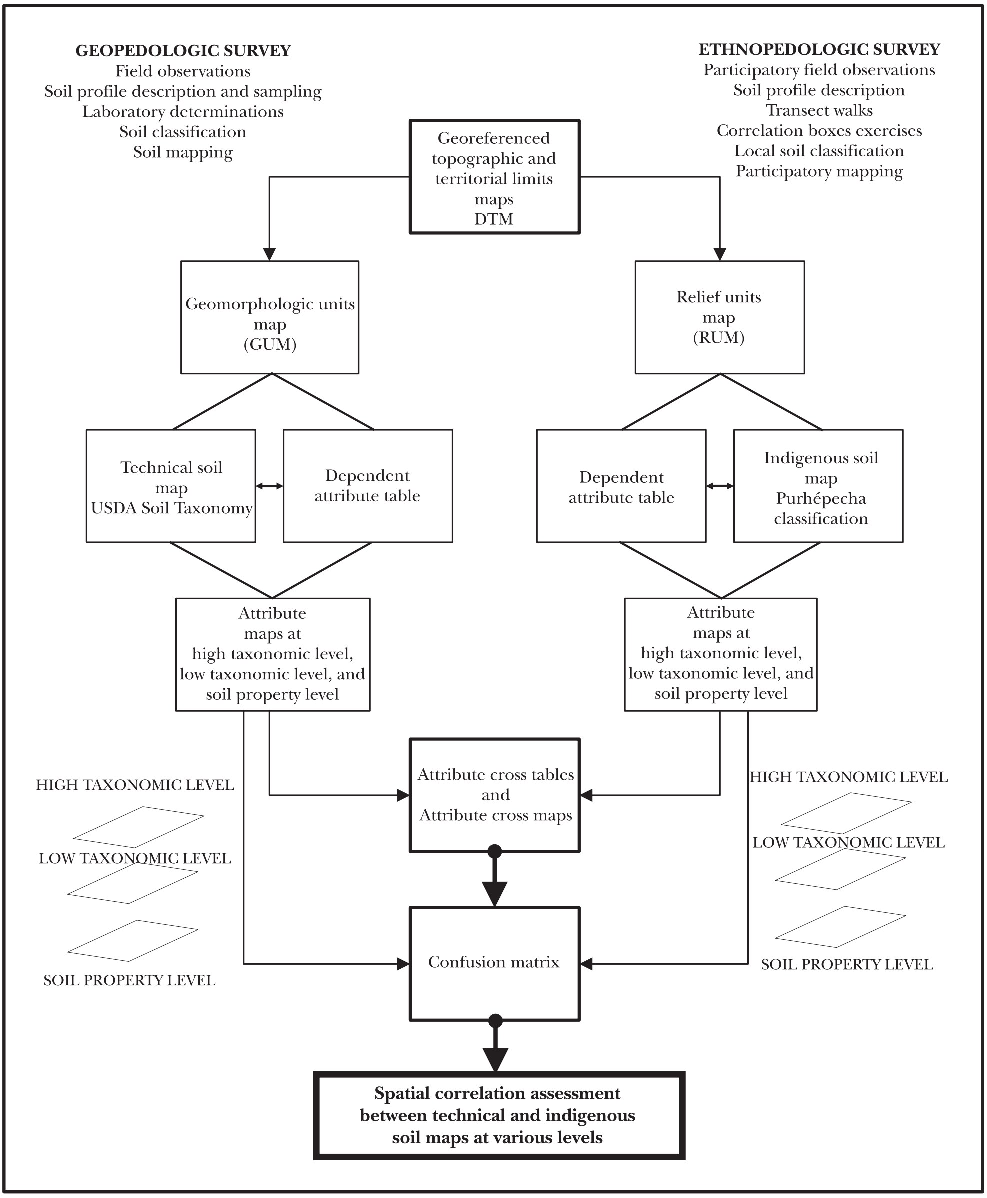



**Figure 14.15.** Spatial correlation analysis model

Steps followed for spatial correlation analysis are described hereafter (Figure 14.15):

(1) technical and indigenous raster soil maps were used as bases for spatial correlation analysis. Both maps used the same georeference and domain;
(2) a dependent attribute table was created for each map using the same domain as the raster maps;
(3) the technical attribute table consisted in 23 columns starting from relief units and followed by

soil map units according to the USDA Soil Taxonomy and 20 dependent soil properties, with 11 of them correlated. Profile descriptions and laboratory determinations (soil properties) were stored in the rows corresponding to each relief and soil map unit. Soil properties represented by numerical, such as pH or organic matter content, were converted into semantic classes according to conventional criteria (e.g. 6% organic matter was converted to class Very High). Prior to this, all profile observations and laboratory determinations were adjusted to 0-40 cm depth or topsoil. Of note is that not all geopedologic units had information of soil properties, as some of them were inferred during the geopedological survey and were thus not correlated at soil property level;

(4) the indigenous attribute table consisted in 19 columns starting from relief units and followed by soil map units according to the Purhépecha soil classification and 17 dependent soil properties assessed by farmers, with 11 of them correlated. All soil property determinations were stored as semantic classes. Of note is that all indigenous soil map units had soil property information but not all of them were correlated, as not all technical soil map units recorded soil property determinations;

(5) thirteen attribute raster maps were created from each technical and indigenous soil map unit, totaling 26 attribute maps that were latter overlaid using a cross operation in ILWIS 3.1 software. By creating an attribute map, the class name of each pixel in the original (input) map is replaced by the class found in a certain column in the attribute table. The attribute (output) map uses the same domain as the specified attribute column and the same georeference as the input map;

(6) a pair of attribute maps showing the same information at the three levels (e.g. the technical topsoil moist color and the indigenous topsoil moist color maps) was overlaid using the cross function operation, which performs an overlay of two raster maps. This operation allows to compare pixels at the same position in both attribute maps. The occurring combinations of class names of pixels in the first and second input maps are stored. These combinations give an output cross map and a cross table. The cross table includes the combinations of input classes, the number of pixels that occur for each combination, and the area of each combination. Combinations of undefined values will by default not appear on the output cross map and cross table, i.e. undefined classes are ignored;

(7) a confusion matrix operation was conducted after the spatial correlation analysis (the cross operation) was carried out for each of the 13 pairs of attribute maps, producing 13 cross maps with their dependent cross tables. Confusion matrix allowed to assess the spatial correlation degree (i.e. high correlation against low correlation) at high and low taxonomic levels, or the correlation percentage of similar technical and indigenous soil property classes (i.e. 60% correlation between the technical silty clay loam textural class and the tupuri-charandani (dusty-clayey) indigenous textural class) of the assessed cross maps, as well as their quantities. Quantities are given in number of pixels; thus, it was possible to convert these figures into area size and area percentage, knowing the pixel size. The confusion matrix procedure gives a two-way possibility to assess spatial correlation accuracy as it can create matrices using both attribute tables as first and second columns (i.e. the technical topsoil consistence dry table as a first column with the indigenous consistence dry table as a second column, against the indigenous consistence dry table as a first column with the technical topsoil consistence dry table as a second column), which in this case gave different results. This is because the confusion matrix operation is generally used to assess the accuracy of an image classification when compared to ground truth information and to identify the nature of classification errors, as well as their quantities. In this case, similar images are correlated to find the degree of accuracy and reliability. In contrast, the same correlation matrix used soil maps derived from different procedures (quantitative against qualitative approaches), to find commonalities and differences between different maps. This is why the accuracy and reliability averages were not useful in the last case, and

(8) assessing the degree of spatial correlation between the technical and indigenous soil maps required a further evaluation. Information derived from cross mapping and confusion matrices at

high and low taxonomic levels was classified into two main domains: (1) high spatial correlation and (2) low spatial correlation. Spatial correlation was considered to be high whenever one dominant technical soil class or two similar soil classes, one being at least 50%, occupied 75% or more of the extent of an indigenous soil cartographic unit, otherwise spatial correlation was considered to be low. For the purpose of spatial correlation, local soil cartographic units were taken as reference units. At soil property level, spatial correlation analysis was taken from similarities between the technical and indigenous classes in a straightforward way. Percentage of spatial correlation between similar technical and indigenous soil property classes was taken as reference to assess which soil properties matched or did not. Spatial correlation was considered nil when two dissimilar classes were represented in the same cartographic unit (i.e. when the technical 'Very High' organic matter content class was spatially correlated with the indigenous 'Low' organic matter content class). Findings from the spatial correlation analysis are discussed in chapter Twenty Two.

### 14.9. Conclusion

This chapter presents the research framework and the ample repertory of research methods and techniques that were used to deal with the multifaceted nature of local ethnopedology. Only by working at multiple scales, with multiple data sources, and by linking qualitative and quantitative methods, was it possible to generate appropriate data, information and insights, that allowed the analysis presented in chapters of Part Three.

The bulk of information that is analyzed at local level was derived from primary sources, including findings from an extensive communication exchange with the local actors (Figure 14.16), although extensive use was also made of secondary sources, such as archival documents, statistical data and information derived from previous research done by the author of this thesis and others. However, the close collaboration with villagers, that took a great deal of time and effort, made possible to acquire and analyze the necessary data. An interdisciplinary and interpretive research strategy allowed to combine natural and social sciences methodology, with the active participation of numerous local individuals.

**Figure 14.16.** Participants at the first participatory workshop held in 1997

# CHAPTER FIFTEEN

## THE PÁTZCUARO LAKE BASIN: BIO-PHYSICAL PATTERNS, NATURAL HISTORY AND ENVIRONMENTAL DEGRADATION

### 15.1. INTRODUCTION

Chapter Fifteen analyzes the Pátzcuaro Lake Basin as a natural region. Main bio-physical characteristics are discussed to show the complexity of this lake basin despite its small size and recent volcanic origin. The overlapping of climatic, geomorphic, pedological and vegetational patterns leads to a patchwork-like distribution of landscapes controlled by elevation, climate and topography. The natural fragility of the Pátzcuaro Basin derives from its mountainous landscapes and the presence of an endorreic permanent lake, largely fed by shallow groundwater inflow and local runoff during the rainy season.

This chapter aims to present the eco-geographic context of the location of San Francisco Pichátaro, the local case study area. It offers relevant information about the natural resources that have provided the ecological base for the long-standing occupation of the Pátzcuaro Basin, including the indigenous Purhépecha people. It also discusses the natural evolution of the basin and the lake using palinological, paleo-climatic, biogeographic and geomorphic data. The multilineal natural history of the last 50,000 years shows periods of environmental degradation, such as the eutrophication of the lake caused by climate change and volcanism. Finally, this chapter assesses the contemporaneous environmental degradation largely caused by human impact.

Chapter Fifteen is subdivided in six sections. Section 15.2 describes the general characteristics and the location of the Pátzcuaro Lake Basin within the Trans-Mexican Volcanic Belt (TMVB). Section 15.3 analyzes climatic, geomorphic, pedological, vegetational and limnological characteristics and spatial patterns. It also offers a bioclimatic zonation that synthesizes the eco-geographic patchwork-like pattern of the basin. Section 15.4 analyzes the paleo-geographic evolution of the basin during the last 50,000 years. Section 15.5 assesses environmental degradation of the basin using the morphogenesis-pedogenesis balance as an approach to interpret stability and resilience stages of the surrounding landscapes. Section 15.6 summarizes relevant conclusions.

### 15.2. MAIN CHARACTERISTICS AND GEOGRAPHIC LOCATION WITHIN THE TRANS-MEXICAN VOLCANIC BELT

The region of Lake Pátzcuaro is located in the state of Michoacán, central Mexico. This relatively small region is one of the 25 lacustrine basins distributed along the Trans-Mexican Volcanic Belt (TMVB), a strip of late Tertiary and Quaternary volcanoes that traverses central Mexico from the Pacific coast to the Gulf of Mexico, mostly between 19º and 20º N. The TMVB intersperses with the southern portion of the Central Mexican Highlands, creating a landscape of tectonic depressions bordered by volcanoes (Figure 15.1).

The TMVB crosses the sub-humid temperate highlands, one of the six agro-ecological zones of Middle America. In detail, the TMVB consists of areas with numerous small volcanoes (monogenetic fields) intercalated with areas dominated by large strato-volcanoes. The area of central Michoacán, called Meseta Tarasca, including the Pátzcuaro Lake Basin, is an example of these monogenetic fields, while 12 strato-volcanoes peak above 3,800 m.a.s.l., and the three highest – Pico de Orizaba or Citlaltépetl (5,675 m.a.s.l), Popocatépetl (5,452 m.a.s.l) and Iztacchíhuatl (5,286 m.a.s.l) – are high enough to support small glaciers at present. Elevation in the bottomlands of the TMVB ranges from 2,000 to 2,500 m.a.s.l., and under the present temperate climate, with seasonal rainfall and high evaporation, some basins support small lakes, like Pátzcuaro, one of the most preserved lakes of central Mexico.

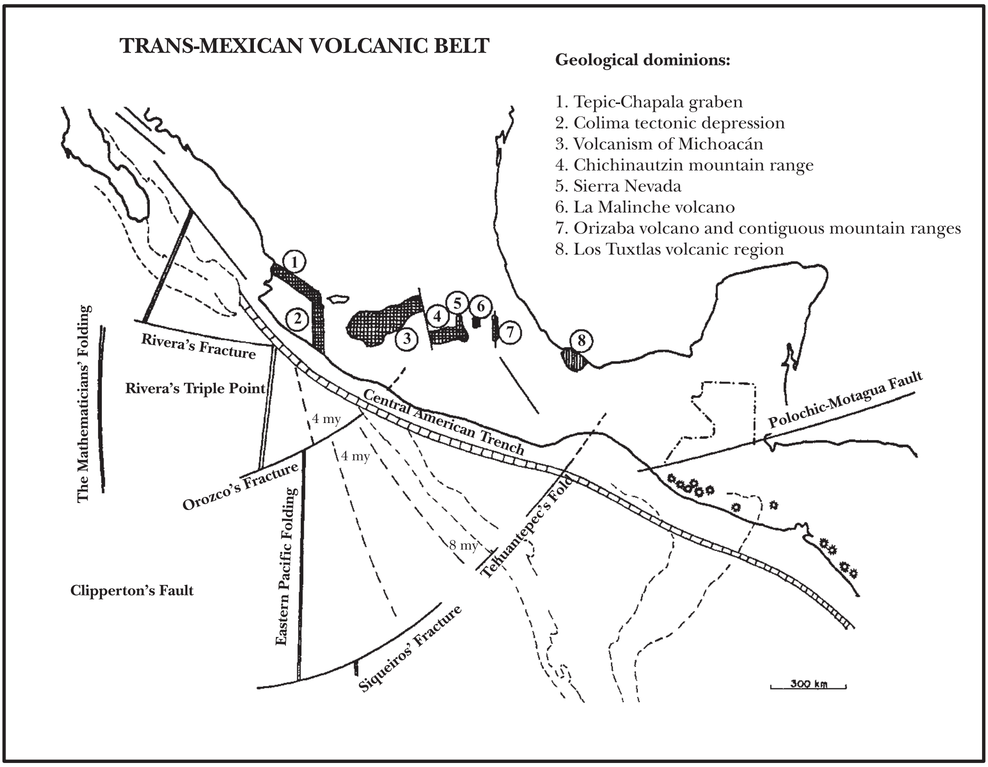



**Figure 15.1.** Trans-Mexican Volcanic Belt and its geological dominions. **Sources:** Demant (1978); Barrera-Bassols (1986)

The TMVB is part of the most densely populated area of the country since pre-Hispanic times. Fertile soils and extended lakes supported large populations, complex agricultural systems and tributary empires, long before the Spanish conquest. Tenochtitlan Lake in the Basin of Mexico and Pátzcuaro Lake, the geopolitical cores of the Aztec and Purhépecha (or Tarascan) States, respectively, were among the most important ones. Favorable climatic conditions for colonists maintained dense populations during the 500 years following the Spanish conquest. Today, the TMVB faces fast urbanization and industrial development, coexisting with traditional agricultural practices in the rural areas inhabited by small-scale *Mestizo* farmers and indigenous communities. Land-use changes, deforestation, extreme poverty and migration constitute main land degradation factors that are reshaping the mountainous landscapes of the TMVB. These factors are discussed in Chapters Sixteen and Seventeeen.

The region of Lake Pátzcuaro faces challenges similar to those of the TMVB. Being the capital of one of the most outstanding pre-Hispanic societies, occupied since at least 4,000 years, this small and environmentally fragile basin stands as one of the most vital indigenous areas in contemporary Middle America. The maintenance of rural production had an impact on the fragile natural environment in the past. Rampant urbanization, land-use changes, cultural changes, rapid population growth and extreme poverty accelerated land degradation and the eutrophication of the lake during the last 60 years. Since then, governmental agrarian policies, international food demands, rural modernization, tourism affluence and the long-standing exploitation and misunderstanding of the historical inhabitants –the Purhépecha–, have led to increased environmental degradation, despite the natural and cultural richness and potentiality of the region.

The region of Lake Pátzcuaro (19° 27' – 19° 44' N and 101° 27' – 101° 53' W) lies at an elevation range of 2,040 to 3,400 m.a.s.l., about 60 kilometers east-southeast of Morelia City, the capital of Michoacán (Figure 15.2) (Barrera-Bassols, 1986). This relatively small endorreic basin (1,000 km$^2$) forms part of the Michoacán Volcanic Dominion (MVD), one of the four geological areas of the TMVB. The MVD is considered as a monogenetic field that comprises the greatest number of Quaternary –Paricutín style- volcanoes in the TMVB (Figure 15.3) (Demant, 1978, 1981, 1992).

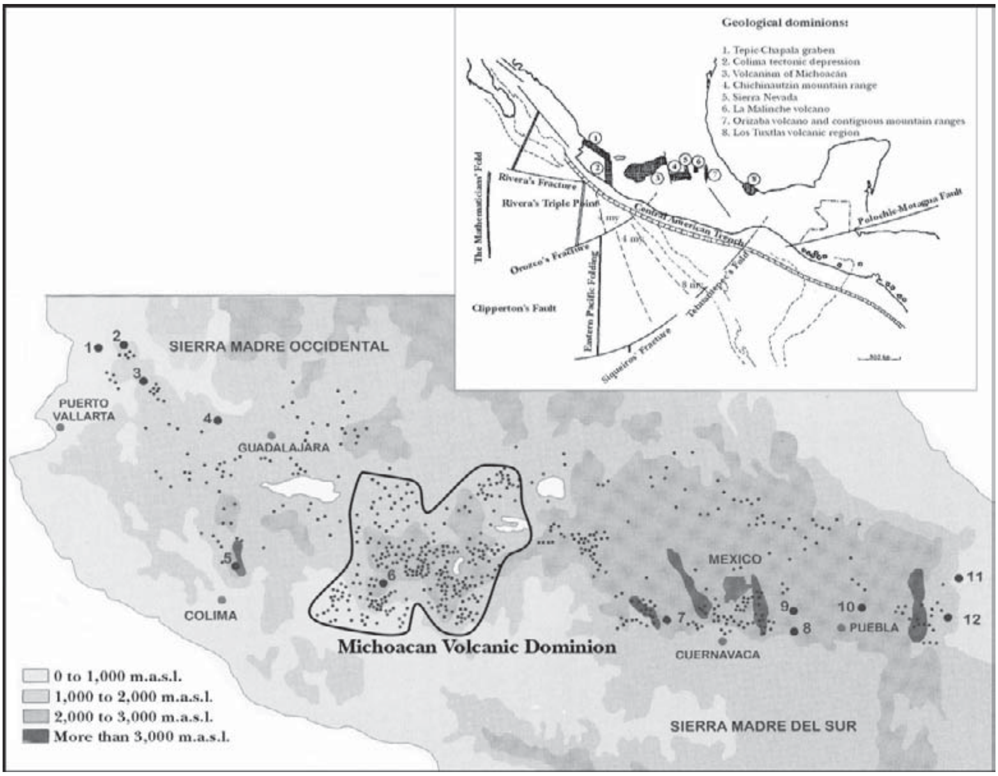



**Figure 15.2.** Michoacán Volcanic Dominion within the TMVB. Dots represent monogenetic volcanoes and numbers represent strato-volcanoes with peaks above 4,500 m.a.s.l.

The main characteristics of the MVD are:

(1) young volcanism (Holocene), expressed by a great number of small monogenetic volcanoes (escoria and cinder cones), with lava flows of less than 1km$^3$ (>15,000 years BP) (Hasenaka and Carmichael, 1985);
(2) the presence of older and higher monogenetic volcanoes (Plio-Quaternary) surrounding the escoria cones, that form the principal mountain ranges of the area (300,000–1.5My) (Demant, 1978);
(3) the absence of strato-volcanoes that are characteristic of other geological dominions of the TMVB (Demant, 1981);
(4) the presence of grabens with ENE-WSW or N-S orientation due to the influence of tension-slackening tectonism and faulting (Pasquare et al., 1988), and
(5) the relatively low volume of magma emitted during the Quaternary, despite the presence of numerous volcanoes (Hasenaka and Carmichael, 1985).

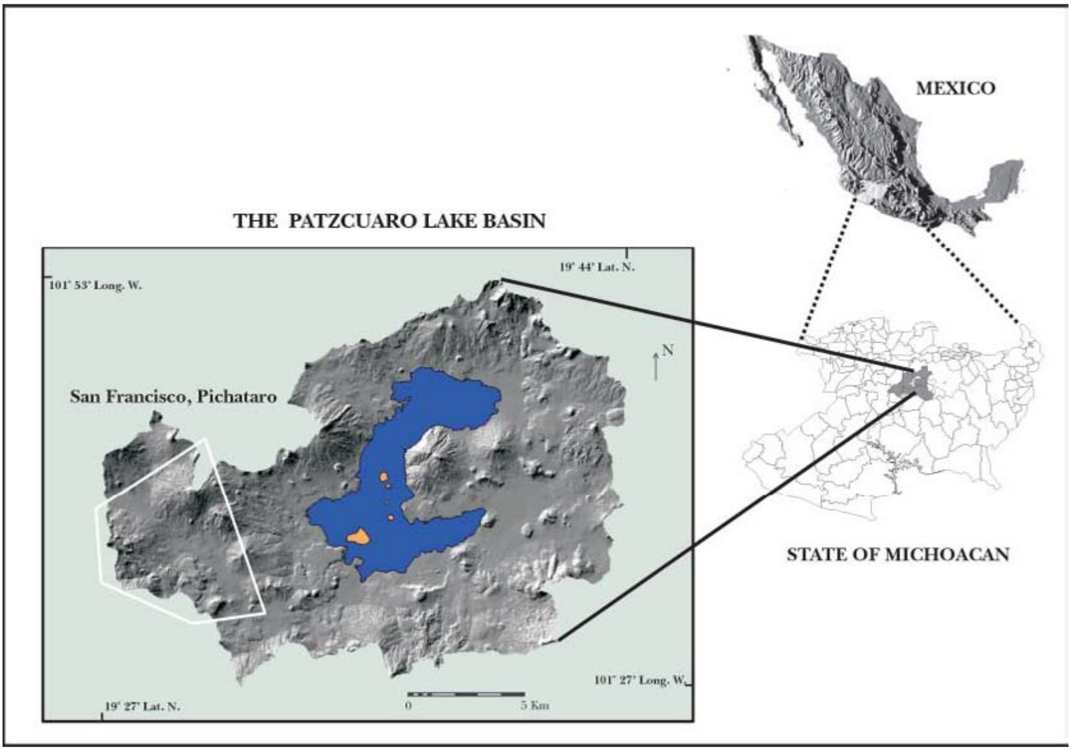



**Figure 15.3.** The Pátzcuaro Lake Basin location within the state of Michoacán, Mexico

Volcanism and block faulting originated the basin of Lake Pátzcuaro, one of the grabens formed by tectonism in the MVD during the Miocene-Pliocene and Pleistocene. Other grabens in this geological dominion are the Zirahuén, Zacapu and Cuitzeo basins. Pasquare and collaborators (1988) recognize two tectonic periods that explain the geological evolution of northern central Michoacán. The first period occurred during the Low-Mid Pliocene, evidenced by ENE-WSW primary fault lines that induced the formation of N-S tectonic depressions, as is the case of the Pátzcuaro Basin. The second tectonic period occurred during the Pleistocene, evidenced by NNW-SSE primary faults and ENE-WSW secondary faulting (Demant, 1992). Volcanic activity, through the action of lava flows and uplifting that dammed and compartmentalized pre-existing tributaries of the Rio Lerma system during the Pleistocene, contributed to the formation of Lake Pátzcuaro (De Buen, 1943, Barrera-Bassols, 1986; Israde and Graduño, 2002). Pleistocene volcanism and tectonism formed the lakes Zirahuén, Zacapu and Cuitzeo (De Buen, 1943; Barbour, 1973; Tricart, 1992; Chacón, 1993; Bradbury, 1989, 2000). The persistence of Lake Pátzcuaro during the last 48,000 years indicates that this region did not witness severe aridity, although climatic changes since the Wisconsin (Würm) age have impacted the ecology of the lake (Watts and Bradbury, 1982; Bradbury, 1989, 2000).

## 15.3. Bio-physical patterns

### 15.3.1. Climate

The present climate of Lake Pátzcuaro region is characterized by mid- to late-summer rainfall, that results from the northward migration of the Inter-Tropical Convergence Zone (ITCZ) and the expansion of the Bermuda/ Azores and East Pacific Highs (Barrera-Bassols, 1986; Metcalfe, 1987). The moisture is presumed to come from the Caribbean in the east, although eastern Pacific and Gulf of California moisture sources may be more important, especially for Western Mexico (Barrera-Bassols, 1986; Douglas et al., 1993; Bradbury, 2000). During the winter, stable dry conditions occur as the ITCZ returns toward the equator and the subtropical high-pressure belt with westerly flow humid conditions extends over much of Mexico. However, cold outbreaks of polar air (*nortes*), associated with meridional flow, can bring winter rainfall and low temperatures to the Central Highlands at the latitude of Lake Pátzcuaro and even farther south (Metcalfe, 1987).

The regional climate is temperate sub-humid and this is the most humid of the sub-humid temperate climates in Mexico (C ($W'_2$) (W) b (i') g), according to Köppen modified by Garcia (1981) for the Mexican climatic conditions. Mean annual rainfall is about 1,000 mm, but varies significantly according to elevation and from year to year. Mean annual evaporation (about 1,500 mm/year) is highest during spring and early summer, when high temperatures and windy conditions coincide during the dry season. Annual temperature averages 16.3°C (Barrera-Bassols, 1986; Chacón, 1993). The seasonal variation of temperature shows maximum monthly temperatures (20°C) during the early summer (May-June). Rainfall significantly cools mid- and late-summer temperatures. Winter temperatures average 12-13°C and frost occasionally occurs in winter months (Figures 15.4 and 15.5). Rainfall extends during summer and part of autumn, with a percentage of winter rains less than 5% of the total annual rainfall. Temperature regime is mesic, with a cool and long summer and with low temperature oscillation during the year. Maximum temperatures occur before the summer solstice (Barrera-Bassols, 1986).

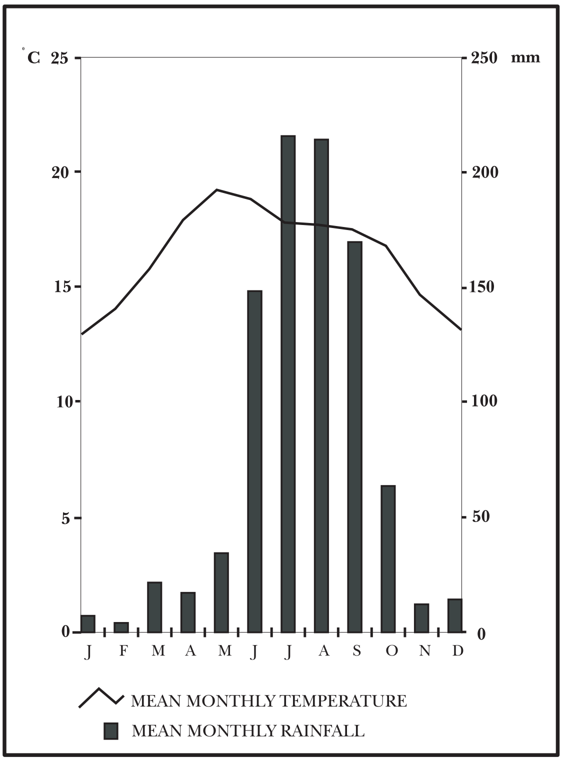



**Figure 15.4.** Temperature and rainfall regimes (1940-1990). Pátzcuaro station (2,040 m.a.s.l.).
**Source:** Barrera-Bassols (1986)

## 15.3.2 Geomorphology

Volcanic mountains, inter-mountainous valleys, piedmonts, hillands and lacustrine plains are the main landscapes dominating the region of Lake Pátzcuaro (Figure 15.6).

(1) Volcanic mountains

Volcanic mountain ranges (*sierras*) surround the endorreic basin of Pátzcuaro. They dominate in the northern (Sierras de Comanjá, El Zirate and El Tigre), western (Sierras de Pátzcuaro and Pichátaro) and southern (Sierras de Santa Clara, Tingambato and Nahuatzen) portions of the basin (Figure 15.7). Four of the highest peaks surpass 3,000 m.a.s.l. (Zirate Mt., 3,300 m.a.s.l; Frijol and Zirahuén Mts., 3,270 m.a.s.l., and La Virgen and El Chivo Mts., 3,250 m.a.s.l.). Most of them are Plio-Quaternary monogenetic volcanoes with steep slopes and convex summits as a result of the partial erosion of their craters. They present steep escarpment and are highly dissected in radial patterns. Escarpments and cuestas composed by volcanic breccias, hanging basaltic lava flows and scarps are main relief types and landform types (Barrera-Bassols, 1986).
El Zirate is the only mountain composed by Plio-Pleistocene andesites, representing the oldest volcanism in the region while the majority of volcanoes are composed by Pleistocene-Holocene basalts, representing the youngest volcanism in the region (Demant, 1992).

(2) Inter-mountainous valleys

Unevenly and scattered inter-mountainous valleys were formed by the compartmentalization of former fluvio-lacustrine valleys by Pleistocene and /or Holocene volcanism and tectonism. Former tributary valleys were blocked by lava flows and uplifting, and filled by fluvio-volcanic and alluvial deposits, producing concave bottom-level lands. They are surrounded by Plio-Quaternary volcanoes, Holocene scoria and cinder cones, and basaltic lava plateaus. Relevant examples at regional level are the Cananguio, Pichátaro and Huiramangaro-Tumbio valleys (Figure 15.7).

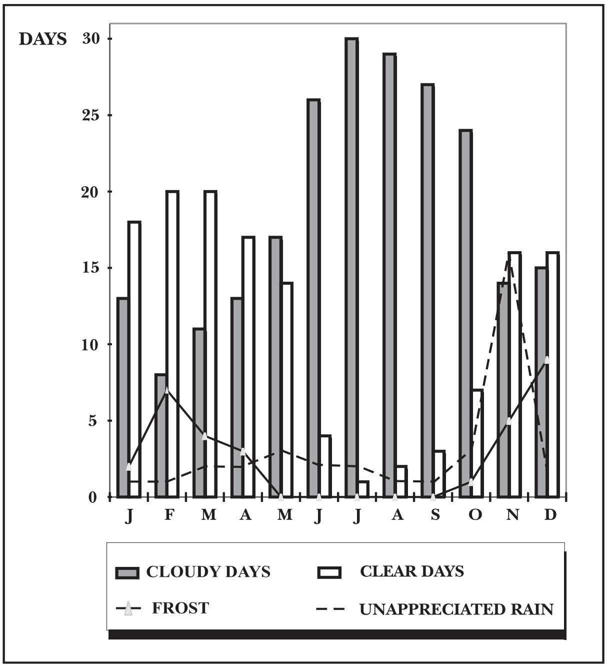



**Figure 15.5.** Mean monthly cloudy days (1940-1990). Pátzcuaro station (2,040 m.a.s.l.).**Source:** Barrera-Bassols (1986)

(3) Piedmonts

Piedmonts form an extended but scattered landscape surrounding the catchment, stretching along the hillands and Plio-Quaternary mountains, with slopes varying from steep to nearly level. The piedmonts have alluvial and colluvio-alluvial materials in the form of glacis (or pediments) and fans, according to the geopedologic taxonomic system (Zinck, 1988/1989). Dissected depositional glacis are composed of coalescent alluvial fans with heterometric materials, including gravels, cobbles and boulders. Typical erosional features are *barrancos (*gullies deeper than 25 m*)*, gullies and rills. Active alluvial fans receive and transport heterometric sediment loads from the highlands. Some of them are deeply incised, forming rugged bottom terrains or barrancos formed by intermittent streams. Depositional glacis, formed by gently sloping coalescent fans of colluvio-alluvial origin, are located in the lower portions of the piedmonts.

(4) Hilland

Hillands are located at the bottom of the volcanic mountains or stretching along the piedmonts and the lacustrine plains. Hills also occur as isolated relief forms within the lacustrine plains. Small –Paricutín type –Holocene volcanic cones with well-preserved morphological features including craters, old volcanic cones, 1-5 $km^3$ basaltic lava flows, small volcanic domes, and uplifted alluvial or fluvio-lacustrine valleys and vales are main relief forms. Faulting and explosive volcanism are the main forming processes, showing the most recent volcanic activity and tectonism in the region. For practical purpose, piedmonts and hillands are integrated as one landscape unit according to the scale of analysis (Figure 15.6).

(5) Lacustrine plains

Lacustrine plains were formed in tectonic depressions (grabens) and filled in by Quaternary fluvio-volcanic and/or lacustrine sediments. Lacustrine plains are scattered along the Pátzcuaro lakeshore and present slightly concave to flat and slightly sloping to level topography. Main relief types are playas and lagunary flats affected

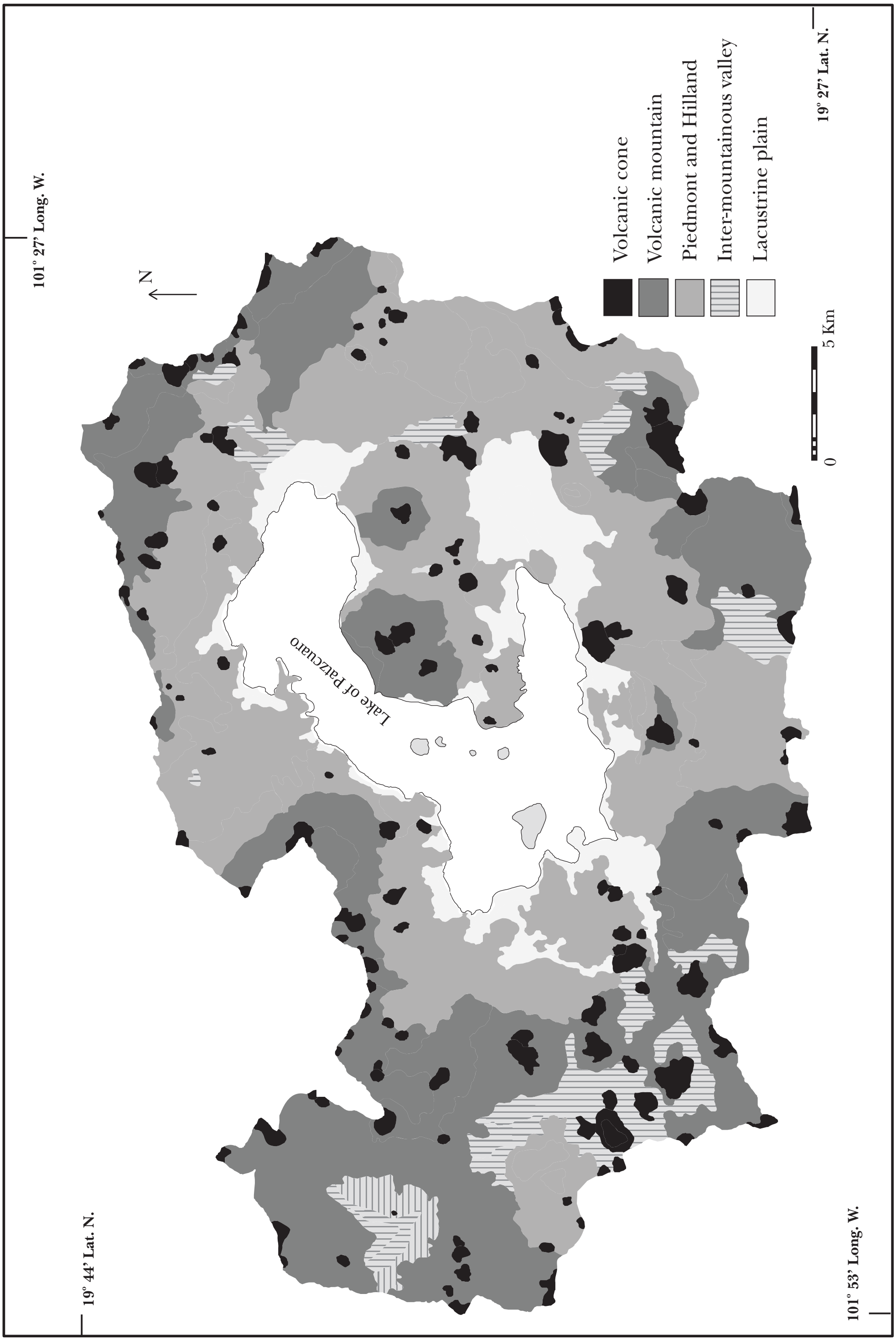



**Figure 15.6.** Main landscapes of the Pátzcuaro Lake Basin, Mexico. **Source:** Barrera-Bassols (1987)

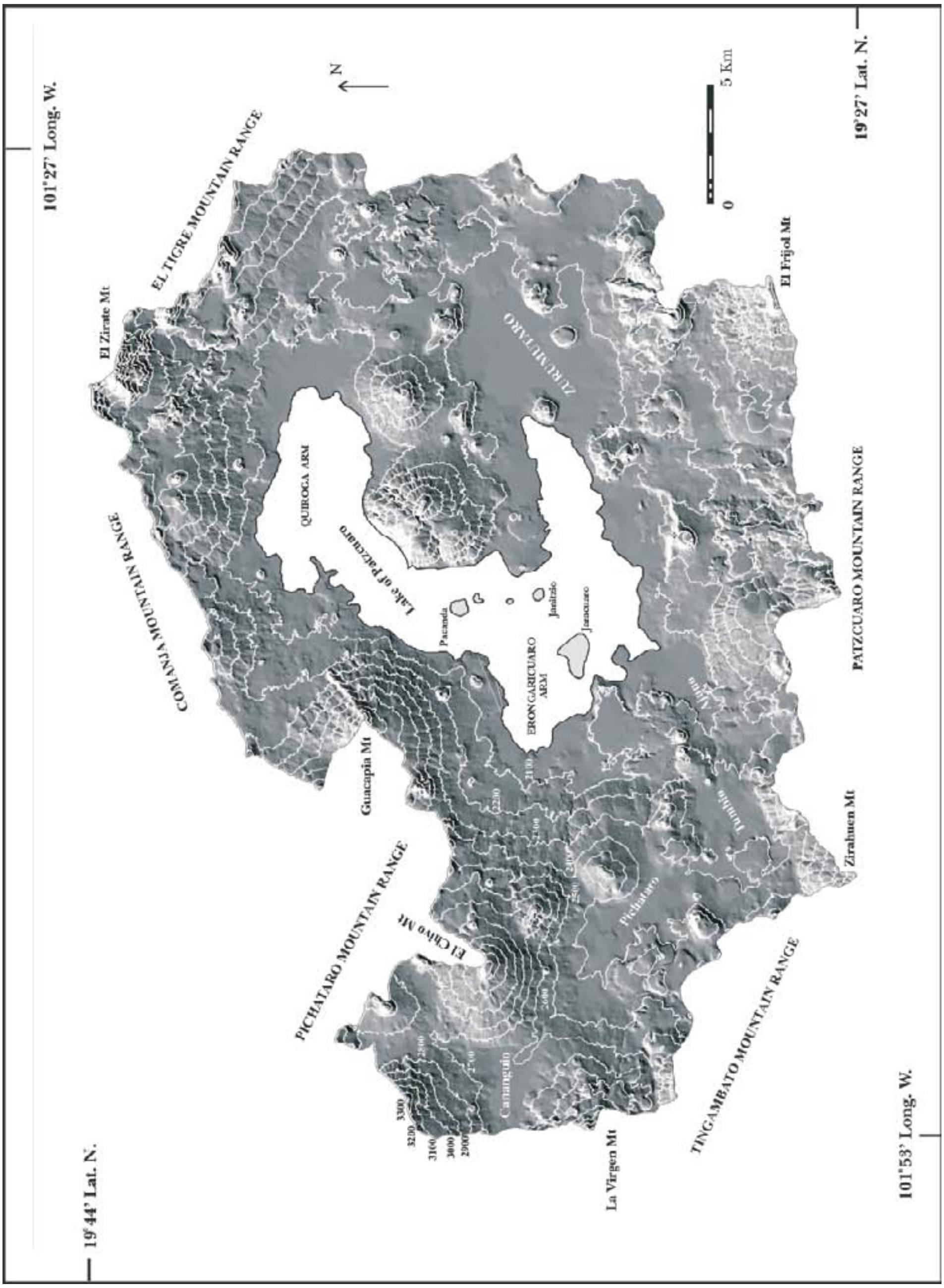



**Figure 15.7**. Digital terrain model of the Pátzcuaro Lake Basin, Mexico

by periodic floods. They are typically underlaid by thick beds of clay with inclusion of organic layers. These scattered landscapes show the former extent of the paleo-lake of Pátzcuaro. Zurumútaro and Quiroga plains, located in the southern and northern portions of the basin, are the most extensive ones (Figure 15.7).

Holocene explosive volcanism, local neo-tectonism and climatic change molded the shape and size of the lacustrine plains, formerly less extended and forming the bed of an exorreic Pleistocene paleo-lake (Israde and Garduño, 2002; Bradbury, 2000). Faulted, tilted and uplifted diatomites and diatomaceous lake sediments, including numerous layers of volcanic ash, crop out specially along the southwestern side of the basin, testifying the effects of tectonics and volcanism in controlling the morphology of the lacustrine plains and the depth of the basin and the lake (Metcalfe, 1985; Tricart, 1992; Israde et al., 2002). Climatic change and /or anthropogenic modifications of the surrounding landscapes during the last 10,000 years negatively impacted the level of the lake and accelerated the deposition and filling in of the lacustrine plains (De Buen, 1943; Barbour, 1973; Watts and Bradbury, 1982; Gorenstein and Pollard, 1983; Barrera-Bassols, 1986; Chacón, 1993; O'Hara et al., 1993).

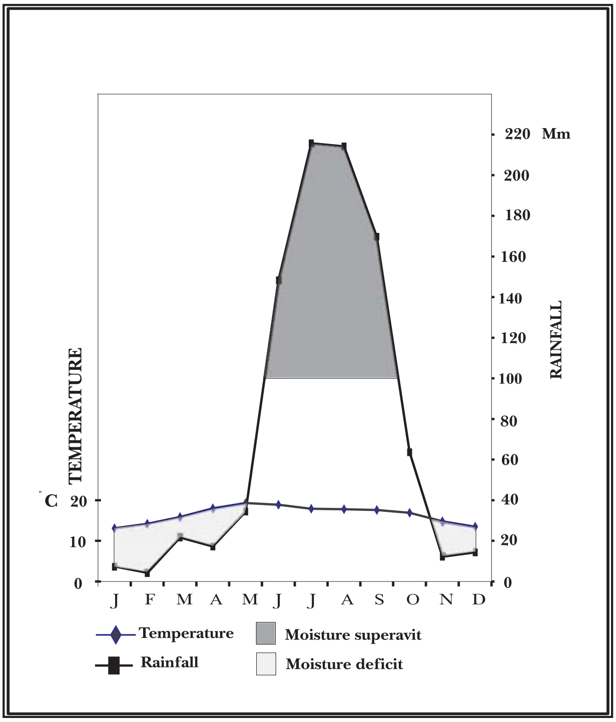



**Figure 15.8.** Umbrothermic regime of the Pátzcuaro Lake Basin. **Source:** Barrera-Bassols (1986)

### 15.3.3 Soils

The soil moisture regime is ustic and soils are commonly dry for less than six months . Exceptions are found along the lake borders and in some flat depressions with aquic regime, and above 2,900 m.a.s.l. with udic regime. The soil temperature regime is isomesic, with an average soil temperature of 12-14°C and the difference between winter and summer soil temperatures of less than 5°C (estimated from air temperature data) (Figure 15.8). Volcanism, topography and the permanent presence of a lake body since at least 50,000 years BP have influenced soil formation (West, 1947; Watts and Bradbury, 1982; Bradbury, 2000). Andisols, Acrisols, Luvisols, Lithosols, Gleysols, Cambisols, Vertisols, Phaeozems, and Planosols occur in a patchwork-like pattern within the catchment (FAO/ UNESCO/DETENAL, 1980) (Figure 15.9). The following soil description is generalized from pedological maps and laboratory determinations (Barrera-Bassols, 1986).

(1) Andisols

Andisols occur especially in the southwestern and western portions of the Pátzcuaro Lake Basin, with some inclusions in the southern and northern portions (Figure 15.9). These are the most representative soils, covering 50% of the basin. The southern and western portions of the Pátzcuaro Lake Basin form the boundary of the Sierra Tarasca, where Holocene volcanism dominates (Demant, 1979; Ferrusquía-Villafranca, 1993). Sierra Tarasca is still an active volcanic area. Volcanic explosions took place in the Sierra Tarasca during the last 200 years. The last one that gave rise to the Paricutín volcano, at just 60 kilometers to the east of Pátzcuaro, occurred during 1943-1949 (West, 1947). Paricutín-style monogenetic volcanoes dominate the Sierra Tarasca and the Pátzcuaro basin, determining the distribution of Andisols. These soils are distributed mainly from 2,200 m.a.s.l.

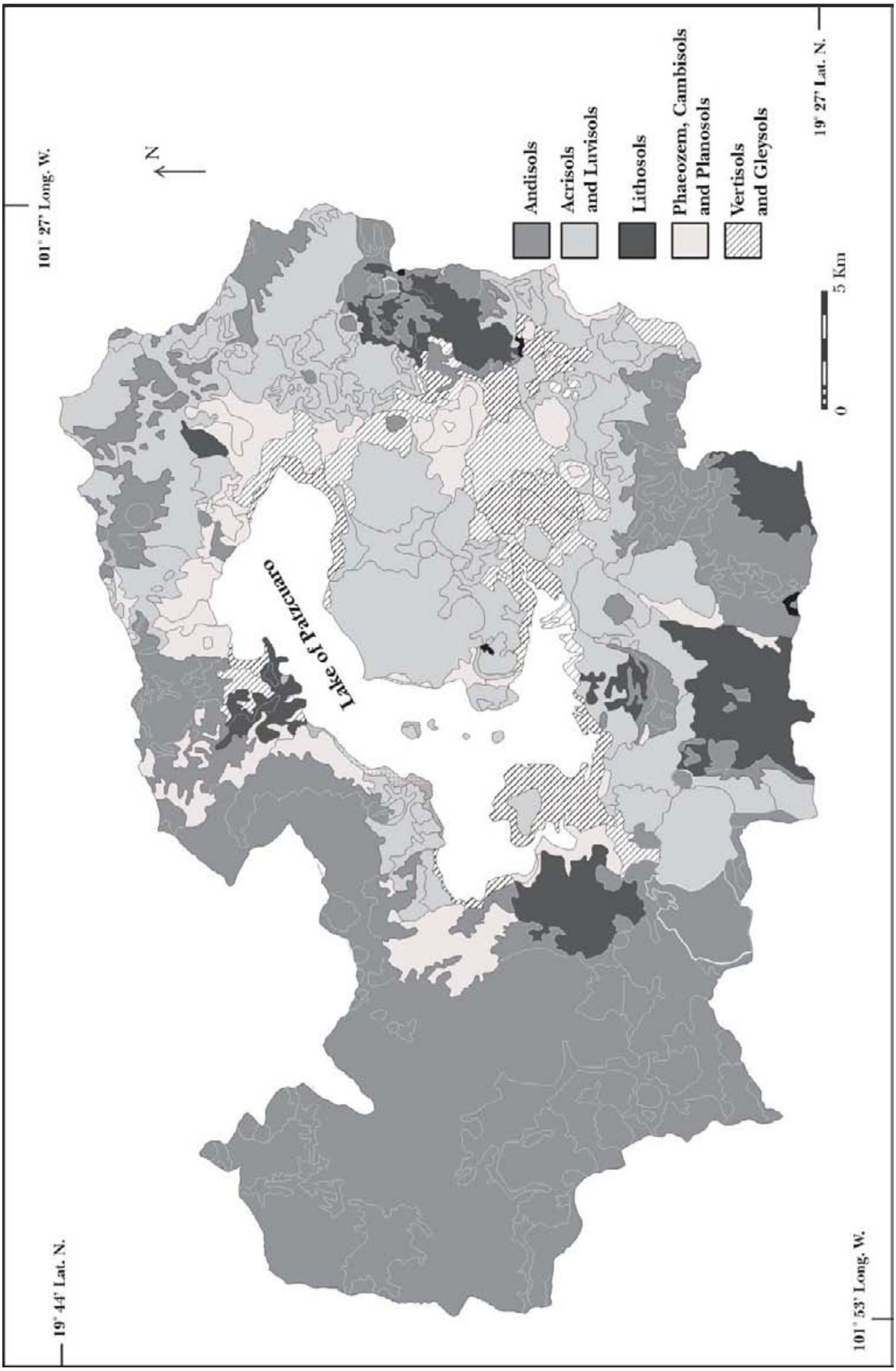



**Figure 15.9.** Main soil types of the Pátzcuaro Basin according to FAO/UNESCO/DETENAL soil legend. **Modified from:** DETENAL, (1980)

up to the higher peaks, at 3,340 m.a.s.l. They are the dominant soils in the mountains, in the inter-mountainous valleys and, to some extent, in the piedmonts of the basin. Main soil sub-types are the Humic and Ochric Andisols, according to the FAO/UNESCO/DETENAL (Cartas Edafológicas E-14 A21, A22, A31 and A32, scale 1:50,000).

Humic and Ochric Andisols (FAO/UNESCO/DETENAL, 1979) occur on slopes and bottomlands, respectively. They are friable and loose to a good depth, with low bulk density and aggregates showing considerable structural stability. Color of the surface horizons varies from yellowish brown to black under moist conditions, according to the Munsell color chart (1992). Soil reaction varies from moderately to strongly acid. Andisols contain high amounts of phosphorous and (non-exchangable) aluminum, have relatively high amounts of organic matter in surface and sub-surface horizons, and are moderately fertile for agricultural purposes, despite being intensively used over the last 4,000 years. The texture of surface and subsurface horizons ranges from silt to silty loam, as reflection of different depositional phases. Soil structure is weak to moderate subangular blocky in surface and sub-surface horizons, and soil depth ranges from moderately deep to very deep. Andisols often present lithologic discontinuities and buried soils occur as a result of the Holocene volcanic activity in the region. They show no evidence of run-off erosion but, when dry, they are prone to wind erosion.

(2) Acrisols and Luvisols

Acrisols and Luvisols (FAO/UNESCO/DETENAL, 1979), cover some 25% of the basin, dominating in the northern and eastern portions with some inclusions in the southern portion (Figure 15.9). They occur under udic and ustic soil temperature regimes, developing from basaltic or andesitic lithology. Acrisols and Luvisols are distributed mainly on the Plio-Quaternary volcanoes, the oldest in the region, and above 2,100 m.a.s.l. Main annual rainfall ranging from 900 to 1,000 mm and steep slopes are other determining factors for the occurrence of these soils. In some areas, they occur as buried soils under Andisols, but in most cases they present a leached A horizon with rock outcrops. They are the most eroded soils in the region, where gullies are common features. Time, favorable rain conditions, relief and lithology are the main factors determining the development of Acrisols and Luvisols in the basin. In the field, they present an illuviated, brown to reddish brown (Munsell, 1992) and shallow A horizon, with strong subangular blocky structure, low organic matter content and moderately acid soil reaction. The B horizon is a thick, reddish argic horizon, with concentration of sesquioxides and concretions. Texture is clayey, structure moderate to weak subangular blocky, and consistence sticky and plastic when wet and hard when dry. The main processes contributing to the formation of these soils are braunification and leaching in the A horizons, and illuviation, desilication and rubification in the B horizons. The main differences between Acrisols and Luvisols are that the first ones present a more developed argic B horizon and are deeper soils than Luvisols, showing more intensive desilication.

(3) Lithosols

Lithosols cover some 8% of the basin and their location is restricted to the Holocene basaltic lava flows. They occur at different elevations (Figure 15.9). These incipient mineral soils are very shallow (<25 cm), with an important accumulation of organic matter on the surface when covered by oak or pine-oak forest, but without formation of an organic-mineral complex. They are well-drained, but with low moisture retention capacity.

(4) Phaeozems, Cambisols and Planosols

This group of soil types covers 5% of the basin and occurs mainly in the piedmonts, from 2,100 to 2,300 m.a.s.l. They are scattered throughout the region on gently sloping surfaces (Figure 15.9). These soils are grouped because they occur on similar surfaces, although, they have distinct soil properties and pedogenetic processes.

Phaeozems present a dark, clay loam, mollic A horizon, rich in organic matter and nutrients. They have a stable structure, high porosity and high available water retention capacity. The admixture of organic matter produces the darkening of initially light-colored mineral unconsolidated materials, a process known as melanization. A clay loam, reddish brown argic B horizon (Munsell, 1992), overlying the parent material, is permeated with calcium. Low moisture content during the dry season and stoniness are the main agricultural restrictions of these soils in Pátzcuaro.

Cambisols are shallow (<50 cm), brownish (Munsell, 1992) loamy soils. Soil reaction is slightly acid to acid (pH 5.5-6.5) and organic matter content is low. They present a distinct dark brown B horizon, with a higher clay content than in the surface horizon but not enough to be considered as an argic B horizon and show concentration of sesquioxides with formation of concretions, overlying the basaltic parent material. Structure is weak subangular blocky, and consistence is sticky when wet and soft when dry. They present high porosity, good drainage and moisture retention capacity.

Planosols occur on slightly undulating surfaces, in narrow belts along the low and flat margins of the hillands and near the lakeshore. They present a silty or loamy gray surface horizon with weak subangular blocky structure, hard when dry but not cemented, showing signs of wetness and a light-colored eluvial subsurface horizons. Planosols present an abrupt textural change from the topsoil to the subsoil. The B horizon has higher clay content on top of which water stagnates. The clayey subsoil has a strong, coarse subangular blocky structure. These soils support herbaceous vegetation and their use is restricted to rangeland.

(5) Vertisols and Gleysols

Vertisols and Gleysols cover 5% of the basin and are restricted to the lacustrine plains and to the borders of the lake, respectively. They occur between 2,040 and 2,100 m.a.s.l. Vertisols distribution shows, to some extent, the former size of the paleo-lake of Pátzcuaro (Figure 15.9). Gleysols distribution varies according to the cyclic fluctuations of the water level. Vertisols are seasonally waterlogged, while Gleysols are permanently waterlogged.

Vertisols are located at the bottom of periodically inundated depressions. They are very slightly to slightly acid. Vertisols are deep, very clayey soils (>48% clay), with dark surface and subsurface horizons, dominated by clay minerals such as smectites that expand upon wetting and shrink upon drying. These soils are mainly derived from fine volcanic materials and fluvio-lacustrine alluvium. They present wide cracks from the soil surface down to 60 cm depth when drying out. They are very sticky and plastic when wet and very hard when dry. Vertisols present low organic matter content throughout the soil profile, high CEC (30 cmol (+) $kg^{-1}$ soil) and high base saturation (50%). Surface horizons have prismatic structure, while subsoil horizons present wedge-shaped parallelepipeded structural aggregates. Surface horizons show a gilgai micro-relief, typical of Vertisols as a consequence of churning of the soil material. They are used for mechanized irrigated agriculture but present limitations for trafficability and tend to alkalinize.

Gleysols occur along the rim of the Pátzcuaro Lake, especially on its southern shallow margins (Figure 15.9). They present a dark (Munsell, 1992), silty clay surface horizon with high organic matter content, but lack well-defined sub-horizons. The continuous deposition of mineral sediments on the surface layer and the reduction of iron under anaerobic soil conditions, producing bluish to greenish gray matrix colors (Munsell, 1992), with iron and manganese concretions, are relevant pedogenetic features of the Gleysols.

## 15.3.4. Vegetation

The region of Lake Pátzcuaro shows a notable ecological diversity, despite its relatively small size and homogenous lithology (Barrera-Bassols, 1986). There is a great variety of vegetation communities within the basin, according to elevation, relief, meso- and microclimates, and soil patterns (Caballero et al., 1991, 1993). However, pine, oak and alnus dominate the pollen record during the 50,000 years BP, thereby suggesting that there were not drastic vegetation changes since the Pleistocene (Bradbury, 2000). Anthropogenic modifications of the vegetation cover during the last 4,000 years have been significant, thus influencing the extent, distribution and floristic composition of the current vegetation cover. The imprint of ecological and anthropogenic factors makes it difficult to recognize the original composition of the vegetation communities and to assess to which extent their distribution obeys to ecological conditions and not to anthropogenic modifications. The historical use and management of the vegetation communities had great impact, thus all vegetation types are now considered of secondary origin (Caballero et al., 1991, 1993).

The original vegetational diversity of Pátzcuaro is related to the fact that this area belongs to the Mountainous Middle American phyto-geographic region, a transitional zone between the neoartic and neotropical floristic biomes in North America (Rzedowsky, 1978). The confluence of elements of both floristic kingdoms, influenced by the TMVB, determines great floristic richness and high species endemism (Challenger, 1998). The persistence of the Lake of Pátzcuaro during the last 50,000 years has also influenced and enriched the vegetational diversity of the region (Lot and Novelo, 1988; Chacón, 1993; Bradbury, 2000). Labat (1988, 1992) proposed a descriptive model explaining the occurrence of main vegetation types in relation to temperature, rainfall and soil forming processes for northern central Michoacán, including the Pátzcuaro Lake Basin (Figure 15.10). Two main vegetation types occur in the basin: (a) terrestrial vegetation and (b) aquatic vegetation.

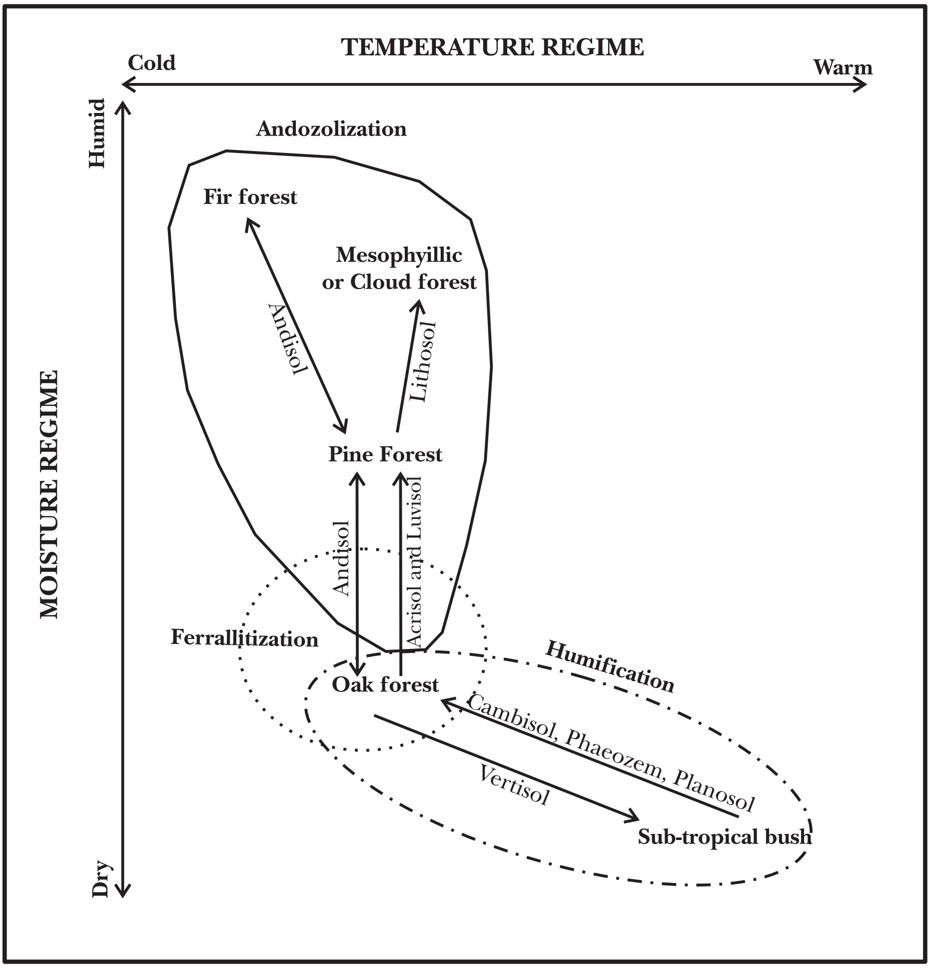



**Figure 15.10.** Descriptive model of the occurrence of vegetation types in relation to temperature and moisture regimes, and main soil forming process in central Michoacán. **Source:** Labat (1988)

(1) Terrestrial vegetation

Six main terrestrial vegetation types, composed by several plant communities, are distributed within the catchment (Figure 15.11) (Caballero et al., 1991, 1993):

(a) Alpine grassland
Alpine grassland (*Zacatonal de altura,* in Spanish) reaches the highest mountain summits of the region, above 3,000 m.a.s.l., as an open grassland or inter-mixed with fir and pine forests. This vegetation type occurs on very steep slopes under cold and very humid meso-climatic conditions, and is dominated by *Muhlenbergia macroura, Arctostaphylos* aff. *polifolia, Lupinus* spp., *Penstemon campanulatus, Abies religiosa* and *Pinus michoacana* var. *quevedoi.*

(b) Fir forest
The fir forest is confined to the highest mountains of the region above 2,900 m.a.s.l. Firs forest is dominated by *Abies religiosa* (*Oyamel* or *Pinabete,* in Spanish), *Pinus pseudostrobus, Quercus rugosa, Quercus laurina* and *Clethra mexicana.* This vegetation type occurs on very steep slopes and under cold and very humid meso-climatic conditions.

(c) Pine forest
Pine forest is the most extended vegetation type, covering some 40% of the region (Barrera-Bassols, 1986). It has an ample distribution, ranging from 2,100 to 3,000 m.a.s.l., due to its low ecological requirements as compared to the fir forest. Pine forest occurs in a variety of soils but mainly on Andisols, Acrisols and Luvisols, and from very steep slopes to flat surfaces on soils having dominant rock outcrops or on highly eroded soils, and under the whole rainfall variability spectrum within the region. Five main pine forest associations are found within the catchment:

- Forest association of *Pinus teocote* and *Pinus lawsoni* (2,100 to 2,500 m.a.s.l.)
- Forest of *Pinus leiophylla* (2,100 to 2,800 m.a.s.l.)
- Forest of *Pinus pseudostrobus* (2,100 to 2,800 m.a.s.l.)
- Forest of *Pinus michoacana* var. *cornuta* (2,200 to 2,900 m.a.s.l.)
- Forest of *Pinus montezumae* (2,900 to 3,100 m.a.s.l.)

*(d) Baccharis* bush
Anthropogenic modifications of the pine forest through fire and deforestation lead to the development of a fire-induced bush dominated by *Baccharis conferta* and *Baccharis halimifolia.* This shrub community grows in almost any ecological condition where pine forest occurs and presents a patchwork-like pattern composed of forest-grassland-agricultural plots.

(e) Oak forest
Oak forest is widely distributed, covering some 20% of the region (Barrera-Bassols, 1986). It occurs in all landscapes, elevations, meso-climates and soils, although dense, non-disturbed oak forest communities are found preferably on recent lava flows (Lithosols) and in gullies (barrancos). Oak forest composition is complex and mixed with neoartic and neotropical species. Other plant species occurring in these communities are *Pinus pseudostrobus, Pinus montezumae, Quercus candicans, Quercus obtusata, Ternstroemia pringlei, Tilia mexicana, Alnus acuminanta, Alnus jorullensis, Clethra mexicana* and *Crataegus mexicana.* The occurrence of species from both floristic biomes depends on meso-climatic conditions where moisture stands as one of main controlling factors. Two main oak forest communities are found within the region:

- Oak forest dominated by *Quercus rugosa* (2,100 to 2,900 m.a.s.l.).
- Oak forest dominated by *Quercus laurina* (2,100 to 2,600 m.a.s.l.).

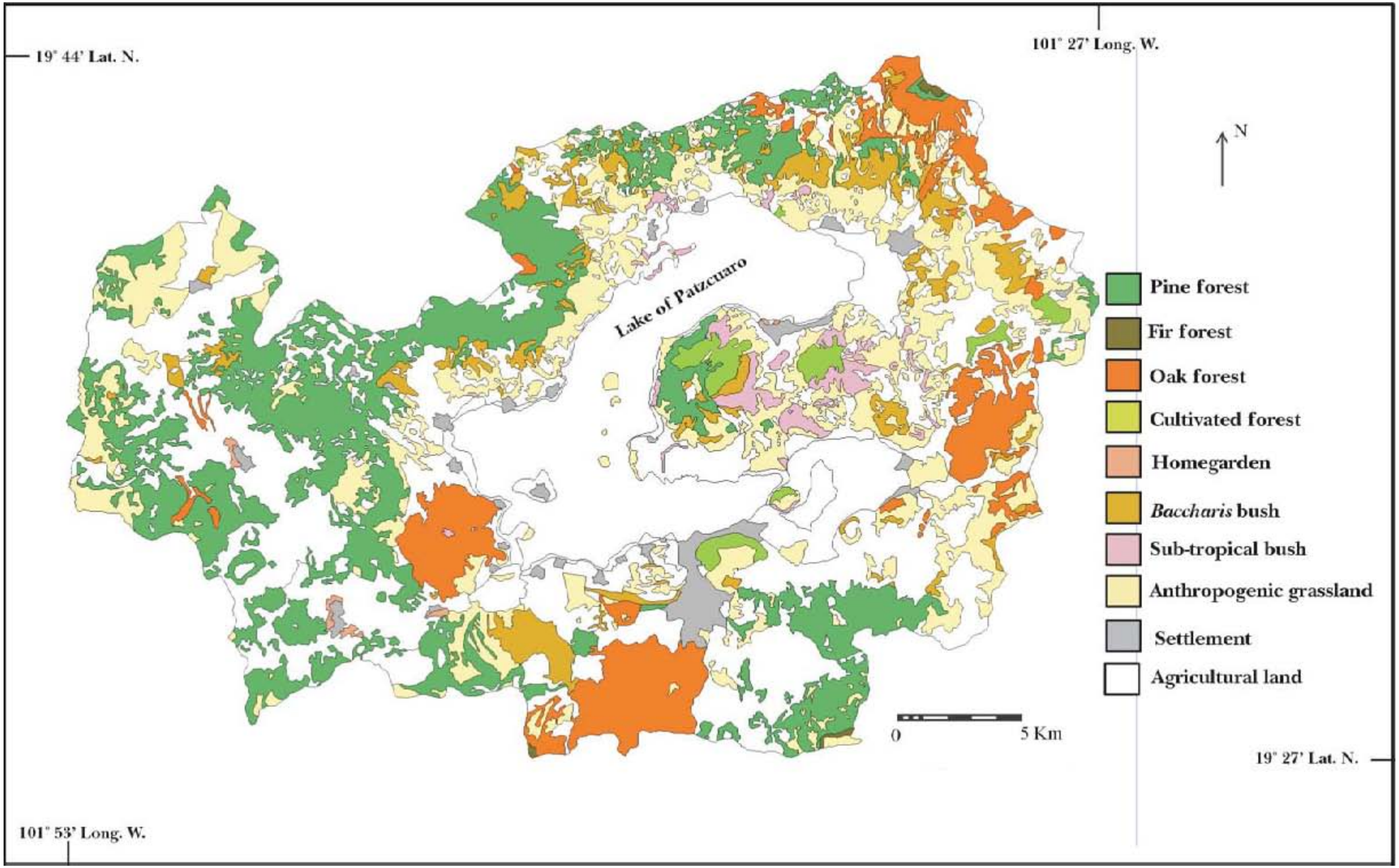



**Figure 15.11.** Vegetation map of the Pátzcuaro Lake Basin. **Source:** Barrera-Bassols (1992)

(f) Sub-tropical or xerophytic bush

This vegetation type groups several shrub communities composed of species from arid and semi-arid zones of Mexico. Their presence in the Pátzcuaro Basin could be interpreted as an indicator of past dry climatic conditions, but also as an indicator of soil as a limiting factor to maintain the forest cover (Lithosols, Planosols and Cambisols) or as an indicator of anthropogenic modifications of past forest covers. Much probably, all above mentioned factors played a compound role in promoting and maintaining these shrub communities. Their distribution is limited to the hillands bordering the lake at elevations ranging from 2,040 to 2,200 m.a.s.l.

Three distinct shrub communities are found within the catchment:

- Sub-tropical bush dominated by *Sedum oxypetalum, Sedum bourgaei* and *Senecio praecox,* developed over recent lava flows (2,100 to 2,150 m.a.s.l.)
- Xerophyllic bush dominated by *Opuntia spp.* And *Euphorbia calyculata*, developed near pre-Hispanic archaeological sites (2.040 to 2,200 m.a.s.l.)
- Sub-tropical bush dominated by *Acacia pennatula*, developed as a patchwork-like pattern in association with *Bouteloua filiformis* and *Hilaria cenchroides* anthropogenic grassland.

(g) Anthropogenic grassland

This type of vegetation dominated by gramineae has anthropogenic origin and groups two distinct plant communities:

- Grassland community dominated by *Bromus ciliatus* and *Eragrostis intermedia*, developed in inter-mountainous valleys (2,400 to 2,700 m.a.s.l.)
- Grassland dominated by *Bouteloua filiformis* and *Hilaria cenchroides*, distributed along the hillands in a patchwork-like pattern associated with sub-tropical bush, agricultural plots and secondary pine-oak forest (2040 to 2,200 m.a.s.l.)

(2) Aquatic vegetation

Four main aquatic vegetation types occur in the Lake of Pátzcuaro. Their distribution relates to different properties of the lake-water: (a) water depth and relief; (b) terrestrial sediments; (c) water fluctuation along the year and among several years; (d) water turbidity, and water and atmospheric air stream occurrence (Lot and Novelo, 1988). Aquatic vegetation is also considered as an indicator of eutrophic levels of the lake (Caballero et al., 1991). The four main types are discribed hereafter:

(a) Emerged plant community (*Tulares* and *Chuspatales*, in Spanish)

This plant community is widely represented on the flooding and gently sloping coastal margins of the lake. The dominant plant species are the monocotyledon *Scirpus americanus*, *Scirpus validus*, *Typha latifolia* and *Typha dominguensis*. All are rooted plants on Gleysols, emerging 1 to 3 m above the water surface. They occur as dense communities, distributed from the seasonally flooded playas until areas 4 m deep in the lake.

(b) Floating-leaf plant community (*Hidrófitas de hojas flotantes*, in Spanish)

This plant community develops on the shallow coastal margins of the lake in areas with calm waters, between 1 to 4 m deep. Rooted species growing on Gleysols and lacustrine sediments are the dominant long-rounded floating leaf plants. Main species are *Nymphea mexicana* and *Potamogeton illinoensis.* They also occur in association with the emerged plant communities.

(c) Submerged plant community
This plant community develops in lake areas with 4 to 6 m deep. Rooting plants grow on lacustrine sediments and are completely submerged. Main species are *Potamogeton latifolius*, *Najas guadalupensis*, *Ceratophyllum demersum* and *Utricularia gibba*.

(d) Free-floating plant community
The distribution of this plant community varies greatly during the year because plants have free movement, as they are no rooted. Several plant associations have been recognized, but *Ecchornia crassipes*, an exotic species recently introduced, is always dominant. *Ecchornia crassipes* (*Lirio acuático*, in Spanish) is usually an aggressive species, that reproduces at extraordinary rates and, is thus commonly considered as a weed that increases the trophic levels of the water bodies in Mexico. In the Pátzcuaro Lake, *Ecchornia crassipes* appears less aggressive and disturbing.

### 15.3.5. The Lake of Pátzcuaro

Currently, the Lake of Pátzcuaro covers an area of about 130 $km^2$ and contains approximately 628 x $10^6$ $m^3$ water. The lake has a "C" or "half-moon" shape, with long axis about 20 km long, a maximum width of 11 km, a maximum depth of 12 m in the northern part, a mean depth of 5 m, and is thereby considered a shallow lake (Chacón, 1993). The lake has a SSW-NNE orientation, which is similar to the TMVB primary fault line system. Basalt and basaltic breccias form islands in the central and southern parts of the lake, most of them corresponding to monogenetic volcanic cones and lava flows. The lake bottom is slightly convex and parabolic. Relief is rugged and sloping (<5%) in the coastal zone, especially in the Erongarícuaro, Zurumútaro and Quiroga arms, and moderately steep sloping (>35%) in the limnetic zone, especially in the northern portions. A gently sloping coastal area (>5%) occurs along the southern lake margins and is considered highly sensitive to sedimentation.

The hydrochemistry of the lake is dominated by sodium and bicarbonate ions, reflecting the nature of the surrounding volcanic landscape (Bradbury, 2000). Water is moderately alkaline, with high contents of total phosphorus, a-type chlorophyll and suspended solids, but with low nitrogen contents. Freshwater dominates with a tendency to be saline. The lake is classified as tropical of the third order. It is tropical because water temperature fluctuates between 15 and 29°C during the year and it is considered as a third-order lake because temperature does not consistently stratify in any season and oxygen is generally abundant at the bottom. Complete circulation throughout the year causes high lake turbidity, especially after the rainy season (Barrera-Bassols, 1986; Chacón 1993).

Water quality as an indicator of primary productivity shows that the lake is eutrophic and susceptible to become hyper-eutrophic in its northern arm. High content of total phosphorous is related to anthropogenic activities in the basin. Emergent aquatic plant communities and flooding areas cover some 40% of the lake surface. Hydro-dynamic is disrupted in these areas and evaporation is higher than in open water areas, contributing to an accelerated reduction in size and volume of the lake under the prevalent dry climate (Chacón, 1993; Bradbury, 2000).

The lake has no significant surface inflow and no surface outflow. It appears to be largely maintained by shallow groundwater and local runoff during the rainy season. Springs at and above the lake margin also contribute to the lake. The lake level varies seasonally 0.5-1 m as a result of evaporation and the balance between groundwater discharge to the lake and lake recharge to the groundwater table (Chacón, 1993). The Lake of Pátzcuaro is endorreic, thus its hydrological balance is basically controlled by rainfall, evaporation and groundwater inflow. Evaporation (1478 mm/y) exceeds rainfall (979 mm/y), thus water infiltration within the basin (499 mm/y) is the only net hydraulic source. Although the lake has no surface outlet, it is not a closed basin *stricto sensu*, inasmuch as it receives and discharges significant amounts of groundwater (Bradbury, 2000). Figure 15.12 shows the water balance of the lake. Of note is that the infiltration rate corresponds to 8% of the E/P balance and 10% of the water volume of the lake. That is why the lake never becomes particularly saline due to evaporation, because solutes gained by evaporation eventually leave the lake through recharge to the groundwater system (Bradbury, 2000).

The hydrologic balance of the Lake of Pátzcuaro has been highly sensitive to short climatic fluctuations during the Holocene and groundwater inflow has been presumably the critical factor for this balance. More recently, 45% reduction of the water infiltration rate was recorded from 1939 to 1986 (Chacón, 1993). Although this sharp reduction of groundwater inflow during the last 45 years is partially caused by the overall rainfall decrease (Figures 15.13 and 15.14), land-use changes, deforestation and soil erosion contributed to accelerate the decrease of the lake depth. Water and land cover changes from 1986 to 2000 on the southern margin of the lake via sediment deposition are shown in figure 15.15. Urban, domestic and agricultural wastewater from the city of Pátzcuaro and from the surrounding towns and fields contribute considerable phosphorus to the lake. Increased deforestation in the watershed has also resulted in greater transport of suspended solids to the lake since the initial limnological studies of Yamashita (1939) and De Buen (1941). As a consequence, secchi transparency values have decreased and the lake has become increasingly eutrophic (Chacón, 1993 ; Bradbury, 2000).

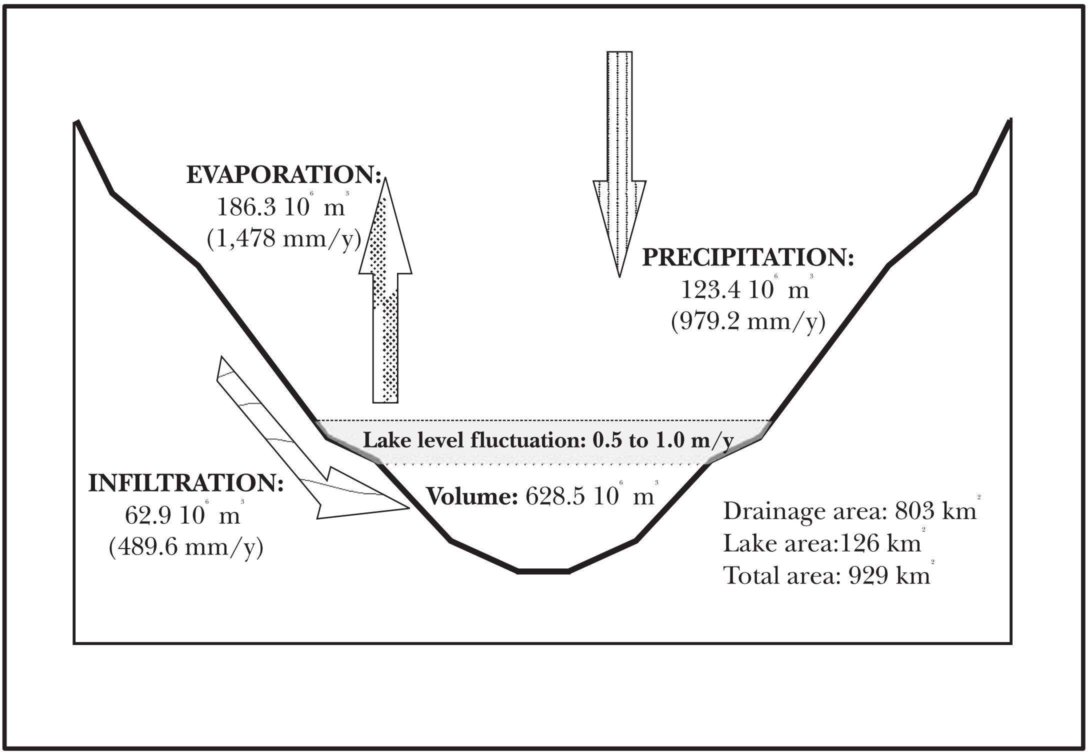



**Figure 15.12.** Hydrologic balance of the Pátzcuaro Lake. **Source:** Chacón (1993).

### 15.3.6. Bioclimatic zonation

Six bioclimatic zones are distinguished from the lake level to the higher mountain peaks, on the basis of: (a) meso-climatic regime; (b) morphogenetic environment and landscape; (c) elevation range; (d) slope gradient; (e) vegetation cover; and (f) main soil type (Figure 15.16 and table 15.1). Being a small basin with an elevation range of 1,300 m and with short and steep slopes, meso-climatic heterogeneity is high and mainly controlled by verticality (Barrera-Bassols, 1986, 1987, 1993). Nevertheless, the TMVB general tendency to present a south-north climatic gradient, with humid and temperate areas towards the south and drier and warmer areas towards the north, is also reflected in Pátzcuaro (Barrera-Bassols, 1986; Labat, 1988). This is why some authors (O'Hara et al., 1994) consider this region as part of "the arid frontier of Mesoamérica", although the presence of a relatively large and permanent water body buffers horizontal climatic variability in Pátzcuaro. The combination of vertical and horizontal zonation produces a patchwork-like bioclimatic pattern where the following zones can be recognized:

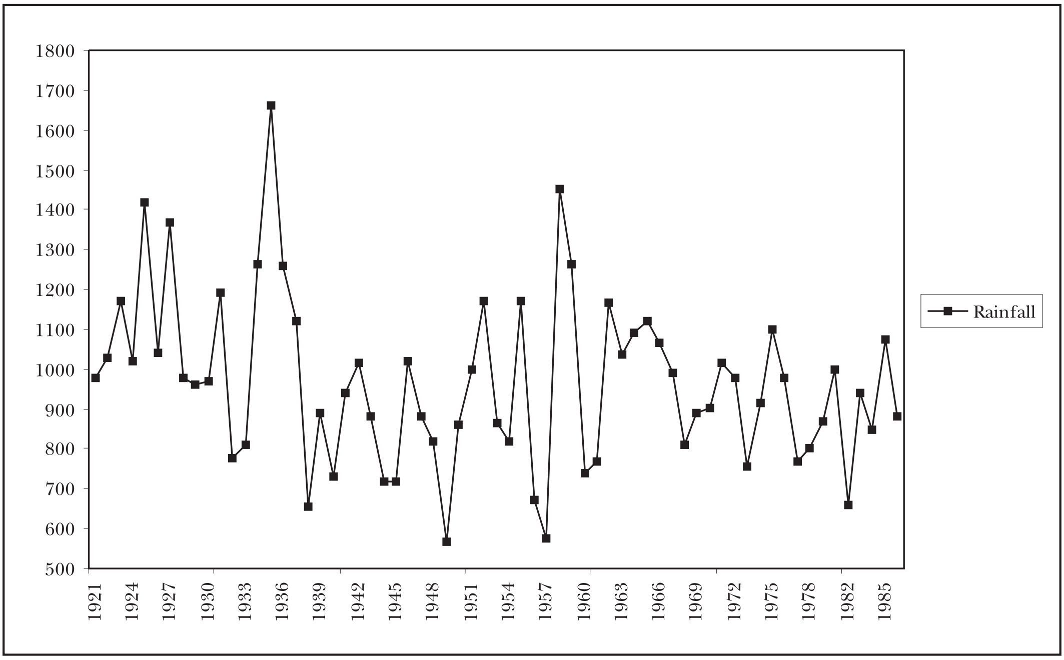



**Figure 15.13.** Annual rainfall distribution in the Pátzcuaro Basin during the 1921-1986 period. Statistical mode was estimated as: Mean – [(Standard deviation) $^2$ /Mean]. **Source:** Chacón (1993)

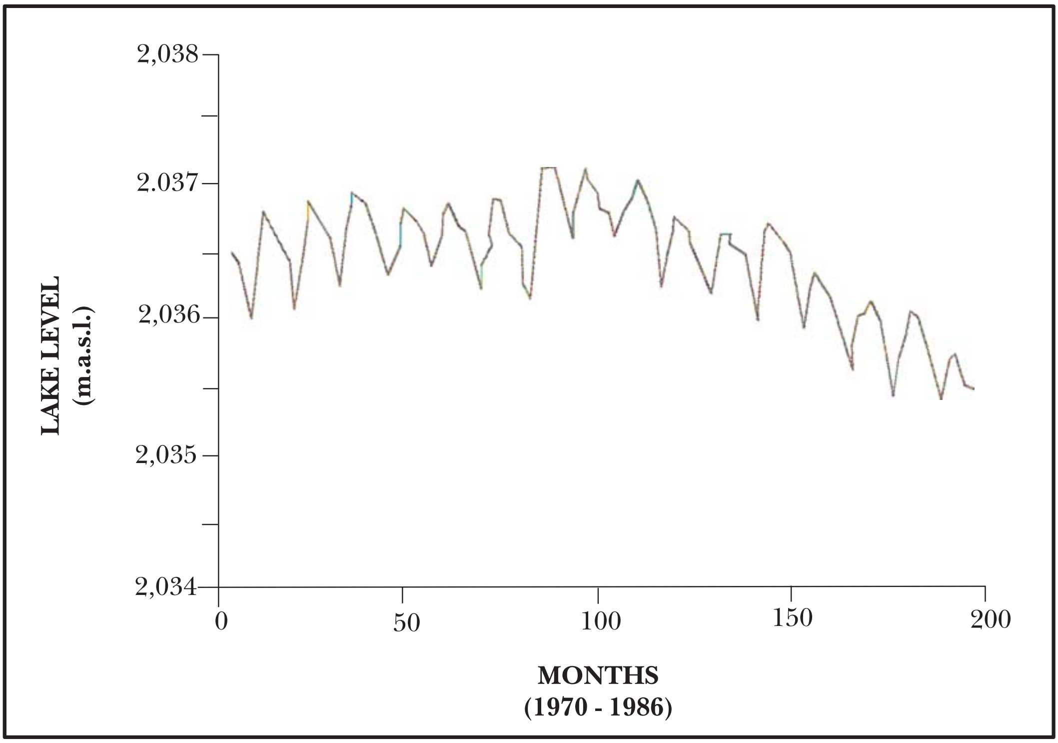
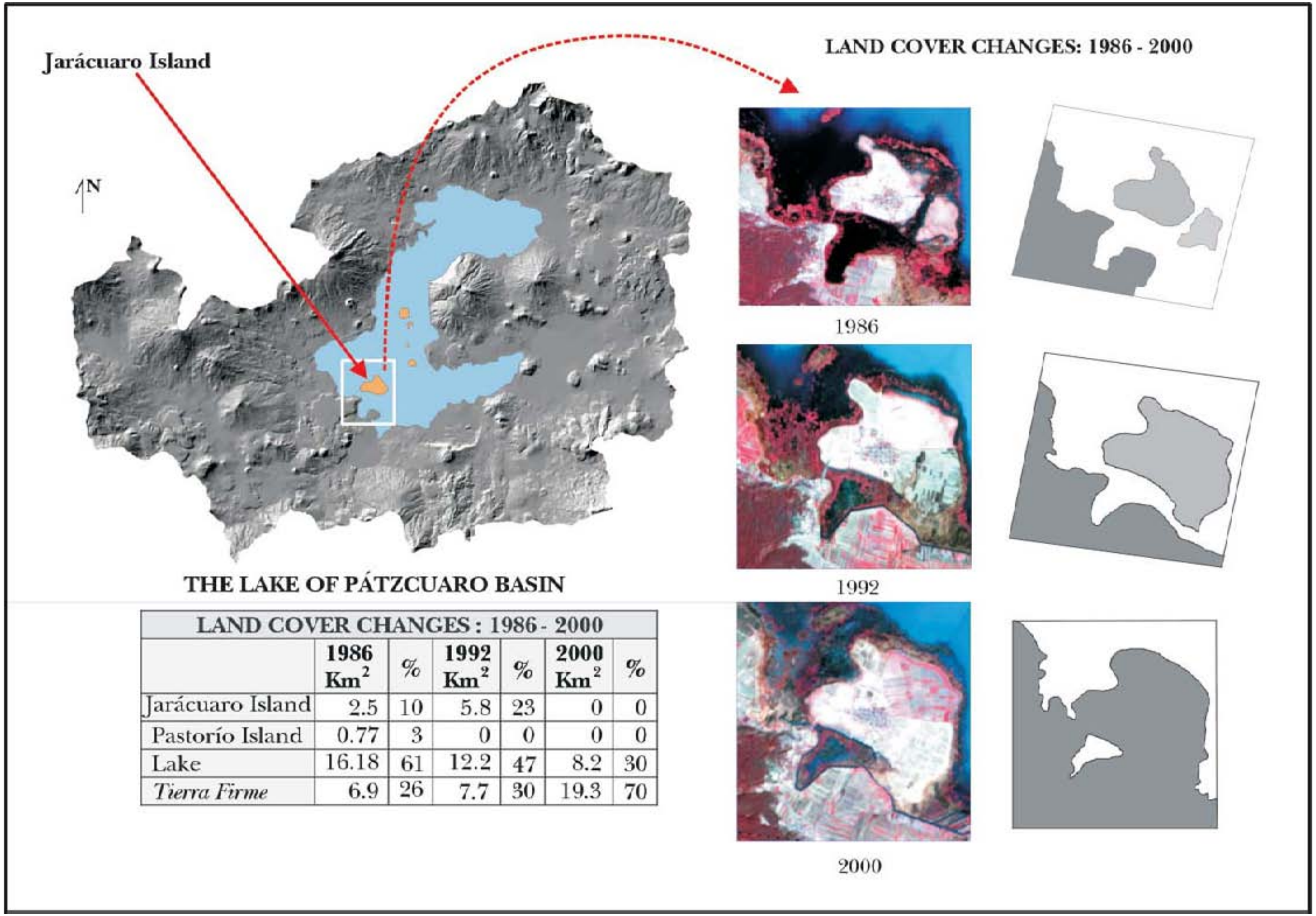



**Figure 15.14.** Lake-level variations in the Lake of Pátzcuaro during the 1970-1986 period. **Source:** Chacón (1993)




| LAND COVER CHANGES : 1986 - 2000 | | | | | | |
|---|---|---|---|---|---|---|
| | 1986 Km² | % | 1992 Km² | % | 2000 Km² | % |
| Jarácuaro Island | 2.5 | 10 | 5.8 | 23 | 0 | 0 |
| Pastorío Island | 0.77 | 3 | 0 | 0 | 0 | 0 |
| Lake | 16.18 | 61 | 12.2 | 47 | 8.2 | 30 |
| *Tierra Firme* | 6.9 | 26 | 7.7 | 30 | 19.3 | 70 |

**Figure 15.15.** Land cover changes in the southern arm of the Pátzcuaro Lake Basin: 1986-2000. **Source:** TM satellite images color composite (3,2,1), 1986, 1992 and 2000.

(1) Very cold and very humid regime
Confined to the highest mountain peaks (2,900 to 3,340 m.a.s.l.) and considered as an Alpine-like zone. The mean annual temperature is below 13ºC and the mean annual rainfall is about 1,300 mm. Mean annual relative humidity is greater than 50%. Frost occurrence during the winter is greater than 60 days and snow occurs during less than seven days per year. Dense fog commonly occurs during the summer-autumn rainy season. Alpine grassland, fir forest and pine forest are found on Andisols and Lithosols.

(2) Cold and humid regime
Dominates the southern and southwestern mountainous area (2,400 to 2,900 m.a.s.l.), including the higher inter-mountainous valleys. Mean annual temperature varies from 12 to 14ºC and mean annual rainfall is about 1,300 mm. Mean annual relative humidity ranges from 45 to 50%. Frost occurrence varies from 50 to 60 days and fog often occurs during the summer-autumn season. Pine, oak and pine-oak forests, and *Baccharis* bush are found on Andisols, Acrisols and Luvisols.

(3) Cold and sub-humid regime
Confined to the highest mountain peaks of the northern mountains in the basin (2,600 to 2,900 m.a.s.l.). Mean annual temperature varies from 12 to 14ºC and mean annual rainfall is about 1,000 mm. Mean annual relative humidity ranges from 35 to 45%. Frost occurrence during the winter varies from 30 to 40 days and snow occurs during seven days or less per year. Alpine grassland, fir forest and pine forest are found on Lithosols and Andisols.

(4) Temperate and humid regime
Distributed along the piedmont, hilland, lower inter-mountainous valleys and lacustrine plains in the southern and central portions of the basin (2,040 to 2,400 m.a.s.l.). Mean annual temperature varies from 15 to 16ºC and mean annual rainfall is about 1,000 mm. Mean annual relative humidity ranges from 30 to 40%. Pine and oak forests, *Baccharis* and sub-tropical bushes and anthropogenic grassland occur on Andisols, Luvisols, Acrisols and Vertisols.

(5) Temperate and sub-humid regime
Distributed along the piedmont of the northern portion in the basin (2,200 to 2,600 m.a.s.l.). Mean annual temperature varies from 15 to 16ºC and mean annual rainfall is about 900 mm. Mean annual relative humidity is 30%. Frost occurrence during the winter varies from 30 to 40 days. Pine and oak forests, *Baccharis* and sub-tropical bushes and anthropogenic grassland are found on Andisols, Luvisols, Acrisols, Cambisols and Phaeozems.

(6) Temperate and semi-dry regime
Confined to the northern and lower portions of the piedmont and lacustrine plains (2,040 to 2,200 m.a.s.l.). Mean annual temperature varies from 15 to 16ºC and mean annual rainfall is the lowest in the region (850 to 900 mm). Mean annual relative humidity is 25%; thus this zone can be considered as transitional between the sub-humid and semi-arid moisture regimes of the TMVB. Frost occurrence during the winter varies from one to ten days. Sub-tropical bush, anthropogenic grassland and oak forest are found on Luvisols, Cambisols, Lithosols, Planosols and Phaeozems.

## 15.4. NATURAL HISTORY

### 15.4.1. Paleo-limnological evidence

The Lake of Pátzcuaro is, limnologically speaking, the best studied lake in Middle America. From a paleo-limnologically perspective, the value of this lake lies in the fact that, for much of the mid- and late Wisconsin and throughout the Holocene, the lake has never been dry. Sediment deposits contain sources of an uninterrupted history of past lake and climate changes, unlike most lakes in central Mexico, because of their arid surroundings and intermittent history of desiccation (De Buen, 1944; Watts and Bradbury, 1982; Chacón, 1993; O'Hara et al., 1994; Bradbury, 2000).

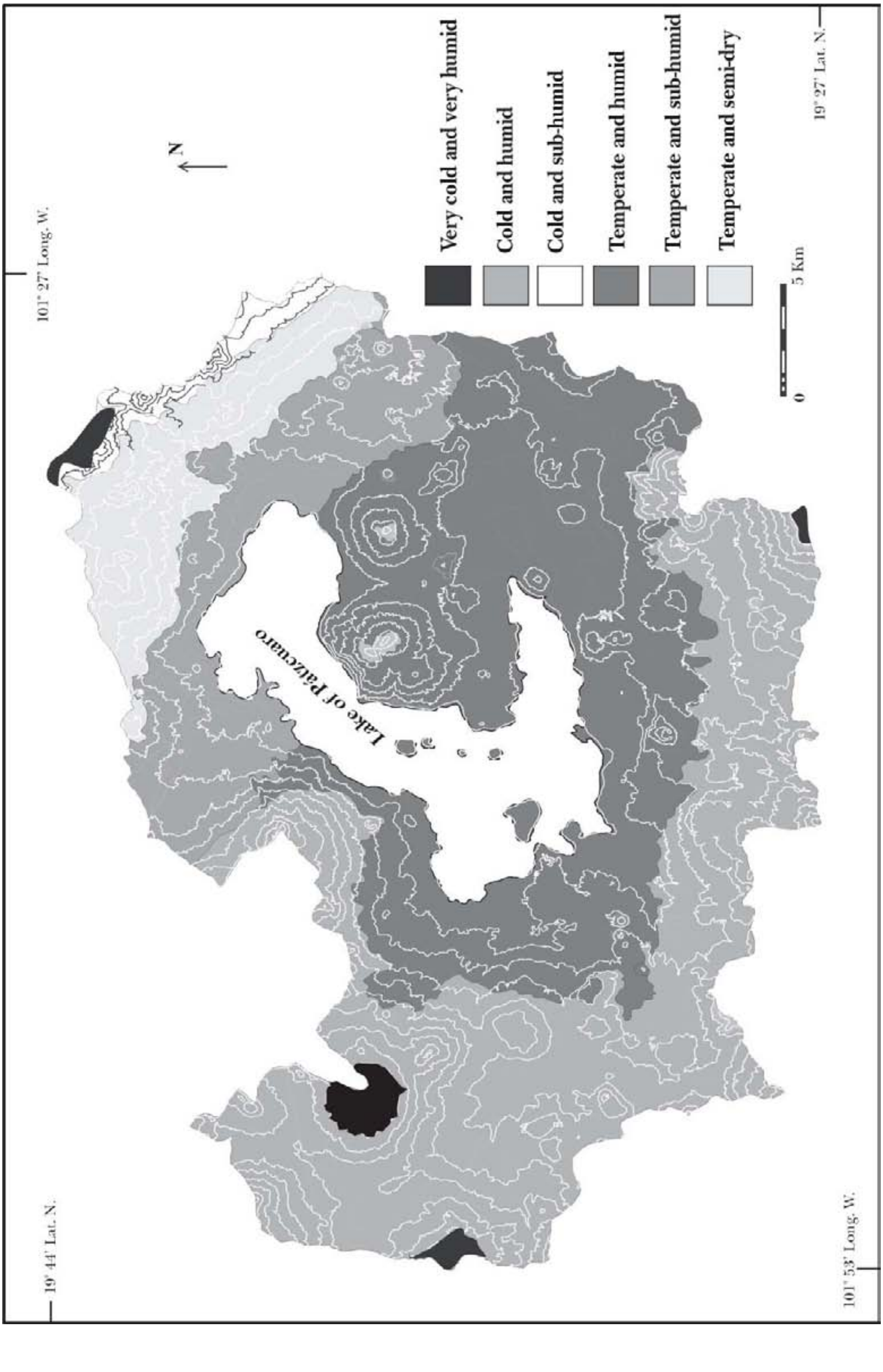



**Figure 15.16.** Bioclimatic zone of the Pátzcuaro Lake Basin, Mexico. **Modified from:** Barrera-Bassols (1993)

**Table 15.1** Bioclimatic zones of the Lake of Pátzcuaro Basin

| MESO-CLIMATIC REGIME[1,2] | MORPHOGENTIC ENVIRONMENT | LANDSCAPE | ELEVATION (m.a.s.l.) | SLOPE GRADIENT % | LOCATION | VEGETATION TYPE | SOIL TYPE[3] |
|---|---|---|---|---|---|---|---|
| Very cold and very humid | Structural-erosional | Highest peaks of volcanic mountain (Alpine zone) | 3,340 to 2,900 | Very steep<br>>45% | El Zirate Mt.<br>La Virgen Mt.<br>El Chivo Mt.<br>El Frijol Mt. | Alpine grassland<br>Fir forest<br>Pine forest | Andisols<br>Lithosols |
| Cold and humid | Structural<br>Erosion-denudation<br>Fluvio-volcanic<br>Colluvio-alluvial | Volcanic mountain<br>Higher inter-mountainous valley | 2,900 to 2,400 | Very steep to steep<br>30 to 45%<br>Undulating<br>3 to 8% | Southern and southwestern mountainous ranges | Pine forest<br>Oak forest<br>*Baccharis* bush | Andisols<br>Lithosols<br>Acrisols<br>Luvisols |
| Cold and sub-humid | Structural-erosional | Volcanic mountain | 2,900 to 2,600 | Very steep to steep<br>30 to 45% | Northern mountain ranges | *Baccharis* bush<br>Pine forest<br>Oak forest<br>*Bromus* and *Eragostis* grassland | Andisols<br>Luvisols |
| Temperate and humid | Erosion-Deposition<br>Fluvio-volcanic<br>Colluvio-alluvial<br>Lacustrine<br>Alluvial | Piedmont<br>Lower inter-mountainous valley<br>Lacustrine plain | 2,400 to 2,040 | Hilly<br>10 to 30%<br>Undulating to nearly level<br>0 to 8% | Southern and central portions of the basin | Pine forest<br>Oak forest<br>*Baccharis* bush<br>Sub-tropical bush | Acrisols<br>Luvisols<br>Lithosols<br>Vertisols |
| Temperate and sub-humid | Erosion-deposition<br>Colluvio-alluvial | Piedmont | 2,600 to 2,200 | Steep to undulating<br>8 to 30% | Northern portion of the basin | Sub-tropical bush<br>*Bouteloua* and *Hilaria* grassland<br>Oak forest | Luvisols<br>Acrisols<br>Planosols<br>Cambisols<br>Phaeozems |
| Temperate and semi-dry | Erosion-deposition<br>Colluvio-alluvial<br>Lacustrine<br>Alluvial | Piedmont<br>Lacustrine plain | 2,200 to 2,040 | Hilly to undulating<br>8 to 15% | Northern portion of the basin | Sub-tropical bush<br>*Bouteloua* and *Hilaria* grassland<br>Oak forest | Luvisols<br>Cambisols,<br>Phaeozems<br>Lithosols |

**Sources:** Barrera-Bassols (1986, 1987, 1993); Caballero et al. (1991, 1993); Chacón (1993); Lot and Novelo (1988)

[1] Temperature gradient analysis was conducted to establish temperature regimes, due to the lack of climatic data at different altitudes within the region. Temperature regimes were recognized using climatic, topographic and vegetation maps and assuming 0.65°C temperature decrease with each 100 m elevation increase, according to the calibration established by Garcia (1981) for the Mexican territory. The mean annual temperature data at the lake level were taken as a base reference.

[2] Atmospheric humidity regimes were calculated using the aridity index calibrated for the Mexican territory (Jáuregui, 1975) and modified by Correa-Pérez et al. (1974) for Michoacán. Aridity index: $I = (T-t)^2 (t+45)/P$. I= Aridity index; T= Mean maximum temperature of the warmest month; t= Mean minimum temperature of the coldest month; 45= humidity index; P= Mean annual temperature.

[3] FAO/UNESCO/DETENAL (1980)

Records of the limnological history of the Lake of Pátzcuaro over the last 50,000 years show that the region did not witness strong aridity and that the lake has always been a fresh-water lake (Bradbury, 2000). Records also show that a stable depositional environment prevailed during most of this period, without large changes in the basin configuration and morphometry. Nevertheless, climatic fluctuations, volcanic activity and tectonism during the Holocene are clearly shown in the sediment core records (Saporito, 1975; Watts and Bradbury, 1982).

De Buen (1944) was the first author proposing a general characterization of the limnological periods of Lake Pátzcuaro (Figure 15.17). A juvenile, deep and freshwater open lake prevailed until 30,000 years ago. This long period correlates with cold and humid climates that presumably occurred in central Mexico, according to Heine (1973). A second major period or transgression epoch of the lake occurred from 30,000 to 20,000 years BP, which correlates with warm and dry climates. An oligotrophic, shallow but freshwater closed lake environment prevailed during this period. A eutrophic lake environment evolved under dry and warm climatic conditions during major parts of the Holocene and prevails until today. These conditions were preceded by a short period of climatic instability where the Lake of Pátzcuaro faced continuous changes (10,000–5,000 years ago). This regression epoch of the lake correlates with anthropogenic modifications of the Pátzcuaro Basin occurred during the last 4,000 years. A hyper-eutrophic lake environment evolved during the last 200 years as a consequence of deforestation in the basin and massive disposal of urban residual waters (Barrera-Bassols, 1993; Chacón, 1993).

Although the lake's chronology proposed by De Buen (1944) is too general and linear, it served as critical baseline information about the lake evolution before cultural impacts and has been enriched by paleo-limnological research carried out during the last 50 years (Bradbury, 2000). Deevey's (1944) early accounts of Holocene pollen analysis showed that pollen of *Pinus*, *Quercus*, and *Alnus* predominated and that pollen of fir was also present throughout the Holocene. Grass (*Gramineae*), *Chenopodiineae* and composite pollen were recorded together with small traces of *Zea* (maize) and *Agave* during the late Holocene. The author concluded that vegetation changes were the result of climatic fluctuations during the Holocene. Hutchinson and collaborators (1956) studied the sediment chemistry and fossil algal flora of Deevey's core. They calculated the ratio of *Pinus* to *Quercus* plus *Alnus* and fir and of *Pinus* to *Quercus* to successive levels of the sediment core and concluded that there were minor climatic oscillations during the late Holocene. Patrick's (1956) diatom analysis of the same core suggested a general trend from cool deep water to warm shallow water with high organic content, with one brief reversion to deep water during the Holocene. The stratigraphy was interpreted as resulting from past fluctuations of temperature and water level but, because of lack of radiocarbon dating, correlations with the archaeological sequence from the Pátzcuaro Basin are only speculative (Watts and Bradbury, 1982).

Watts and Bradbury (1982) were the first authors analyzing a pollen diagram from the Lake of Pátzcuaro covering the last 48,000 years, according to radiocarbon dating. The pollen diagram is dominated by *Pinus*, with more than 60% of the pollen at many levels of the sediment core. *Quercus* ranges from 10 to 1% of the pollen sum at many levels of the sediment core. *Alnus* is present at all levels, but consistently falls below 10% in the late Holocene, perhaps because of drier climate. On the other hand, Cupressaceous pollen, possibly a xeric *Juniperus* species, was found mainly through the Pleistocene levels in the sediment core and is not well represented throughout the Holocene. *Juniperus* pollen coincides with herbaceous pollen, particularly *Artemisia* and *Ambrosia*, which all are considered to indicate drier and possibly cooler conditions than the present ones. The pollen record of *Chenopodiineae* is restricted to the upper part of the core. This herbaceous plant group includes native agricultural crops such as *Amaranthus* and *Chenopodium*, but the pollen likely represent weeds colonizing exposed lakeshore habitats during drought.

Maize (*Zea*) pollen was found from 4,000 years BP on, but the absence of *Zea* from the top of the core may suggest that corn cultivation decreased since the Conquest. Saporito (1975) found 15 tephra layers using the same sediment core. Radiocarbon dating shows that 10 of these tephra layers were deposited within the last 10,000 years, thus throughout the Holocene, and seven of them dated between 3,500 and 2,500 years BP. A combination of natural and human impact events led to episodes of environmental degradation in the Pátzcuaro Basin since 4,000 years BP (O'Hara et al., 1993, 1994). Environmental degradation accelerated during the last 60 years of the 20th century, largely controlled by human impact and climatic fluctuations.

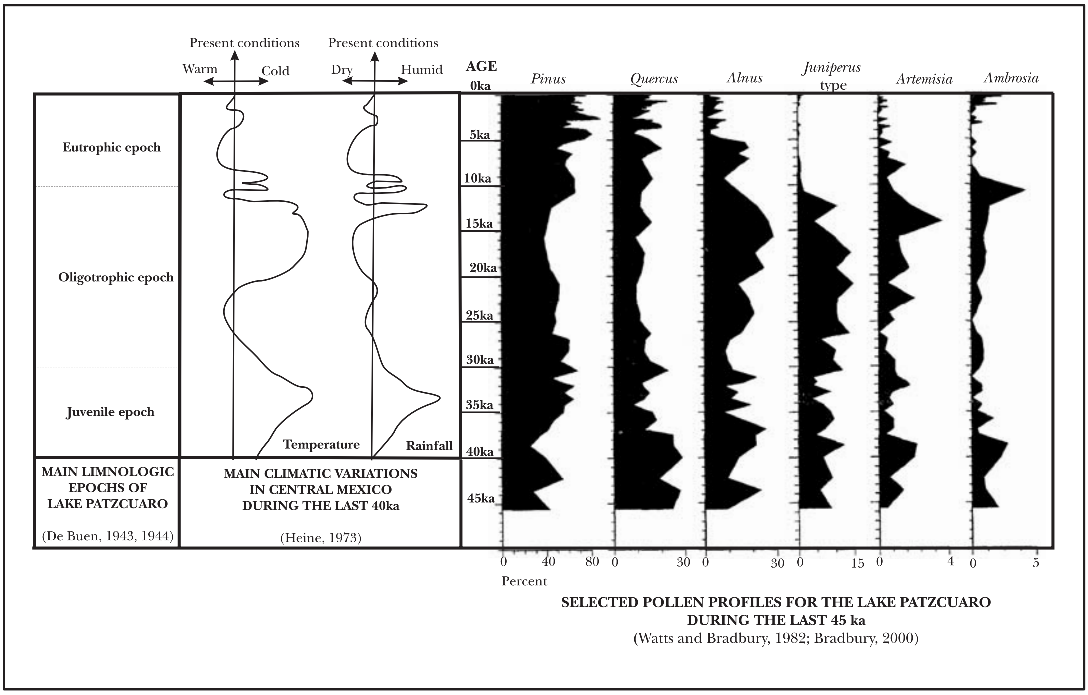



**Figure 15.17.** Main limnological epochs, climatic variations and pollen records of the Lake of Pátzcuaro during the last 45,000 years. **Sources**: De Buen (1943, 1944); Heine (1973); Watts and Bradbury (1982); Bradbury (2000)

### 15.4.2. Biogeographic evidence

Biogeographic research analyzing the natural history of endemic ichtyo-fauna in central Mexico found a presumably former biological communication between the Basin of Mexico and the lakes of Cuitzeo, Pátzcuaro, Zirahuén and Chapala through the Río Lerma (Alvarez, 1972; Barbour, 1973). The former Río Lerma basin, located north of the TMVB, was covered by seawater at the end of the Cretaceous (Tamayo, 1976). Tectonic displacement and active volcanism produced complex compartmentalization of this large area, thus modifying its drainage and producing several exorreic lake basins connected by the Río Lerma drainage system to the Pacific Ocean during the late Tertiary and early Pleistocene. Orogenic uplifts produced by volcanism gave shape to the modern lake basins in the TMVB during the mid- Pleistocene, some of them becoming endorreic, such as the Zirahuén, Pátzcuaro and Cuitzeo basins in Michoacán.

The study of freshwater fishes descendent from the Atherinidae and Cyprinodontidae families, that are restrictedly distributed within the TMVB water bodies, shows the evolution of the Río Lerma drainage and the TMVB lakes (Barbour, 1973; Miller and Smith, 1986). These fish families, that early colonized the continental freshwaters of central Mexico, occur mainly in marine environments but are also found in estuarine and freshwater rivers and lakes (Chacón, 1993). Applegate and Espinoza-Arrubarena (1982) suggested estuarine environments during the Cretaceous for parts of this region.

The descendant *Goodeidae* family and *Chirostoma* genus suffered a long adaptation to freshwater environments and further evolution via fragmentation and vicariance (Barbour, 1973; Alvarez, 1972; Miller and Smith, 1986). The distribution of this group of fishes within the TMVB lakes shows an evolution pattern of biological isolation produced by the geologic compartmentalization of the former Río Lerma Basin. Taxonomic incertitude at species level of the *Chirostoma* genus (*Pescado Blanco*, in Spanish) reveals recent evolutive trend linked to the TMVB geologic history (Barbour and Chernoff, 1984; Echelle and Echelle, 1984). Four *Chirostoma* species are found in the Lake of Pátzcuaro, accounting for 19% of the species belonging to the same genus found in the TMVB lakes. Two of them (*Ch. patzcuarensis and Ch. grandoculae*) are confined to this lake (De Buen, 1940; Barbour, 1973). *Ch. grandoculae* shows morphological similarities with *Ch. compressum,* a species commonly found in the Lake of Cuitzeo until few years ago. *Ch. estor,* another species confined to the lakes of Zirahuén and Pátzcuaro, shows morphological similarities with *Ch. chapalae*, confined to the Lake of Chapala (De Buen, 1940). Morphological similarities of *Chirostoma* suggest a recent connection between these lakes and the Río Lerma basin.

### 15.4.3. Inferred evolutive periods and events

Bradbury (2000) conducted the most comprehensive reconstruction of the paleo-history of the Pátzcuaro Lake during the last 48,000 years. The analysis of diatoms and geochemical proxies of past limnological changes, using radiocarbon dating, complements the pollen analysis that documented vegetational and climate changes in Michoacán from the late mid- Wisconsin until the early 16$^{th}$ century (Watts and Bradbury, 1982). This analysis also supports the biogeographic links between the Lake of Pátzcuaro and the Lerma River Basin during the Pleistocene. Major changes of the paleo-lake and its catchment and climate are shown in table 15.2, according to the reconstruction by Watts and Bradbury (1982) and Bradbury (2000).

A brief account of the paleo-environment of the Lake Pátzcuaro region shows that during the last 48,000 years (48ka) the lake was essentially fresh as it is today. The predominance of freshwater planktic diatoms implies lake levels and open-water areas at least as high and extensive as today. Possibly, lake levels rose high enough in the past to allow the lake to drain by surface outflow (2,100 m.a.s.l.) during the Pleistocene. Faulted diatomite deposits along the southern margin of the lake, 10 to >50 m above the present shore elevation, testify an earlier basin configuration and geological setting that included active volcanism and tectonic displacements (Metcalfe, 1985; Metcalfe et al., 1989).

At 48ka, the southern margins of the lake probably had a marshy-environment, perhaps with through-flowing drainage to the Lerma River or one of its tributaries to the northeast of the basin. The basin geometry implied by this environment was unsuitable for a large, comparatively deep lake and suggests that the tectonic, volcanic and related geomorphic changes, that constructed the current Lake of Pátzcuaro, postdated 48ka. From 47 to 38ka, the lake maintained shallow waters influenced by warm dry summer climate.

A second main period in the natural history of the Pátzcuaro Lake is recorded from 38ka to 15ka. Increased moisture allowed a transgression of the lake under freshwater oligotrophic conditions. During this period, the deepest and freshest episode within the Quaternary history of the lake was recorded (34 to 25ka). The oligotrophic lake may have been regularly frozen in winter and precipitation occurred as snow during the full glacial period (22 to 20ka). This resulted from the climatic effects of the Laurentide ice sheet, influencing vegetation, lake depth, productivity and dynamics.

A third main period in the natural history of the Pátzcuaro Lake occurred from 15ka until today (the whole Holocene). The lake became shallower and more eutrophic under climatic regimes of negative hydrologic budgets, increased seasonality and moisture arriving during summer, as it is today. Records show an overall shallower lake depth and more eutrophic conditions at 5ka. Abrupt fluctuations of pollen, diatoms and geochemical indicators of paleolimnology, vegetation and climate relate to strong environmental variations, in part caused by human and volcanic impacts in the basin, after 5ka and throughout the late Holocene. Pollen of *Zea* (maize) first appears at 3.6ka. Lake level fluctuations, increased amounts of iron-rich red clay and phytolites, rise in water salinity, and presence of tephra layers in the sediment core reflect possible short-term climatic changes and volcanic and human impacts. The Lake of Pátzcuaro rapidly changed trophic status and size, as human impacts and climatic fluctuations affected a progressively more fragile system during the last 200 years.

The lack of geomorphic research in the Pátzcuaro Basin that could explain how and when the lake became endorreic and how the geomorphic environment was constructed during the last 50ka, limits the possibilities for a comprehensive reconstruction of the natural history of this region (but see Israde and Garduño, 2002). De Buen (1944) and Barrera-Bassols (1986) suggest that the former surface outlet from the lake on its southeastern arm (Zurumútaro) was blocked by several and superimposed lava flows that reached

**Table 15.2.** Reconstruction of the history of the lake of Pátzcuaro over the last 50 thousand years

| LIMNOLOGIC CHRONOLOGY (Thousands of years) | PALEO-LIMNOLOGIC EPISODES |
|---|---|
| **48** | Moderate freshwater; shallow and marshy conditions with emergent vegetation and well-oxygenated water, perhaps with through-flowing drainage to the Río Lerma or one of its tributaries. The basin geometry implied by this environment was unsuitable for a large, comparatively deep lake and suggests that the tectonic, volcanic and related geomorphic changes, that produced the modern Lake of Pátzcuaro, postdated 48ka. |
| **47 to 38** | Shallow waters. Warm dry summer climate |
| **41** | Nutrient-rich supply to the lake and warm summer temperatures; volcanism as a source of nutrient and turbidity; lake levels began to rise |
| **38 to 33** | Continued lake level rise; increased moisture conditions |
| **34 to 25** | Freshwater, deep and rather oligotrophic lake; increased deposition of terrestrial organic matter and mineral detritus; increased erosion of iron-rich soils; climates of increased storminess and precipitation. The deepest and freshest episode in the recorded Quaternary history of the lake |
| **25 to 22** | Warm summers. Nutrient-rich, turbulent conditions at times; extensive, coarse grained, mineral-rich littoral habitats maintained by high-energy lake margin waves and currents. Storms and precipitation almost certainly arrived during this time |
| **22 to 20** | The lake may have regularly frozen in winter, and precipitation occurred as snow; oligotrophic conditions; somewhat reduced input of terrestrial organic matter and consequently less wind and overland runoff |
| **20 to 15** | Cool, deep freshwater conditions; oligotrophic lacustrine environment; abundant moisture and transportation of terrestrial organic material to the lake |
| **15 to 10** | Drier terrestrial environments and lower lake level; winter moisture but biseasonal moisture regimes cannot be discarded |
| **5** | Hot, dry climates with the modern precipitation regime during early summer; more eutrophic conditions and shallower freshwater lake; persistent low stand under balanced hydrologic conditions that could reflect a progressive swallowing of the lake by sedimentation |
| **4.6 to 3.8** | Low lake levels; tephra layers suggest potential interaction of volcanism and climate; possible human impact on the water balance of the lake |
| **3.6 to 2.8** | Lake changes potentially attributable to agriculture in the basin occurred after 3.6ka when *Zea* first appeared; erosion and deposition of iron-rich red clay after 3.2ka; higher lake levels; possibly, the favorable moist climates at that time led to the development of agricultural practices in the region |
| **2.8 to 2.0** | An arid interval; low lake levels and more saline than at any time previously; possible reduction of tillage and other forms of human impact at that time |
| **2.4** | Temporary rise in the lake level |
| **1.8 to 1.2** | Significant influx of nutrients to the basin, possibly corresponding to a major episode of indigenous agriculture related to early Classic occupation in the area; the lake remained shallow and somewhat saline compared with the preceding millennium |
| **1.2 to 0.6** | Flooding of clay to the basin decreased shallow-water habitats; short-climate changes within a system progressively more impacted by man; increased eutrophic levels; episodes of flooding and higher lake levels during 1.0 to 0.6ka |
| **0.6 to 0** | Episodes of flooding and higher lake levels; increase of trophic levels as erosion and hydrochemical concentration prevailed in the lake and relates to the progressive deforestation of the watershed, that continues today |

**Sources:** Bradbury and Watts (1982); Bradbury (2000) elevations above 2,100 m.a.s.l., but this hypothesis remains speculative. In contrast, geomorphic research carried out in the Zacapu basin, located 60 km northwest of Pátzcuaro and densely inhabited by pre-Hispanic Purhépecha, allowed the reconstruction of the natural history of its paleo-lake and the surrounding volcanic landscapes (Demant, 1978; Michelet, 1993; Tricart, 1992; Pétrequin and Richard, 1994). Geomorphic, climatic and vegetation changes during the Holocene were correlated with archaeological data, suggesting a complex combination of natural and human factors that impacted the environment of the Zacapu basin since pre-Hispanic times (Arnauld et al., 1993).

## 15.5. MORPHOGENETIC/PEDOGENETIC BALANCE: THE ASSESSMENT OF CURRENT ENVIRONMENTAL DEGRADATION

### 15.5.1. The morphogenesis-pedogenesis approach

Barrera-Bassols (1987) assessed the levels of environmental degradation in the Pátzcuaro Lake Basin according to the concept of morphogenesis-pedogenesis balance (Kilian, 1974; Tricart and Kilian, 1979; Rossignol, 1987). This concept assumes that both processes interact simultaneously in complex and competitive ways within the same natural unit. Morphogenesis controls relief evolution by a given type of geodynamics, either internal or external, or a combination of them. Pedogenesis controls soil development by a set of soil forming factors and processes (including human intervention). Both, morphogenesis and pedogenesis are inseparable, thus the balance of their specific interactions allows recognizing the evolution of natural units according to stability degrees. Three main environmental units are considered within this approach:

(1) stable environments are those natural units where morphogenetic processes are low in intensity, limited in extent and short in periodicity. The morphogenesis-pedogenesis balance is favorable to pedogenesis. These units present well developed and deep soils with well-defined diagnostic horizons;
(2) unstable environments are those natural units where morphogenetic processes are high in intensity, wide in extent and long in periodicity. The morphogenesis-pedogenesis balance is favorable to morphogenesis. Pedogenetic processes are hampered or even completely halted, and
(3) almost stable environments are those natural units presenting a patchwork-like pattern due to the spatial heterogeneity of morphogenetic and pedogenetic processes. One dominates in some sites, while the other dominates in other sites of the same natural unit. Although in general these units are somewhat stable, a sudden change promoted by an internal or external factor (climate, human intervention) can easily disrupt the fragile balance. These environments are best represented in mountainous landscapes.

### 15.5.2 Human-induced degradation in the Pátzcuaro Basin

The interpretation of the morphogenesis-pedogenesis relationships in the Pátzcuaro Basin shows environmental degradation at the landscape level including the three stages proposed by Tricart and Kilian (1979). Current environmental degradation is largely driven by human impact. Environmental degradation is unevenly distributed despite long human occupation and the natural fragility of the whole basin. It reflects diverse land management strategies and local pressure on the patchwork-like landscape configuration. Nevertheless, overexploitation of natural resources has reached a threshold whereby accelerated soil erosion may threaten the whole basin in the near future if no conservation, restoration and reclamation measures are rapidly taken.

Stable environments represent 23% of the catchment. They comprise morpho-pedologic units belonging to structural and depositional environments (Figure 15.18 and table 15.3). On Holocene lava flows, a structural environment, soils are mineral, shallow, and stony and with abundant to moderate rock outcrops (Lithosols). These soils do not present distinctive horizons and morphogenesis is of low intensity because of the recent formation of the lava flows. Soil pockets present Andic properties and humification is important due to the broad-leaf seasonal forest cover. Infiltration is high, thus these units are important aquifers for the hydrologic balance of the lake.

Inter-mountainous valleys, alluvial plains and lacustrine plains are depositional environments, where well-developed deep soils with distinctive horizons occur. This is the case of the Vertisols developed on the lacustrine plains provided with irrigation schemes, although alkalinization of the soil surface occurs locally due to poor irrigation management. Andisols in the alluvial inter-mountainous valleys are managed for rainfed agriculture. They have moderate productivity, but are prone to wind erosion during the winter if not cropped. All stable environments range from flat to sloping lands.

Almost stable environments represent 28% of the catchment, belonging to the Holocene structural morphogenetic environments and to the Plio-Quaternary structural-erosional morphogenetic environments (Figure 15.18 and table 15.3). Lava fields are lava flows covered by pyroclasts, where shallow mineral soils such as Regosols and Cambisols have developed. Phaeozems and Andisols occur locally. Most of these soils are prone to soil erosion when deforested. Intensive rainfed agriculture and grazing have locally caused the acceleration of soil erosion. Deforested patches present rills and gullies, while forested patches show no erosional features. This patchwork-like land-use pattern prevents morpho-pedologic unstability to some extent, but these fragile areas can easily become unstable. Moderately dissected slopes occur on the higher volcanic mountains suitable for forest production. When deforested for sloping agriculture, they become locally unstable due to accelerated erosion on Andisols. Gullies and barrancos are dominant erosional features where no soil conservation measures have been taken. Nevertheless, forest patches buffer local instability, thus hampering rapid evolution to a general unstability under sloping conditions. These are the dominant morpho-pedologic environments in the mountain landscapes of the TMVB, but they are less frequent in the Pátzcuaro watershed.

Unstable environments represent 42% of the catchment. They include fluvio-lacustrine depositional and structural-erosional environments (Figure 15.18 and table 15.3). Lakeshores and swamps are unstable, because water stagnation impedes soil development. The Gleysols are shallow, seasonally saturated and transformed by the ablation-depletion processes of the lake. Deposition of new materials reshapes the surface horizons and the lake level fluctuations accelerate the unstability. When drier conditions occur, soils are completely desiccated; when wetter conditions occur they become permanently saturated and allow the formation of emergent aquatic vegetation, which accelerates sedimentation on lakeshores. On the other hand, these morpho-pedologic units operate as mechanical (sedimentation) and biological (nutrient assimilation) barriers, which buffer the hyper-eutrophication of the lake.

Severely and very severely dissected slopes and very steep lava escarpments are the most unstable morpho-pedologic units in the Pátzcuaro catchment. These units occur on the oldest volcanic mountains, where Acrisols and Luvisols dominate. These fersialitic soils are highly susceptible to soil erosion, especially on steep slopes as in this case. Deforestation, intensive grazing and sloping agriculture accelerate soil erosion on areas only suitable for forest cover. These units are densely gullied and the occurrence of barrancos deeper than 25 m is common. Barrancos or gullies deeper than 25 m, develop from the mountain summits to the lakeshores.

The soil surface horizon has been depleted in most parts. In general, those units where Andisols and /or Lithosols occur are less affected by soil erosion, despite the common assumption that Andisols are highly susceptible to erosion when deforested. The contrary prevails where Acrisols and Luvisols dominate. These are the most eroded soils in the Pátzcuaro Basin.

Morpho-pedological analysis shows that, under current conditions, the Pátzcuaro Lake Basin tends to high environmental instability. Near 50% of the catchment is environmentally unstable, while 25% is almost stable but prone to instability and only 25% is somewhat stable (Figure 15.19). Morpho-pedological unstability in the basin results from the long pressure exerted on the natural resources. This pressure was accelerated during the last 60 years, impacting the natural fragility of the basin (steep slopes; high elevation gradient; small watershed size; short distance between summits and lakeshore; climatic fluctuations; endorreic basin). The nature, intensity, extent and periodicity of agriculture and grazing in areas not suitable for these purposes and the concomitant deforestation have led to the accelerated eutrophication of the Pátzcuaro Lake and environmental degradation of the watershed.

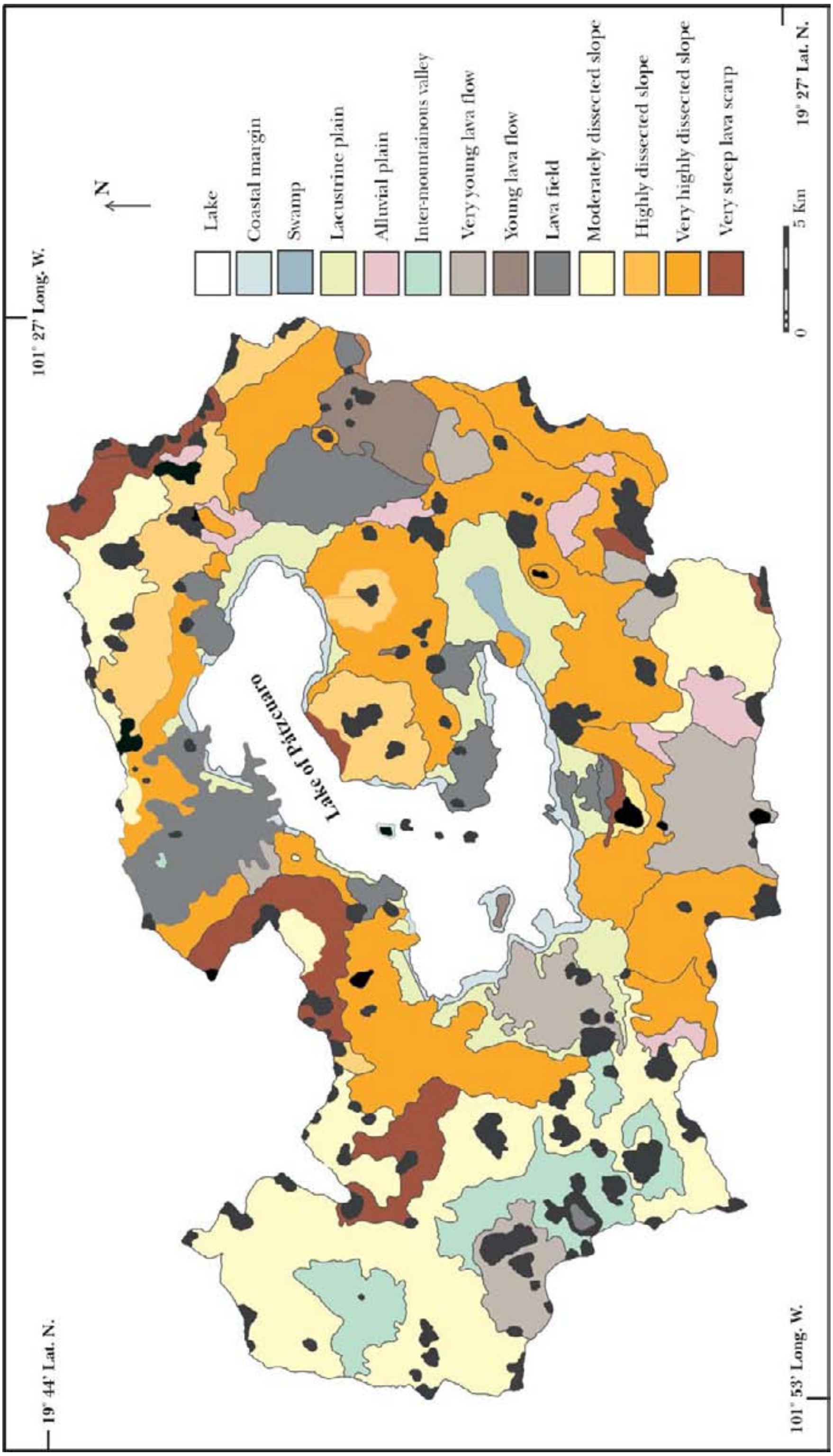



**Figure 15.18.** Morpho-pedological units of the Pátzcuaro Lake Basin, Mexico. **Modified from:** Barrera-Bassols (1986)

**Table 15.3.** Morpho-pedological units legend

| MORPHOGENETIC ENVIRONMENT | SYMBOL | LANDSCAPE | RELIEF/ MOLDING | LITHOLOGY | SLOPE (%) | DRAINAGE PATTERN | SOIL TPYE | PEDOGENESIS | VEGETATION AND LAND COVER | MORPHOGENESIS | MORPHOGENESIS /PEDOGENESIS BALANCE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Quaternary Fluvio-lacustrine depositional environment | | Coastal margin | Floodplain seasonally flooded | Fine lacustrine alluvial material over basalt | 0 to 3 | Underwater springs | Mollic Gleysol | Gleization Cumulization | Aquatic vegetation Agricultural lands | Ablation-depletion | Unstable |
| | | Swamp | Floodplain permanently flooded | Fine lacustrine material over basalt | 0 to 3 | Permanently inundated | Mollic Gleysol Pelic Vertisol | Gleization Vertic properties Alkalinization | Aquatic vegetation | Alluvial deposition | Unstable |
| | | Lacustrine plain | Flat Fluvio-lacustrine deposition | Fine and medium fluvio-lacustrine material over basalt | 3 to 7 | Anthropogenic manipulation (Irrigation schemes) | Pelic Vertisol; Vertic Luvisol | Vertic properties Fersialitization Lessivage Alkalinization | Irrigation and rainfed agriculture | Colluvial-alluvial deposition | Stable andlocally almost stable |
| | | Alluvial plain | Flat Fluvial deposition | Fine and medium fluvio-volcanic material over basalt | 3 to 7 | Chaotic; high infiltration rates | Ochric Andisol; Humic Phaeozem | Andic properties Humification | Rainfed agriculture | Colluvial-alluvial Deposition Wind erosion | Stable |
| | | Intermountainous valley | Depression Erosion-deposition | Fine and medium fluvio-volcanic material over basalt | 3 to 15 | Seasonally stream confluences; 2 m depth Incisions; high infiltration rates | Humic Andisol; Ochric Andisol | Andic properties Humification | Rainfed agriculture | Colluvial-alluvial deposition; local hydromorfism; wind erosion and incisions | Stable and locally almost stable |
| Holocene Structural volcanic environment | | Very young lava flow | Mesa AA lava type | Basalt | 0 to 3 | Chaotic; very high infiltration rates; aquifer | Lithosol; Humic Andisol | Littering Andic properties Humification | Oak-pine forest | Interrupted by recent volcanism | Stable |
| | | Young lava flow | Mesa AA lava type | Basalt locally covered by detritic material | 0 to 7 | Chaotic; high infiltration rates; aquifer | Humic Andisol; Lithosol | Andic properties Littering Humification | Oak-pine forest; Rainfed agriculture | Sheet erosion locally | Stable |
| | | Lava field | Erosion-deposition | Mixed pyroclast and basalt material | 3 to 7 | Chaotic, diffuse and laminar surface drainage | Ochric Andisol; Humic Andisol | Andic properties | *Baccharis* bush; Anthropogenic grassland | Sheet erosion and incisions | Almost stable to unstable |
| Plio-Quaternary Structural-erosional volcanic environment | | Moderately dissected slope | Moderately steep backslope-footslope complex Erosion-denudation | Mixed pyroclast and basalt material | 15 to 20 | Radial pattern with drainage up to the 3rd order | Ochric Andisol; Humic Andisol | Andic properties | Oak-pine forest; *Baccharis* bush; Anthropogenic grassland; Rainfed agriculture | Diluvial, colluvial and alluvial material transport; gullies and incisions; sheet erosion | Almost stable to unstable |
| | | Highly dissected slope | Steep backslope-footslope complex Erosion-denudation | Mixed pyroclast and basalt material | 20 to 25 | Pinnate or radial pattern with drainage up to the 4th order | Orthic Luvisol; Chromic Luvisol; Ochric Andisol | Fersialitization Lessivage Braunification Andic properties | Oak-pine forest; Sub-tropical bush Anthropogenic grassland | Barrancos, gullies and incisions; densely eroded; gully erosion | Unstable |
| | | Very highly dissected slope | Very steep backslope-footslope complex Erosion-denudation | Mixed pyroclast and basalt material | >25% | Pinnate pattern with drainage up to the 6th order | Chromic Luvisol; Orthic Acrisol | Fersialitization Lessivage | Sub-tropical bush; Anthropogenic Grassland; Oak-pine forest | Barrancos and gullies; very densely eroded; gully erosion | Unstable |
| | | Very steep lava scarp | Very steep escarpment Erosion | Basalt | >25% | Pinnate pattern with drainage up to the 7th order | Orthic Acrisol; Orthic Luvisol; Ochric Andisol | Fersialitization Andizolation | Pine forest; Oak forest; *Baccharis* Bush; Rainfed agriculture | Barrancos; very Densely eroded; gully erosion | Unstable |

**Source:** Barrera-Bassols (1986)

## 15.6. CONCLUSION

This chapter discussed the eco-geographic complexity of the Pátzcuaro Lake Basin, as well as evidence of its natural history and current environmental degradation. It offers information about land and water resources, the ecological base for the historical development of populations within the basin since at least 4,000 years ago. It also shows that environmental degradation has been induced by natural causes and /or by natural-human related causes.

The overlapping of bio-physical patterns in a patchwork-like distribution stands as the main factor of the natural complexity of the Pátzcuaro Basin, although this is a small and relatively young basin. Some 120 small Holocene volcanic cones with lava flows with a volume of less than 1 $km^3$ are located within the basin. This gives a density of 1 volcano per each 13 $km^2$. Higher Plio-Pleistocene monogenetic volcanoes form the principal mountain ranges that surround the endorreic lake basin. Structurally speaking, the Pátzcuaro Basin is one of the grabens located within the MVD and one of the 25 lacustrine basins distributed along the TMVB.

Volcanism and tectonism have been the main forming factors of the rugged mountainous landscapes of the basin. Elevation, climatic variations, topography and the presence of a permanent water body control the patchy distribution of biophysical factors and natural resources. On the other hand, steep slopes, high elevation gradient, a small watershed size, short distance between mountain summits and lakeshore, short-term climatic fluctuations and the presence of an endorreic lake are the main factors giving its natural fragility.

Pátzcuaro enjoys a temperate sub-humid climate, but rainfall, temperature and evapotranspiration rates vary significantly according to elevation and a south-north climatic gradient with humid and temperate areas towards the south and dryer and warmer areas towards the north of the basin. Verticality and horizontality control climatic variations, although the presence of a relatively large and permanent water body buffers horizontal climatic variations. Relationships between mean annual temperature, rainfall and relative humidity give six main meso-climatic regimes.

Relationships between elevation, lithology, topography, slope gradient and morphogenetic processes are the main factors controlling the patchy distribution of five main landscapes at regional level. Nine soil types and several subtypes and soil associations are unevenly distributed within the five main landscapes. The soil moisture regime is ustic with exception of the lakeshore and flat depressions where an aquic regime occurs, and above 2,900 m.a.s.l. where an udic regime occurs.

The Pátzcuaro Lake basin shows notable vegetation diversity despite its relatively small size and homogeneous lithology. Natural vegetation has been strongly modified by human intervention during the last 4,000 years, thus all vegetation communities have a secondary origin. Six main terrestrial vegetation types and several plant associations occur in a patchwork-like pattern, according to specific ecological conditions and human intervention. Similarly, four main aquatic vegetation communities occur within the lake. Their distribution is linked to limnologic zonation, water-level fluctuations and management.

The persistence of the Lake of Pátzcuaro since the mid-Wisconsin (50,000 years BP) is one of the relevant features of the region. It indicates that the basin did not witness strong aridity over the long term. Because of its relatively small size, shallow depth and hydrological balance largely controlled by rainfall, evaporation and groundwater inflow, the lake has been highly sensitive to climatic change and stands as a fragile aquatic ecosystem. The lake has no significant surface inflow and no surface outflow. It appears to be largely maintained by shallow groundwater and local runoff during the rainy season. Apparently, groundwater is the only net hydraulic source, thus the lake has always been essentially a fresh-water lake. The hydrochemistry of the lake is dominated by sodium and bicarbonate ions, reflecting the surrounding volcanic landscape. High content of total phosphorous, related to human activities within the catchment, is currently causing eutrophication of the lake.

The overlapping of biophysical patterns causes the eco-geographic complexity of the Pátzcuaro Lake basin. Six main bioclimatic zones are distinguished from the lakeshore to the higher mountains. Bioclimatic zones are the result of the relations between meso-climatic regime, elevation, morphogenetic environment, landscape, slope gradient and aspect, soil type and vegetation cover. Human-induced landscape transformations that occurred since 4,000 years BP have modified the eco-geographic complexity of the Pátzcuaro Basin.

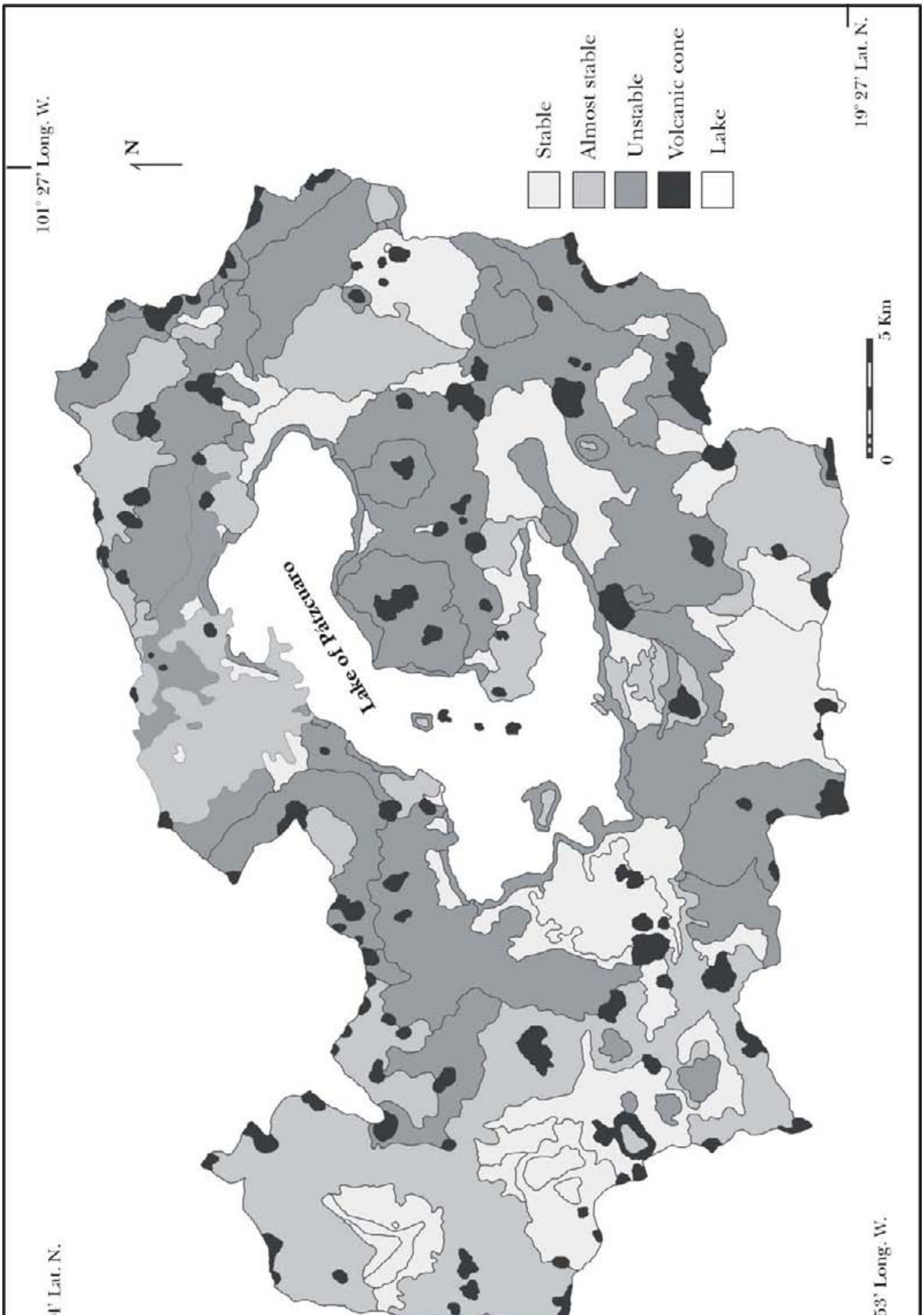



**Figure 15.19.** Current environmental degradation in the Patzcuaro Lake Basin, according to the morphogenesis-pedogenesis approach. **Modified from:** Barrera-Bassols (1986)

Complex relations between volcanism and tectonism, climatic fluctuations and limnological events molded the Pátzcuaro Lake basin during the last 50,000 years. Paleo-limnological research shows that the basin experienced changes, which affected its geomorphologic configuration and the ecology of the lake during the whole Pleistocene and Holocene. Volcanism and tectonism provoked the compartmentalization and damming of a former exorreic lake-basin connected to the Lerma River basin during the Pleistocene. Biogeographic evidence show biological connections between the Pátzcuaro Lake and the Lerma River, followed by isolation and vicariance of endemic ichtyofauna. Furthermore, past environmental changes caused episodes of lake eutrophication without human intervention. Nevertheless, the pollen record from lake sediments shows a relatively stable ecological and depositional environment, allowing the permanence of the lake body despite climatic fluctuations.

The appearance of maize in the pollen record at 4,000 years BP, the increase of iron-rich clay sediments, the presence of tephra layers in the sediment core, inferred lake level fluctuations and the rise in water salinity, reflect climatic fluctuations, volcanic activity and human impacts during the late Holocene. Human-induced degradation has reached a threshold during the last 60 years of the $20^{th}$ century due to pressure on the natural resources. Land and water resources overexploitation and mismanagement have resulted in the acceleration of the lake eutrophication and the increase of soil erosion in some areas of the basin. An environmental degradation assessment of the Pátzcuaro basin during the late 1980s revealed that only 25% of the catchment remained in good conditions, while 28% suffered local degradation and 42% presented severe degradation in the form of physical and chemical soil erosion (Barrera-Bassols, 1986, 1987).

Findings of this chapter pose the following questions: How to assess human-induced environmental degradation over the long term? Who were the actors involved and how were they involved? Why does the Pátzcuaro Lake basin remain relatively preserved if compared to other lacustrine basins in the TMVB, despite the long-standing human occupation of this naturally fragile and small region? These questions are addressed in the following two chapters.

# Chapter sixteen

## Society and nature in the Pátzcuaro lake basin

### 16.1. introduction

The aim of Chapter Sixteen is twofold: it introduces the study region from the socio-cultural point of view and analyzes the historical relations between nature, culture and society in the Pátzcuaro Basin. The objective is to discuss the current demographic, economic and cultural characteristics, with emphasis on the contrasts and imbalances between indigenous and non-indigenous populations and between urban and rural populations, and to reveal how these disparities evolved over the long term. The chapter provides a socio-political framework to understand the environmental degradation events that have occurred within the last 4,000 years, assuming that socio-political factors have been the prime movers of environmental changes since the early occupation of the basin.

The chapter is divided into seven sections. Section 16.2 analyzes the demographic factors, main land-use systems, land tenure regimes and cultural factors that shape the basin's landscape. Section 16.3 discusses the relationship between nature, culture and society since the early occupation of the basin until the eve of the Spanish conquest. Emphasis is given to the formation of the Purhépecha State in relation to natural resource management, centralization of decision-making, social stratification and cosmovision. Section 16.4 analyzes the colonial period, placing emphasize on land tenure policies, land-use systems and the unequal relationship between colonists and colonized. Section 16.5 discusses land tenure and land-use policies after the colonial period and during the whole 19th century and how they affected the environment and populations, leading to social unrest at the eve of the Mexican Revolution. Section 16.6 offers an explanation of the causes and consequences of post-revolutionary land reform policies, rural modernization and demographic explosion during the 20th century. Emphasis is given to changes in rural livelihoods and natural resource management during the last 60 years. Section 16.7 summarizes the main conclusions, which serve as a framework to discuss, in the following chapter, environmental degradation in the Pátzcuaro Lake Basin during each historical period until the present.

### 16.2. the social context in Pátzcuaro at the end of the 20th century

#### 16.2.1. Population

Population, economy and culture in the Pátzcuaro Basin show sharp contrasts at the end of the 20th century, that parallels its natural heterogeneity and complex environmental degradation. Socio-cultural diversity and economic disparities are the result of a long history of resistance of the original population, exposed to external and internal challenges since the colonial times. Pátzcuaro, as an inter-ethnic territory and social fabric, reflects historical tensions between different worldviews, communal and private interests, and unequal social relations. A long history of occupation, with the confluence of diverse ethnic identities embodying contrasting perceptions of nature and its appropriation, has reshaped the landscapes and local political ecologies since the pre-Hispanic period.

These contrasts mirror two realities: cultural richness and extreme poverty and environmental degradation in a territory where rural populations vigorously maintained and adapted complex ecological knowledge-based systems. The analysis of these contrasting realities helps answer when, how and why evolved. Central to this is the understanding of current specific relations between nature, culture and society and how these relations co-evolved in the long term.

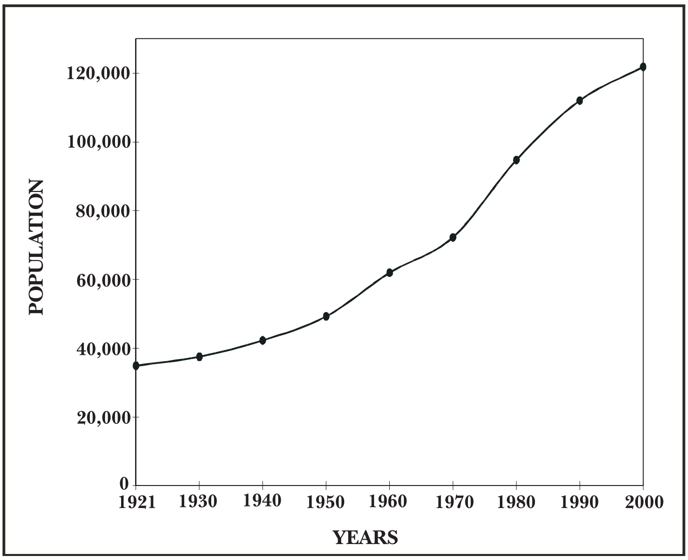



**Figure 16.1.**Population growth in the Pátzcuaro Lake Basin during the 20th century

Population size of the Pátzcuaro Basin stands high at the end of the 20th century (Figure 16.1) (Castilleja, 1993). The last population census registered 122,000 inhabitants living in 92 settlements (INEGI, 2001). There has been an explosive population growth during the last 50 years. Population doubled from 1940 to 1970 and tripled by the end of the 20th century (Table 16.1), with an average annual growth of 2.7%. However, population growth was slightly lower in Pátzcuaro than at national and state levels within the same period.

The regional population density is high, double the population density of Michoacán (60 inhabitants/km²) and triple the national density (46 inhabitants/km²). Population density has increased from 79 inhabitants/km² in 1970 to 138/km² in 2000 (Castilleja, 1993; INEGI, 2001). However, the population is not equally distributed, showing disparities between urban and rural populations within the four main municipalities of the basin (Pátzcuaro, Quiroga, Tzintzuntzan, Erongarícuaro and Tingambato) (Table 16.2).

**Table 16.1.** Population per municipality in the Pátzcuaro Lake Basin: 1921-2000

| Municipality | 1921 | 1930 | 1940 | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 |
|---|---|---|---|---|---|---|---|---|---|
| **Pátzcuaro** | 20,168 | 20,890 | 22,929 | 25,879 | 32,430 | 37,615 | 53,287 | 66,736 | 77,872 |
| **Quiroga** | 9,102 | 10,879 | 8,672 | 10,293 | 12,616 | 16,004 | 19,748 | 21,917 | 23,893 |
| **Tzintzuntzan** | | | 5,249 | 6,350 | 7,820 | 9,139 | 10,440 | 11,439 | 12,414 |
| **Erongarícuaro** | 5,629 | 5,726 | 5,244 | 6,716 | 9,079 | 9,470 | 11,270 | 11,930 | 13,161 |
| **TOTAL** | **34,899** | 37,495 | 42,274 | 49,238 | 61,945 | **72,228** | 94,745 | 112,022 | **127,290** |
| **% Michoacán** | **3.4** | **3.7** | **3.6** | **3.5** | **3.4** | **3** | **3** | **3.2** | **3.2** |

**Sources:** Castilleja (1993); INEGI (2001)

Population growth was markedly higher in the urban areas during the 20th century. Nowadays, Pátzcuaro and Quiroga cities concentrate 48% of the regional population. Official estimates account for 65% of urban population, although some of the localities considered urban according to official standards (localities with more than 2,499 inhabitants) should be considered rural. Some of these localities do not have urban infrastructure, and a large proportion of the economically active population relies on agricultural activities, despite surpassing official demographic standards. According to this, urban and rural populations are equally distributed, but rural localities represent 90% of the settlements in the basin (Castilleja, 1993).

Concentration of settlements per municipality shows that Pátzcuaro and Tzintzuntzan, with 50% of the basin area, account for 55% of the localities. The distribution of urban and rural localities also shows disparities between municipalities. Urban populations of Pátzcuaro and Quiroga account for 71% and 83% of their total populations, while rural populations of Erongarícuaro and Tzintzuntzan account for 75% and 50%, respectively. Population distribution in the Pátzcuaro Basin shows two main patterns: a large concentration of urban populations in two localities and a large dispersion of rural populations located in 90 localities. These patterns reflect the national tendency for urbanization and the regional agrarian tradition. Patterns also show the historical occupation of the basin linked to access to the most fertile tracts of land and lake resources.

**Table 16.2.** Population characteristics per municipality in the Pátzcuaro Lake Basin in 2000

| Municipality | Area km$^2$ | % | Total population | % | Urban population | % | Rural population | % | Number of localities | Population density inhab/km$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pátzcuaro** | 261 | 28 | 77,872 | 61 | 55,599 | 71 | 22,273 | 29 | 44 | 298 |
| **Quiroga** | 285 | 31 | 23,893 | 19 | 19,943 | 83 | 3,950 | 17 | 11 | 84 |
| **Tzintzuntzan** | 157 | 17 | 12,414 | 10 | 6,241 | 52 | 5,983 | 48 | 29 | 79 |
| **Erongarícuaro** | 216 | 24 | 13,161 | 10 | 2,573 | 24 | 10,588 | 76 | 16 | 61 |
| **TOTAL** | **919** | **100** | **127,290** | **100** | **84,563** | **66** | **42,794** | **34** | **100** | **138.5** |

**Source:** INEGI (2001)

The relation between numbers of localities per landscape shows unequal distribution of populations and their limited access to the natural resources of the basin (Figure 16.2). Sixty four settlements are located in the lacustrine plains and islands (2,040 to 2,100 m.a.s.l.), corresponding to 70% of the localities and accounting for 48% of the regional population. Twenty two settlements are located within the piedmont (2,100 to 2,400 m.a.s.l.), corresponding to 24% of the localities and accounting for 45% of the regional population. Four settlements are located within the inter-mountainous valleys (2,300 to 2,700 m.a.s.l.), corresponding to 4% of the localities and accounting for 6% of the regional population.

Two settlements are located in the volcanic mountains (2,400 to 3,340 m.a.s.l.), corresponding to 2% of the localities and accounting for 1% of the regional population. Before the Spanish conquest, localities concentrated in the fertile lacustrine plains and on the fragile sloping lands (Gorenstein and Pollard, 1983).

### 16.2.2. Land-use systems

Land-use in the Pátzcuaro Basin shows a patchwork-like pattern controlled by four main sets of factors: (a) biophysical factors; (b) land management systems; (c) land tenure regimes; and (d) social institutions (Toledo et al., 1980; Alvarez-Icaza and Garibay, 1993).

The rugged mountainous landscape and the presence of a permanent water body largely influence land-use suitability, while land management systems, land tenure regimes, economic and ecological rationale, and technological adoption are shaped by diverse social institutions including cultural identity. In general, two main forms of natural resource management co-exist within the basin. Mountainous land management systems are linked to indigenous communal land tenure regimes, with a tendency for multiple land management. The flatland management systems, located in the fertile lacustrine and alluvial plains, are linked to private and social land tenure regimes with specialized land management (Toledo and Barrera-Bassols, 1984). Mountainous land management systems operate on marginal (sloping) agricultural lands, with the exception of the inter-mountainous valleys, but possess 75% of the forestland of the basin, while flatland management systems control more favorable agricultural lands and have access to lake resources. The two land management systems compliment each other to satisfy the local and regional markets networks since pre-Hispanic times.

Forest, pasture and agricultural lands are almost equally distributed within the basin (Figure 16.3 and table 16.3), with some differences between municipalities. Forestland is still the main land-use type, although it has decreased over the last 40 years. Official estimates indicate that forested areas decreased by 45%, with some areas completely deforested during the period 1963-1990 (Alvarez-Icaza and Garibay, 1993; Masera et al., 1998).

Deforestation is seen as a consequence of agricultural expansion and biomass mining (Barrera-Bassols, 1992; Becerra et al., 1997). However, recent case studies challenge these generalizations when showing that

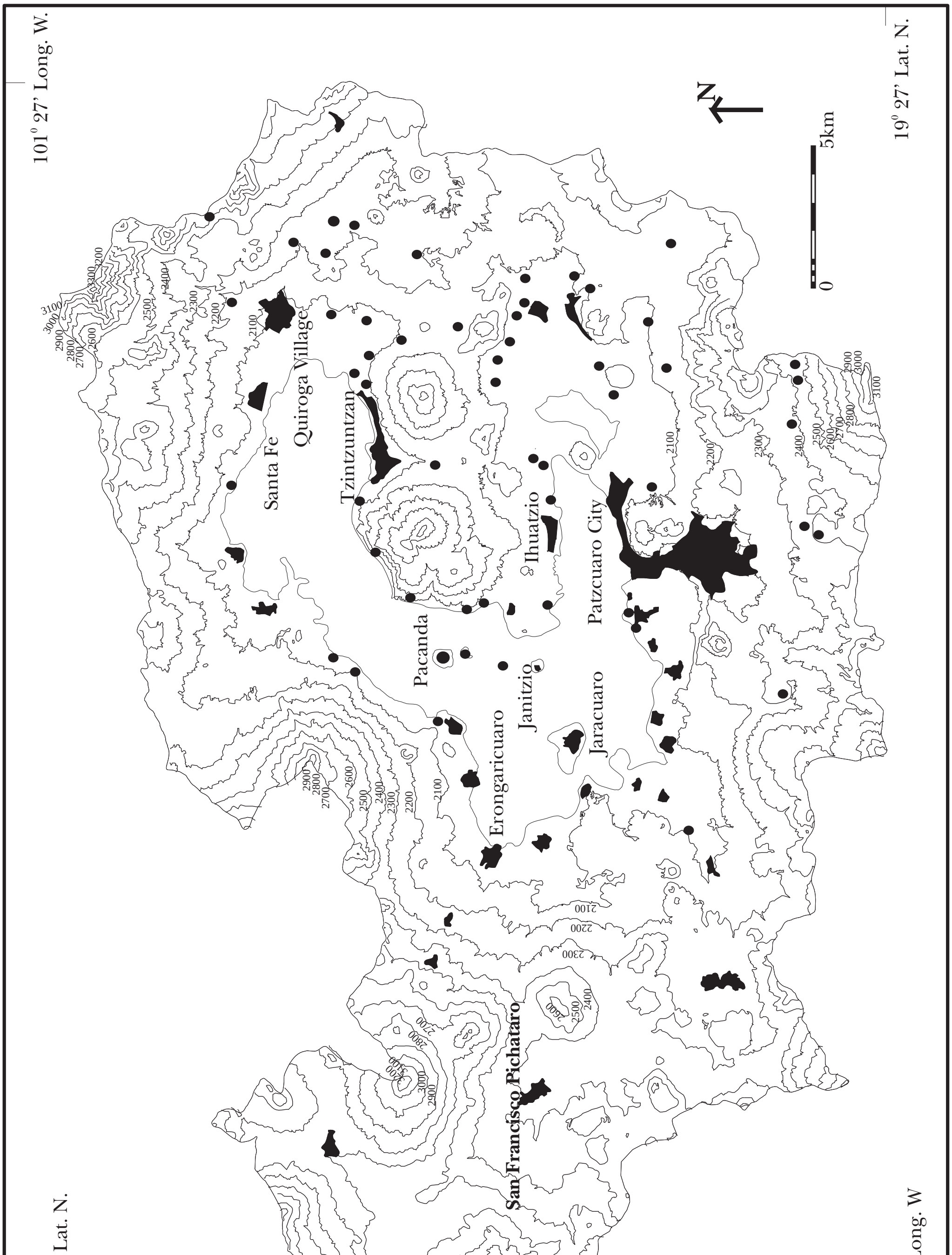



**Figure 16.2.** Distribution of settlements in the Pátzcuaro Lake Basin

deforestation is not a lineal process of agricultural expansion and biomass mining but a complex process where agricultural land abandonment, social migration and the ecological effect of selective cutting are factors inducing reforestation at local scale (Klooster, 2000 and 2001). Forest exploitation is varied but basically extractive and mainly for fuelwood (food preparation and handicraft production at household level), resin extraction and commercial logging. Forest exploitation relies on local, regional, national and international demands (Masera et al., 1998), thus different internal and external forces control deforestation-reforestation.

**Table 16.3.** Land-use and land cover in the Pátzcuaro Basin

| Municipality | Forest cover | | Pastureland | | Agricultural land | |
|---|---|---|---|---|---|---|
| | ha | % | ha | % | ha | % |
| Pátzcuaro | 16,305 | 47 | 14,978 | 45 | 8,159 | 34 |
| Quiroga | 5,335 | 16 | 9,872 | 30 | 6,073 | 26 |
| Erongarícuaro | 8,435 | 24 | 2,553 | 8 | 6,372 | 27 |
| Tzintzuntzan | 4,535 | 13 | 5,837 | 17 | 3,110 | 13 |
| **Sub-total** | **34,340** | **100** | **33,240** | **100** | **23,714** | **100** |
| **Percentage** | **38%** | | **36%** | | **26%** | |

**Sources:** Barrera-Bassols (1986); Alvarez-Icaza (1993)

Agricultural lands are largely used for rainfed maize production and, locally, for irrigated maize (Table 16.4). Social and private *Mestizo* farms possess mechanized irrigation systems, while varied rainfed agricultural systems prevail on indigenous communal lands. Maize productivity in rainfed systems (1.5 tons/ha) is similar to the national average (1.7 tons/ha), while maize productivity in irrigation schemes (2 to 4 tons/ha) is much lower than the national average (8 to 12 tons/ha).

**Table 16.4.** Main crops in the Pátzcuaro Basin

| Crop | Surface area ha | % |
|---|---|---|
| **Maize** | 8,062 | 72 |
| **Wheat** | 706 | 6 |
| **Fruit trees** | 598 | 5 |
| **Janamargo** | 505 | 5 |
| **Beans** | 460 | 4 |
| **Oats** | 342 | 3 |
| **Lentils** | 208 | 2 |
| **Others** | 375 | 3 |
| **TOTAL** | **11,256** | **100** |

**Source:** Álvarez-Icaza and Garibay (1993)

There has been a reduction of agricultural activities in the Pátzcuaro Basin during the last 30 years. The maize area decreased by more than half between the 1969 and 1993. Low profitability on marginal lands has led to partial abandonment as the logical outcome of international agricultural policies encouraged by the national political neoliberalism. Maize prices have fallen by more than half since 1986 and the effective income from maize harvest has also fallen (Klooster, 2001). Farmers are better off when buying imported maize from the USA than growing it themselves. While some small farmers continue to crop only a fraction of the maize and beans they consume, the bulk of their rural livelihood comes from beyond the borders of their communities.

Off-farm income is generated especially by wage labor in commercial agriculture, construction work, handicraft, petty commerce and remittance from the USA by temporary migrants. Nevertheless, some 10,000 farmers still rely on maize production (Tizcareño-López et al., 1999) because of cultural and economic factors. Maize has been cropped in the region for 4,000 years and constitutes the major food security crop for the majority of the rural households. Maize also remains as a primordial symbol in the contemporaneous Purhépecha cosmovision (Argueta, 1985; Mapes, 1987; Mapes et al., 1990; Garibay, 1996; Klooster, 2000). One-year cropping/fallow maize system largely dominates in the basin. Estimates show that nearly half of the agricultural land is cropped per year, while the other half is fallowed and temporarily grazed (Nuñez, 1989; Alvarez-Icaza and Garibay, 1993).

Livestock raising is extensive, with low productivity rates (0.6 animals/ha), and linked to the rainfed agricultural system since colonial times. It forms part of the subsistence security strategy of *Mestizo* and indigenous small farmers.

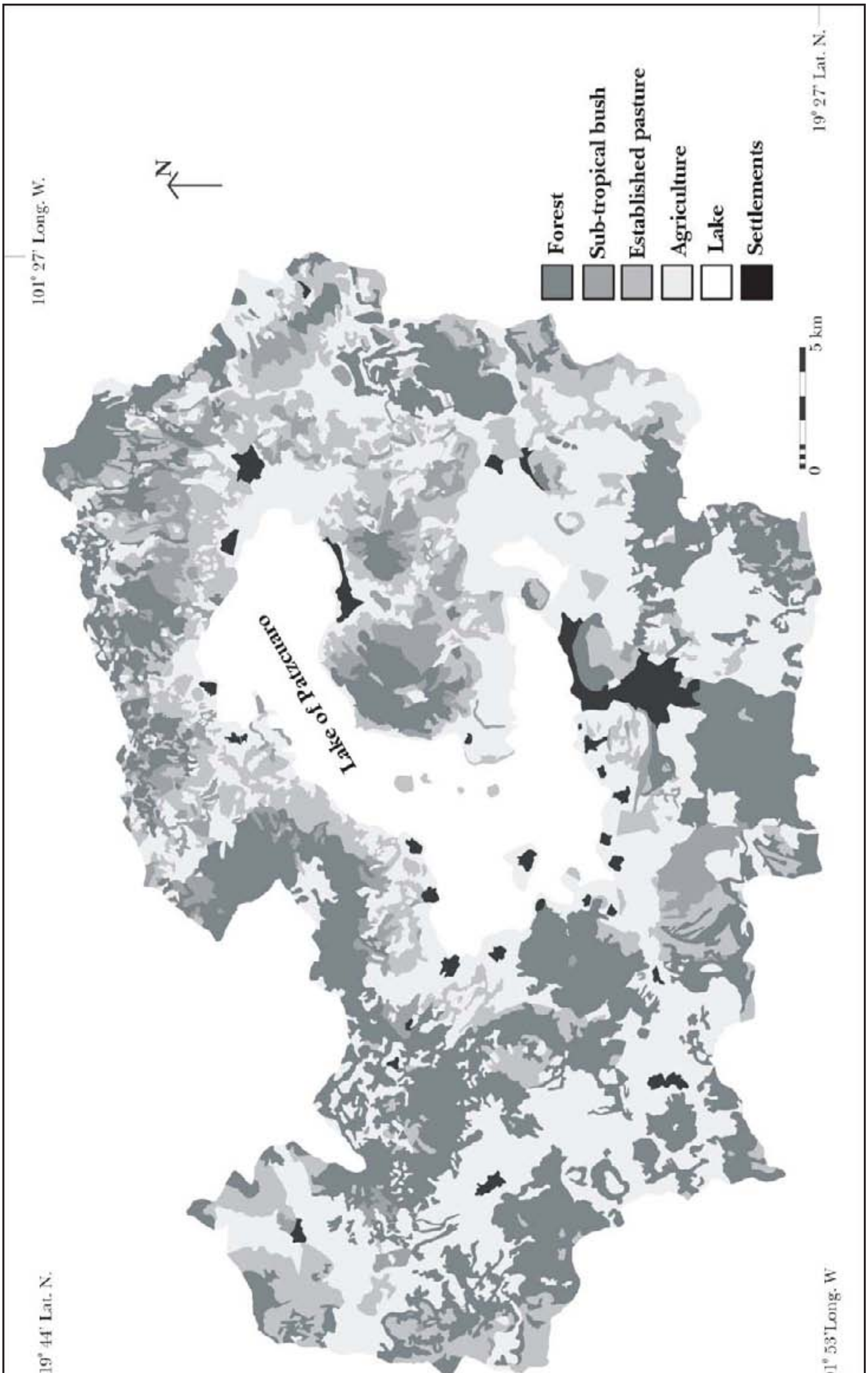



**Figure 16.3.** Land-use and land cover in the Pátzcuaro Lake Basin. **Source:** Barrera-Bassols (1992)

Cattle graze on established pastures, bush and forest land during the agricultural cycle (summer-autumn) and after on fallow parcels (winter-spring). This rotation subsidizes land fertility (3.5 tons of maize stalks/ha) in a system that lacks financial capital. Wheat and other cereals are produced for double-purpose (milk and meat) intensive cattle system. On private landholdings, commercial livestock raising may be extensive stock or in stable. Both practices are linked to local and regional markets (Alvarez-Icaza and Garibay, 1993).

### 16.2.3. Land tenure regimes

Land tenure in the Pátzcuaro Basin is heterogeneous but largely dominated by social property regimes (Table 16.5 and figure 16.4). Indigenous communities and social property lands (ejidos) possess 68% of the land, while private holders own only 30%. Of note is that 11% of the private landholders are small farmers managing less than 25 ha. Small private landholders are subsistence farmers practicing a multi-purpose land management as a security strategy, similar to land management by indigenous communities and ejidos.

Some differences are found when comparing land tenure with land-use systems. This is a critical comparison because it shows not only which land tenure regime controls the main land-use systems but also the degrees of land-use specialization, reflecting land-use decision-making strategies and management systems. Localities having land as social property tend to specialize in agro-sylvicultural systems, while small private farmers mainly rely on subsistence agriculture and livestock raising and large private holders exploit forests and raise commercial livestock, by far the most profitable production systems in the region. However, the distribution of land-use systems in social and private landholding regimes shows an overall tendency for land management diversification in the basin (Alvarez-Icaza and Garibay, 1993).

**Table 16.5.** Land-use per landholding regime in the Pátzcuaro Basin

| Landholding regimes | Forest cover (%) | Agricultural land (%) | Pastureland (%) | Total (%) |
|---|---|---|---|---|
| Indigenous communities | 47 | 33 | 20 | 100 |
| Ejidos | 42 | 41 | 15 | 100 |
| Private small farmers | 27 | 47 | 26 | 100 |
| Intermediate and large private farmers | 44 | 19 | 37 | 100 |

**Sources:** Alvarez-Icaza and Garibay (1993); Barrera-Bassols (1993)

### 16.2.4. Culture and society

The Pátzcuaro Basin is culturally diverse and social relations are influenced by unequal inter-ethnic connections. Cultural diversity is the result of the confluence of the Purhépecha and European traditions during the last 500 years, allowing the permanence of vigorous Indian and *Mestizo* populations. Subordination/domination tensions have molded the historical resistance of the Purhépecha people for maintaining their cultural identity since the colonial period. These relations shaped the local political economies and interactions between indigenous and non-indigenous populations. Cultural differentiation is now influenced by the new globalized economic and political realities in the region. The resurgence of the Purhépecha socio-political organization, agricultural internationalization, extreme poverty and mass out-migration interact reshaping cultural identities of ethnic, urban and rural populations (Zárate, 1993; Gledhill, 1995; Garibay, 1996; Dietz, 1999).

The Pátzcuaro Basin forms part of a wider indigenous territory historically occupied by the Purhépecha people, a Middle American society. The Purhépecha territory is located in north and central Michoacán, with a few smaller areas south of the main territory. Three geographical and contiguous regions comprise this territory, including the Pátzcuaro Basin, the Meseta or Sierra Tarasca and La Cañada. The Purhépecha population represents some 6% (120,000 inhabitants) of the total population of Michoacán and 90% of the

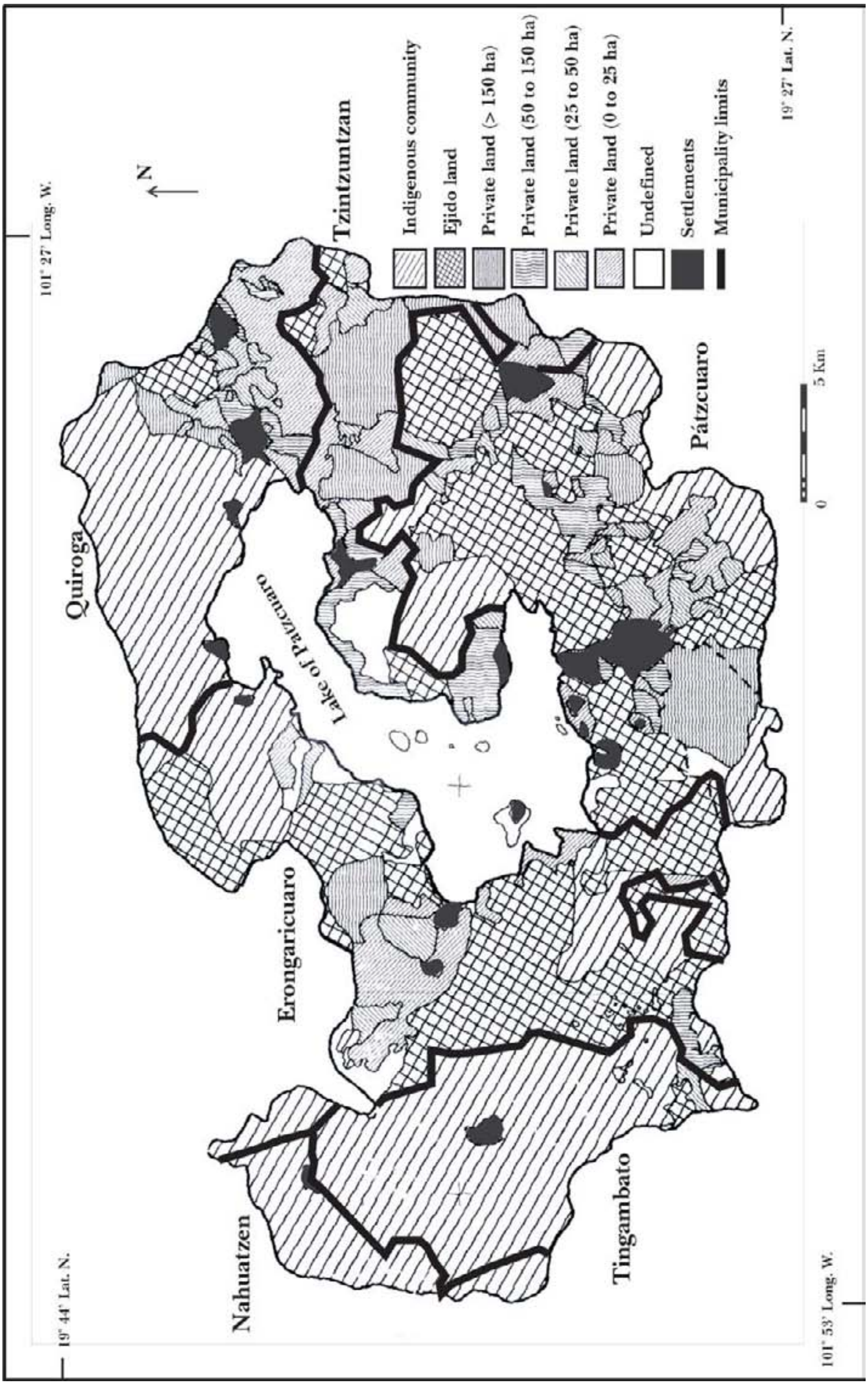



**Figure 16.4.** Land tenure regimes in the Pátzcuaro Lake Basin. **Source:** Alvarez-Icaza and Garibay (1993)

indigenous population of the state (INEGI, 2001). The Purhépecha living in the Pátzcuaro Basin are distributed in 25 localities (27% of the localities within the basin), corresponding to 36% of the total Purhépecha-speaking population (Castilleja, 1993; INI, 1993; INEGI, 2001).

The Purhépecha-speaking population doubled over the last 60 years (West, 1948; INEGI, 2001). The population census of 1940 registered 20,000 inhabitants, while 44,000 were registered in the last population census. However, both censuses registered only individuals older than 5 years, therefore the real Purhépecha-speaking population was underestimated.

When compared to the total population of the basin, the Purhépecha population shows an overall decrease of 4% during the period 1980-2000. The ethnic composition of the population of the Pátzcuaro Basin gives a numeric majority to the *Mestizo* inhabitants (Spanish-speaking individuals older than 5 years), comprising 82% of the total population (INEGI, 2001). The sole use of the native language by individuals older than 5 years for measuring ethnic composition underestimates indigenous populations in areas like Pátzcuaro, where a large proportion of the inhabitants is younger than 6 years and where language-shifting is an important cultural process.

Today, more than 90% of Purhépecha speakers are bilingual. About 50% of monolingual people are female. Formal education and constant migration appear to be main language-shifting factors. Females remain monolingual due to their restricted access to formal education and less opportunities for out-migration. Despite this, the Purhépecha territory, including the Pátzcuaro region, still maintains as a relatively solid block of indigenous speech (Dietz, 1999).

Non-official estimates show that 50-60% of the Pátzcuaro Basin population consider themselves as indigenous (INI, 1993; PNUD, 1996). In addition to language, account customary laws, land tenure regimes, local environmental knowledge and management systems, social institutions and cosmology as main cultural elements shaping the identity of Purhépecha individuals. Though indigenous population varies considerably according to different estimates, the indigenous identity is vigorous in the basin, but shows substantial differences within the four municipalities (Table 16.6). Erongarícuaro and Tzintzuntzan remain indigenous municipalities, while Quiroga shows a slight majority of *Mestizo* population and Pátzcuaro stands as the most *Mestizo* municipality.

**Table 16.6** Demographic and cultural indicators in the municipalities of the Pátzcuaro Basin

| Municipality | Localities | Rural localities | Total population | Indigenous Population % | | Rural Population % | | Extreme poverty ranking | Migration rates |
|---|---|---|---|---|---|---|---|---|---|
| **Pátzcuaro** | 44 | 41 | 77,872 | 8,745 | 18 | 22,583 | 29 | Low | Low emigration |
| **Quiroga** | 11 | 9 | 23,893 | 8,186 | 40 | 10,035 | 42 | Low | Strong emigration |
| **Tzintzuntzan** | 29 | 27 | 12,414 | 11,919 | 72 | 5,959 | 48 | Intermediate | Strong immigration |
| **Erongarícuaro** | 16 | 15 | 13,161 | 10,646 | 89 | 10,528 | 80 | Intermediate | Strong emigration |
| **Tingambato** | 2 | 1 | 4,627 | 3,569 | 37 | 4,627 | 100 | Intermediate | Strong emigration |
| **TOTAL** | **102** | **93** | **131,917** | **39,496** | **30** | **53,732** | **41** | | |

**Sources:** Castilleja (1993); INEGI (2001)

Correlation between Purhépecha and rural populations is high at municipality level. Eighty percent of the population in Erongarícuaro is considered rural (localities with >2,500 inhabitants, according to the official convention), while 80% of the total population is Purhépecha-speaking. Seventeen out of 18 localities of the municipality have less than 2,500 inhabitants. Almost half of the Tzintzuntzan population is rural, while 72%

is Purhépecha-speaking and 30 out of 32 of the localities have less than 2,500 inhabitants. Some 40% of the population in Quiroga is Purhépecha-speaking, while the same percentage is considered rural, living in 14 out of its 17 localities. Rural population in the Pátzcuaro municipality accounts for less than 30%, while the Purhépecha-speaking population accounts for less than 20% of the total population. Nevertheless, 66 out of 69 localities within the Pátzcuaro municipality are rural, according to population size.

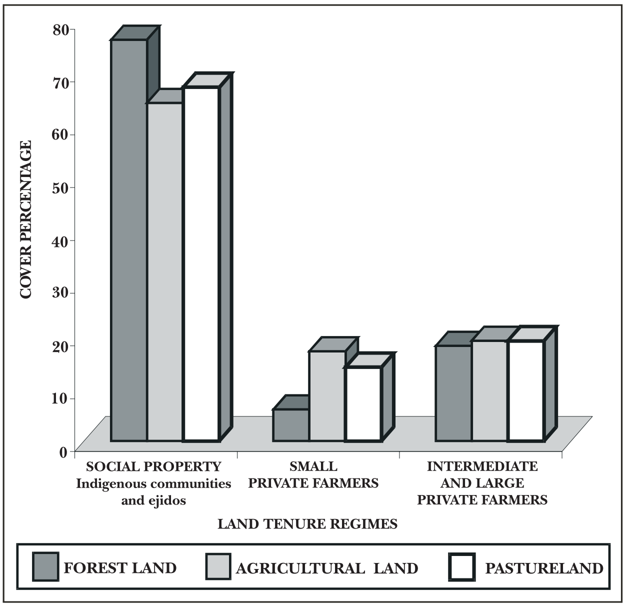



**Figure 16.5.** Land-use and land tenure regimes. **Source:** Barrera-Bassols (1993)

Correlation between Purhépecha-speaking and rural populations helps understand which is the sector of the regional population that is directly linked to agricultural activities and if this correlation shows a strong cultural component. Figure 16.5 shows that natural resource management is mainly carried out by the Purhépecha farmers living in the basin. Of note is that 25 out of the 92 localities in the region are indigenous. This correlation shows to some extent how inter-ethnic relations are shaping the political economy of the region. It is clear that the two urban enclaves (Pátzcuaro and Quiroga cities), comprising the majority of the *Mestizo* population, are benefited by indigenous rural activities.

The unequal distribution of the Purhépecha population shows that rurality, extreme poverty and migration rates largely prevail in the indigenous municipalities and localities. These socio-economic and cultural factors reveal, to some extent, the subordination condition of the indigenous population. The two most indigenous and rural municipalities of the basin show higher degrees of poverty and migration rates than the two urban and *Mestizo* municipalities.

Cultural and social differences have shaped the modern landscape of the Pátzcuaro Basin and the unequal inter-ethnic relations mirror the degrees of poverty between indigenous and non-indigenous populations. Regional, municipal and local cultural contrasts have historically influenced the ways of perceiving and managing the natural resources. The historical analysis of the relations between nature, culture and society in the Pátzcuaro Basin shows how, when and why the Purhépecha were influenced by regional, national and international demands.

## 16.3. NATURE, CULTURE AND SOCIETY: AN HISTORICAL PERSPECTIVE

### 16.3.1. Pre-Hispanic period: the establishment of early agrarian populations

### (1) Geographic and cultural setting

The Pátzcuaro Basin forms part of pre-Hispanic Western Middle America, one of the six cultural regions of Middle America (Figure 16.6). Five main structuring factors should be taken into account for a better comprehension of the proto-history of Pátzcuaro:

(a) Western Middle America (WMA) was an extended region covering main parts of two of the most important river basins of Middle America: the Lerma-Santiago Basin located to the north

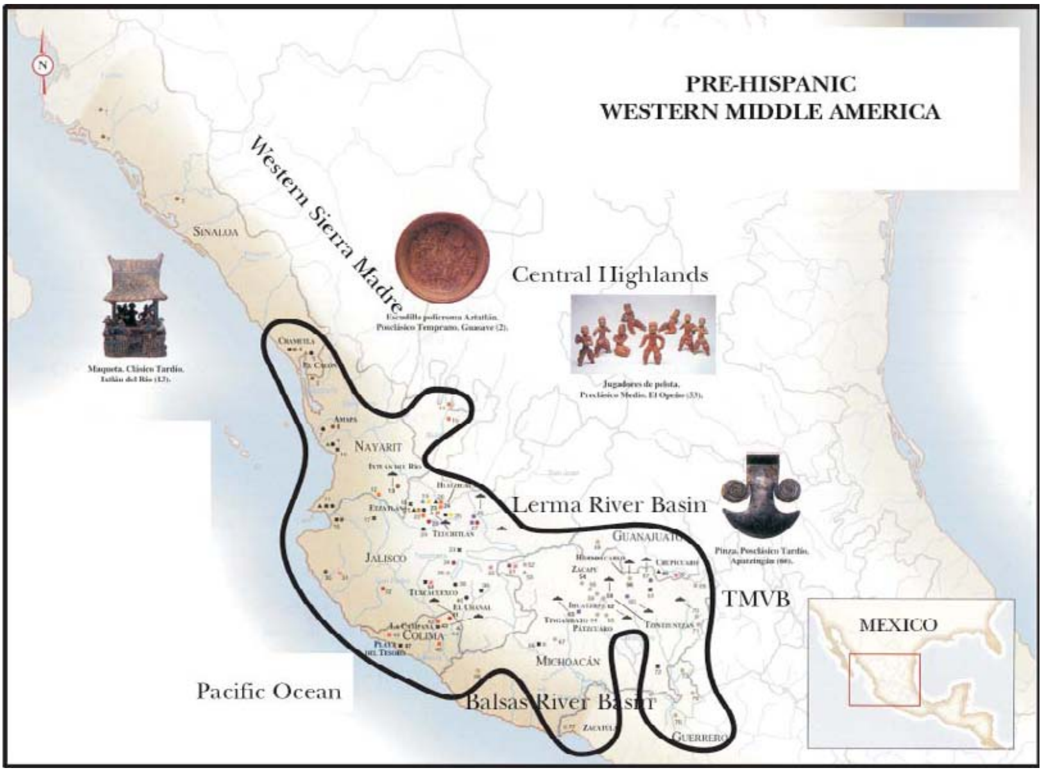



**Figure 16.6.** Pre-Hispanic Western Middle America

of the Trans-Mexican Volcanic Belt (TMVB), and the Balsas Basin located to the south of the TMVB (West, 1948; Sauer, 1952).

(b) WMA covered a variety of ecosystems, extending from the Pacific Coast to the Western Sierra Madre to the Central Highlands and including the western portions of the TMVB; thus it was well provided with natural resources. It included some of the most important lake basins of Central Mexico (the Chapala, Cuitzeo, Pátzcuaro and Zirahuén lakes).

(c) WMA experienced economic and cultural exchange via the Lerma and Balsas rivers and was influenced by cultural exchange with Arid America, Central Middle America and the Andean region in South America. It constituted a complex inter-ethnic and densely populated area (Williams, 1996).

(d) Migration, inter-ethnic relations and climatic changes shaped cultural adaptation to diverse natural environments and influenced the socio-political development during the last 5,000 years (Schöndube, 1994).

(e) The Purhépecha State controlled major parts of the WMA from the Late Postclassic period until the Spanish conquest (1350–1525 AD). The formation of the Purhépecha State was benefited by the natural richness of the WMA and its consolidation was an independent process from the Aztec Empire of Central Middle America (Pollard, 1996; Williams, 1996).

(f) The Purhépecha State established its geopolitical core in the Pátzcuaro Basin, controlling a territory of 75,000 km$^2$. The Purhépecha are considered one of the most sophisticated societies of the Post-Classic Middle America, including the Aztec and Maya civilizations (López-Austin and López-Lujan, 1996).

The cultural heritage of the occupation of the Pátzcuaro Basin from which the Purhépecha State emerged is still poorly understood (Gorenstein and Pollard, 1983;Pollard, 1993; Williams, 1996; Fisher et al., 2003). Archaeological research has been limited, site-oriented and mostly without radiocarbon dating; thus the record of cultural development before the establishment of the Purhepecha State is preliminary. Nevertheless, Pollard (1993, 1996) and Fisher and collaborators (1999, 2003) provide a tentative division into periods of the proto-historic occupation of the region. Table 16.7 includes the main historical periods after the Spanish conquest.

(2) Early establishment of agrarian societies

There is no archaeological evidence for an occupation of the Pátzcuaro Basin before 1500 BC (3,500 BP). Nevertheless, archaeological evidence elsewhere in the WMA and near the basin suggests a possible early occupation of the region by small groups of hunter-gatherers before 2500 BC (Arnauld et al., 1988). The Pátzcuaro Basin, an area rich in natural resources including the lake, much probably was occupied by small groups of hunter-gatherers and fishermen during this period, although the lack of artifact evidence maintains this speculative.

**Table 16.7.** Chronology of the Pátzcuaro Lake Basin

| | Years | Historical period | Historical phase | |
|---|---|---|---|---|
| **HISTORIC EPOCH** | 2001 AD | **Modern Mexico** | Neo-liberalism | |
| | 1980 AD | | Modernization | |
| | 1950 AD | | Social reform | |
| | 1920 AD | | Mexican revolution | |
| | 1910 AD | **Independent Mexico** | Liberal | |
| | 1821 AD | **New Spain** | Colonial | |
| | 1523 AD | **Conquest period** | | |
| **Middle America** | | **Western Middle America** | **Pátzcuaro cultural phases** | **Central Middle America** |
| **PROTO-HISTORIC EPOCH** | 1521 AD | Late Post-Classic | Tzintzuntzan | Tenochtitlan |
| | 1350 AD | Middle Post-Classic | Late Urichu | |
| | 1100 AD | Early Post-Classic | Early Urichu | Tula |
| | 900 AD | Epi-Classic | Lupe-La Joya | |
| | 600 AD | Classic | Jarácuaro | Teotihuacán |
| | 350AD | Late Pre-Classic | | Cuicuilco |
| | | Middle Pre-Classic | | Development of regional capitals |
| | | | | Agrarian societies |
| | 1500 BC | Early Pre-Classic | First appearance of maize pollen in the lake sediment record | Development of agrarian societies |

**Sources:** Niederberger (1979); Michelet (1992); Pollard (1993 and 1996)

A sediment core from the Pátzcuaro Lake revealed the presence of domesticated maize pollen from approximately 4,000 years BP, suggesting widespread human settlement within the basin during the Early Pre-Classic period (2500 to 1200 BC) (Deevey et al., 1944; Watts and Bradbury, 1982; Pollard, 1996; Bradbury, 2000). But, archaeological evidence suggests the existence of populations concentrated in agricultural villages, as localized rustic cultures with distinctive ethnic roots, histories and patterns of interactions with adjacent sites, not until the Late-Preclassic Period (>350 AD) (Fisher, 2000). This socio-cultural diversity remains until the emergence of the Purhépecha State (Pollard, 1993, 1996).

Small-scale agrarian societies, with religions strongly related to the cult of death and primarily adapted to lacustrine environments, are found in the Pátzcuaro Basin during the Early Classic period (350 BC to 600 AD). Rustic villages were located on the islands and along the lakeshores (Fisher et al., 1999; Fisher, 2000). Social stratification may have existed in the larger settlements located on the lacustrine plains. The absence of settlements on defensible positions indicates minimal local aggressions and/or movements of peoples. Archaeological artifacts found in Urichu, in the southern portion of the Pátzcuaro Basin, indicate significant social interaction between Western and Central Middle America at this time (Pollard, 1996; Fisher et al., 1999).

A major cultural transformation took place in the Pátzcuaro Basin during the Middle Classic and Early Post-Classic periods (400 to 900 AD). The appearance of ceremonial centers as new forms of settlement in rustic villages that were autonomous for centuries, showing local economic adaptation, reflects populations interacting with the extensive Teotihuacan economic network and/or migration of elites out of the Basin of Mexico, following the collapse of Teotihuacan. Tingambato, a nearby Teotihuacan-style archaeological site, only few kilometers to the south of the Pátzcuaro Basin and Urichu, form part of these ceremonial centers. These contacts increased social differentiation and stimulated the emergence of discrete territoriality and competing policies in the basin (Pollard, 1996). In addition to Urichu and Tingambato, several other centers greater than 40 ha in size also emerged in the southern portion of the basin. Sites smaller than 20 ha occurred only on the islands.

Fisher and collaborators (1999; Fisher, 2000) found records of rapid and constant fluctuations of the level of the pre-historic Pátzcuaro Lake for most of the Classic period. Two low lake stages took place between 120 and 650 AD. A long-term regression of the lake was found from 775 until 1200 AD, which correlates with ethnohistoric literature (Relación de Michoacán, 1977; Pollard, 1993), documented by the work of O'Hara and collaborators (1994).

(3) Consolidation of agrarian societies and agricultural intensification

Agricultural intensification took place during 120–885 AD (Fisher et al., 1999; Fisher, 2000). Wetland agricultural features were found associated with maize pollen, suggesting raised planting platforms on the lake bed near Urichu. These agricultural features are contemporaneous with periods of relatively low population densities, suggesting that intensification was not related to demography or political centralization, and that agricultural intensification was well established long before the Purhépecha State formation.

The Early /Middle Post-Classic periods (900 to 1350 AD) marked another shift in the socio-political organization of the Pátzcuaro Basin, due in part to the breakdown of the Classic period exchange network and reorganization of the Mexican Highlands (Pollard, 1993). Major defensible upland centers expanded and much of the lakeshore settlements were abandoned during this period. Settlements moved to defensible sites in the piedmont and on lava flows. Pyramids, ball courts and sunken plazas were built in the new settlements. This resettlement suggests more competition for local and regional natural resources. Climate change leading to a series of prolonged droughts and possibly lowering the lake level by 4 – 5 m caused resettlements and competition for larger areas of irrigated land (O'Hara 1991; O'Hara 1993; O'Hara et al., 1994: Pollard, 1996; Fisher et al., 1999; Fisher, 2000).

By the Middle Post-Classic (1200 AD), local centers were participating in regional cultures, showing traits and beliefs that are characteristic of the Purhépecha. Local elites competed for communities, basing their fortune on polychrome pottery, metal goods and patron deities. The absence of regional authority and decision-making in the face of what appear to have been increasing populations led to the formation of highly nucleated areas in the southern portion of the basin, such as Urichu (Pollard, 1996; Fisher, 2000).

### 16.3.2. Rise and consolidation of the Purhépecha State

During the Middle Post-Classic period (1110 to 1350 AD), a series of migrations towards the lake basin took place. Ethnohistorical information (Relación de Michoacán, 1514) reveals the arrival of several ethnic groups including the Uacúsecha (eagles), the ancestors of the Purhépecha royal dynasty. The integration of an inter-ethnic society in the Pátzcuaro Basin by 1200 AD, associated with the rise of the lake level (1300 AD) and the Uacúsecha domination in the region, inaugurates the advent of the Purhépecha State. Agricultural intensification during this period is associated with emerging elites attempting to control the fertile lacustrine lands to consolidate their regional power (Fisher et al., 1999; Fisher, 2000).

(1) Territorial distribution of the Purhépecha State at the eve of the Spanish conquest

By the beginning of the 16th century, the Purhépecha State controlled a vast territory (Brand, 1943; West, 1948; López-Austin, 1990; Gorenstein and Pollard, 1983; Pollard, 1993). The expansion and consolidation of the Purhépecha State during the last 175 years of the Post-Classic period (1350–1525 AD) are considered the result of the reorganization of the Mexican Highlands after the collapse of Teotihuacan in the Basin of Mexico (López-Austin and López-Lujan, 1996). During this process, the Uacúsecha became the ruling elite controlling communities and ethnic groups already established in the Pátzcuaro Basin through military conquests, political alliances, religious imposition and economic exchanges. Established in Tzintzuntzan, the capital of the Pátzcuaro Basin, the Uacúsecha first reorganized the economy in their geopolitical core and then expanded outside its frontiers.

At the eve of the Spanish conquest, the Purhépecha State governed over some 1,300,000 inhabitants, including the localities of the Pátzcuaro Basin that accounted for some 100,000 inhabitants and the 25,000-35,000 people living in Tzintzuntzan (López-Austin and López-Lujan, 1996). The political and military strength of the Purhépecha impeded the invasion and control from the Aztec Empire over their territory, becoming their foremost enemy (Pollard, 1993). The importance and complexity of the Purhépecha State led to the development of cultural characteristics that are unique but linked to the Middle American civilization. The analysis of some of these cultural elements allows understanding the ways natural resource management and administration were carried out within the Pátzcuaro Basin:

(a) the development of a primary capital (Tzintzuntzan), with weakly urban development elsewhere (Pollard and Gorenstein, 1980);
(b) the rise of full-time craft specialists, who were associated with the royal palace (Pollard, 1993);
(c) household- and workshop-level production serving local and regional markets (Castro-Leal, 1986);
(d) the development of a geopolitical core that was spatially and demographically small in relation to the territory under control, yet dependent on territorial tribute for basic resources (Pollard, 1982);
(e) an ethnically homogeneous economic heartland surrounded by multiethnic communities along the military frontiers (Pollard, 1993);
(f) a high degree of specialization in administrative and judicial functions, reinforced by the interweaving of state and religious authority (Pollard, 1993 and 1996), and
(g) socio-political organization of the Purhépecha State.

Socio-political organization within the Pátzcuaro Basin was complex and founded on territorial administration and social stratification controlled by the ruling elite based in Tzintzuntzan. Lords (*Achaecha*), who reported directly to the royal dynasty in Tzintzuntzan, governed eight administrative centers, supervising tribute collection, maintaining the census and organizing labor for public works. Each of these administrative centres, including Tzintzuntzan, contained dependent villages and hamlets considered as wards of these centers, thus controlling the 92 settlements of the basin. Each administrative center had between one and 16 dependent communities representing 2,500-10,000 inhabitants, except Tzintzuntzan (Pollard, 1993). These geographical units are believed to approximate the current administrative units within the basin (Figures 16.4 and 16.7) and were organized to provide both the material means and needs of the imperial elite. These administrative units also organized the exchange of goods and services by means of barter in three main marketplaces that serviced the Pátzcuaro Basin. Markets provided many of the basic commodities used in the Purhépecha farmer households.

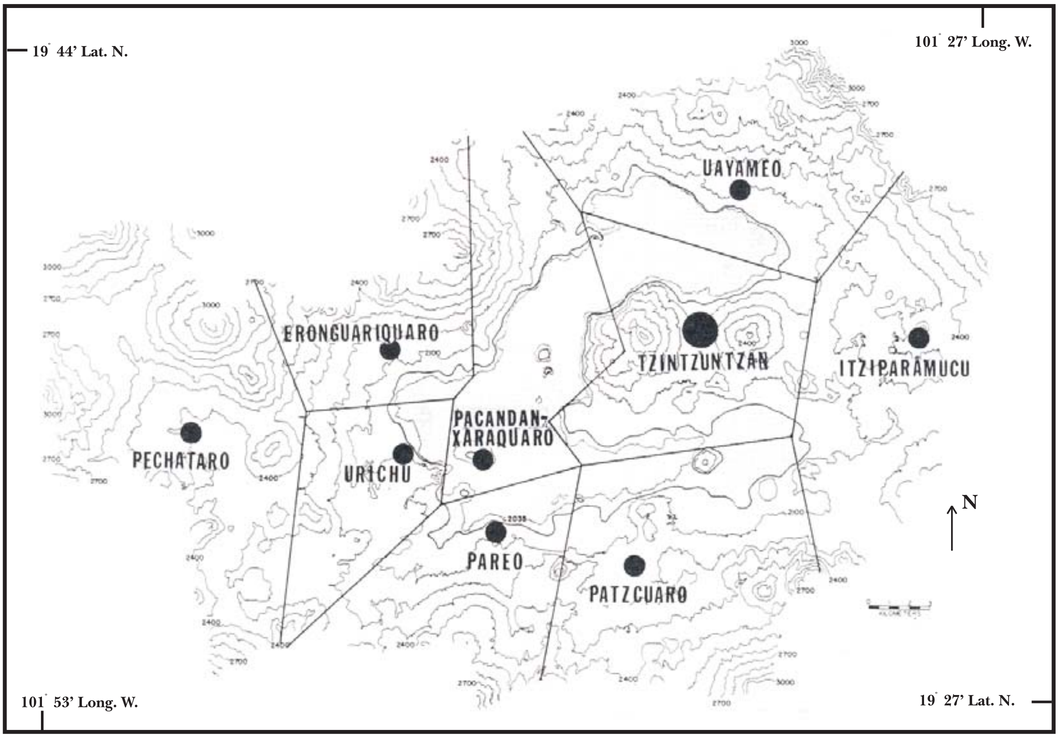



**Figure 16.7.** Proto-historic administrative division of the Pátzcuaro Lake Basin. **Source:** Pollard (1993)

Population distributed in a variety of functionally differentiated communities, characterized the Pátzcuaro Basin at the end of the 15th century. Production specialization of these communities was according to their agro-ecological context. More than 90% of the settlements and population were distributed over the lacustrine plains, lakeshores and lower piedmonts, but 69% of settlements and 74% of the population were living on the lakeshores alone (Gorenstein and Pollard, 1983).

The lake of Pátzcuaro served for transportation of people and goods and connected the majority of the settlements with marketplaces, religious and political centres, all of them well connected to Tzintzuntzan. A sophisticated foot-based road network connected the settlements located on the mountain slopes and in the inter-mountainous valleys. Territorial distribution of administrative units, hierarchical organization of settlements within these units, economic and transport networks, and strategic location of central and specialized places functioned as a complex and overlapping network system used by the *Uacúsecha* and *Achaecha* to control means and goods within the basin.

The Purhépecha socio-political, economic and religious organization was highly centralized, unequal, bureaucratic and based on military control (García-Alcaráz, 1976; López-Austin, 1990;Pollard, 1993). Centralization of power by the royal family and the ruling elite was an efficient way to control and expand the Purhépecha territory. In the absence of large irrigable areas within the Pátzcuaro Basin, seizing additional resources outside the geopolitical core reduced economic risk. With a large enough supply to mount effective militar campaigns but not large enough to colonize other regions, the Purhépecha elite tapped into existing local community networks and focused them into a central tributary hierarchy (Pollard, 1993).

The Purhépecha elite centered its power in Tzintzuntzan, the major urban settlement of their territory. The strategic importance of Tzintzuntzan is given by the settlement (7 km$^2$) and population size (25,000-35,000 inhabitants) (Pollard, 1996). The royal family, the administrative bureaucracy, the religious elite, artisans, commoners and slaves in service to the court inhabited Tzintzuntzan (Castro-Leal, 1986; Pollard, 1996). Tzintzuntzan population accounted for 20-25% of the total population of the basin and lived at the expenses of the territorial domination of the empire. Four social classes lived in the capital city. Dress, household structure, marriage, wealth, responsibilities, privileges and access to diverse occupations distinguished each class. Social stratification norms and values did not allow easy movement between classes. The four social classes were: (a) the king (*Irecha or Cazonci*), his family and lords (*Acambaecha*); (b) the nobility (*Achaecha*); (c) the commoners (low people or *Purhépecha*); and (c) the slaves. Figure 16.8 shows social stratification in the Pátzcuaro Basin, according to ethnohistorical information.

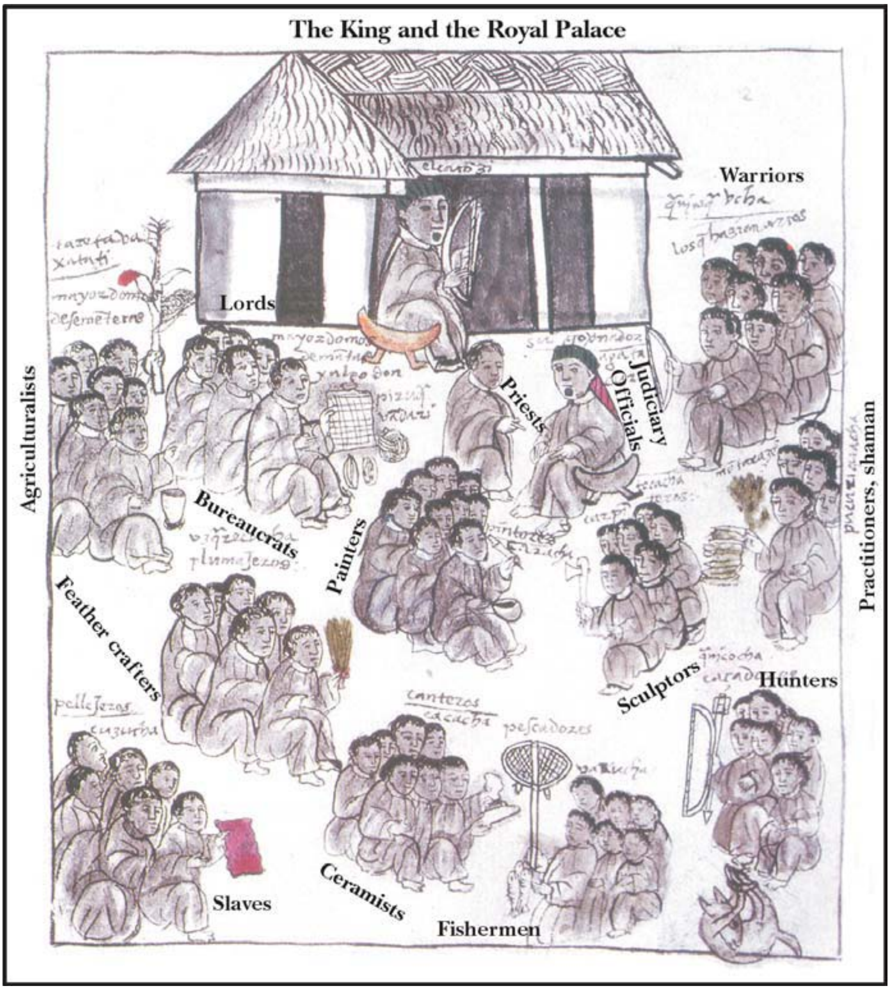



**Figure 16.8.** Social stratification of the Purhépecha State. **Source:** Relación de Michoacán , Plate XXVIII (1977 [1541])

(3) Dominating ideology and religion in the Pátzcuaro Basin

The Purhépecha basic conception of the world shared fundamental principles with those of all Middle American societies. The establishment of a new ideology, which served to unite the ruling elite into a legitimately bounded social class and culturally unify the multi-ethnic population within the territory, accompanied the consolidation of the Purhépecha State. The system of ideas, values and attitudes that the *Uacúsecha* imposed on the population served to justify their political and economic control. The universalization of symbols benefited the elite, giving them the status of cosmic truth. The ruling elite obtained power and force from their personal relationship to the universal power of the sun god *Curicaueri* (the patron god of burning and fire).

Alliances were important for domination by the *Uacúsecha*, and the assimilation of deities belonging to other ethnic communities into the Purhépecha religion reinforced ties between former enemies and permitted the consolidation of the imposed ideology. The patron gods of the dominant ethnic elite were elevated to celestial power, while the various regional deities and worldviews were elevated, incorporated or marginalized (Pollard, 1993). The new ideology evolved as a robust cosmological system controlled by the State and performed through rituals by the religious elite. Commonalities between the Purhépecha and the Aztec cosmovisions are:

(a) the establishment of a mythical history that included an historical struggle against adversity and a hero in human form (*Tariacuri* or *Tariat Kheri,* the great wind). This charismatic leader had special relationship with sacred powers, thus was the tool for the creation of a secular life;
(b) the division of the cosmological world into three main and interwoven parts: the sky, the earth or land and the underground world;
(c) the sky and the underground world were conceived as places of deities, sacred powers and forces ruling the earth where humans lived in a circular cycle: birth-conception-death-rebirth;
(d) a dualist interpretation of the world that balanced opposite forces and powers for the perpetual life cycle;
(e) the inversion of causes into consequences to maintain sacred powers and non-humans as main forces ruling te secular life;
(f) high number of deities with supra-living being forces and powers, that were performed according to circumstances, benevolent or malefic to humans;
(g) humans were believed to be able to be possessed by deities;
(h) fertility as the central force controlling perpetuation of the holy cycle, embedded in the cosmological and agricultural calendars, and
(i) maize as the synthesis of secular and sacred forces and as a metaphor for birth, strength and renewal of the society as a whole.

The Purhépecha worldview, cosmology and rituals were complex (Corona Nuñez, 1986; López-Austin, 1990) (Figure 16.9). The universe was organized in three parts. The sky (*auandarhu*), represented by *Curicaueri* (the sun god), was associated with obsidian, black eagles, squirrels, blood, thunder and fire. *Curicaueri,* a male deity controlling all descendent forces, was the patron god of the ruling elite. He represented dry and warm forces necessary for the battle, as counterparts of wet and cold female forces. *Xaratanga*, the moon goddess and patroness of childbirth and fertility, ruled the earth or land (*echerendo*). She was the daughter of the earth creator (*Cuerauáperi*) and the wife of the sun (*Curicaueri*), and was associated with water, fish, thermal springs, coyote, vulture, owls, snakes, chili pepper, beans and maize. She represented the balance between masculine and female deities controlling fertility through the moon cycle. The goddess of creation, the great grandmother (*Cuerauáperi*), represented the underground world (*kumichekuarhu*). She was associated with vapor from hot springs (ascendant forces), which rises to form clouds and rain coming from the east. She could withhold rain and send famine. She was the mother of all the gods of the land and was associated with maize, frost, dew, soft wind and running water. *Ukumu* (mole) was her counterpart and the emissary of death. Death was associated with caves, gophers, mice and snakes that lived in the underground world.

The three parts of the universe were divided into five cardinal directions, including the center as a cardinal direction, geographical units and colors (Relación de Michoacán, 1541). The Pátzcuaro Basin was the center of the universe. A deity that controlled the holy forces of wind and rain dominated each of the five corners. *Tiripemencha* (golden or beautiful water) were the five emissaries of the patron god (*Curicaueri*). They were placed in geographical centres encircling the Pátzcuaro Basin:

(a) *Tiripeme Xungapeti* had his home in Pichátaro. He was the yellow north deity who breaks bare soil;
(b) *Tiripeme Tupuren* was the white god of the west or setting sun. His home was in Urichu; he was associated with white dusty clays;
(c) *Tiripeme Kheri* was the black deity of the south or noon sun. His home was in Pareo and he was associated with black clays;
(d) *Tiripeme Kuarencha* was the red god of the east or the rising sun, or the morning star, Venus. He was associated with red clays; and
(e) *Chupi Tiripeme* was the blue god of the center, or the god of capture, exile or sacrifice. His home was the island of Pacandan, located at the center of the Lake of Pátzcuaro.

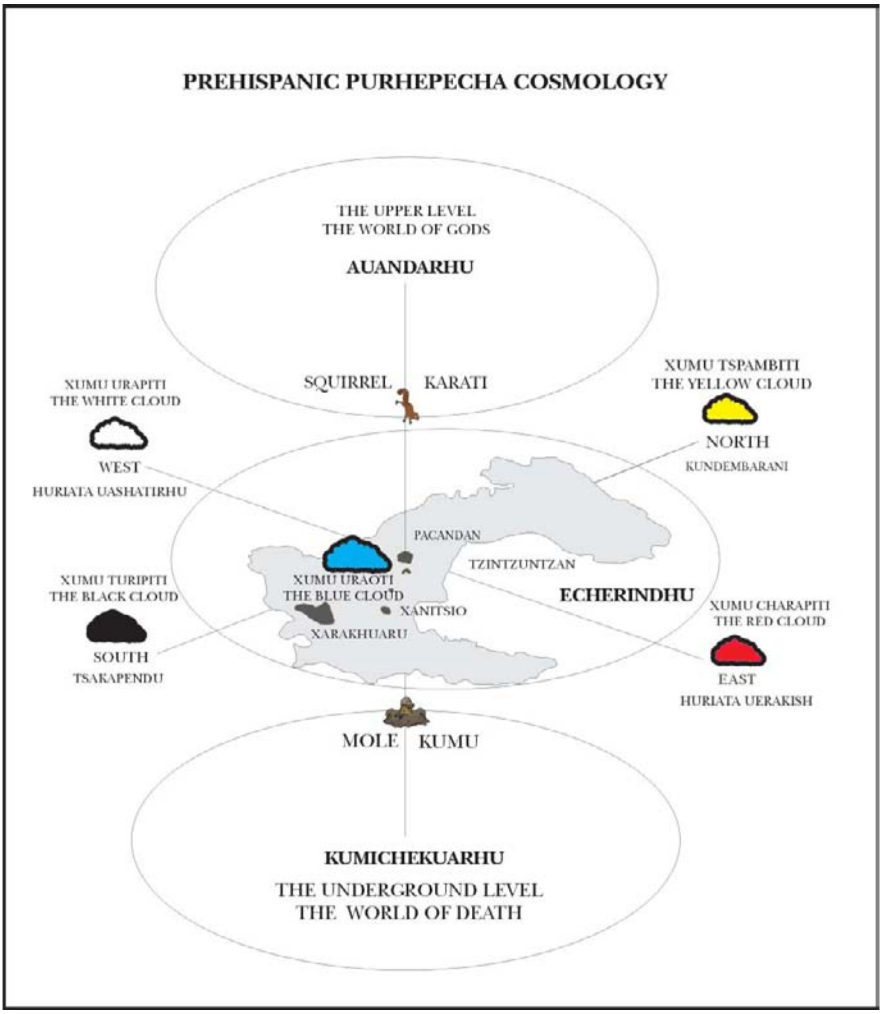



**Figure 16.9.** Pre-Hispanic Purhépecha cosmology

(4) Symbolic meanings of volcanism

The cult of mountains has been recognized among the Aztec and other Middle American societies (Broda, 1991, 1996; López-Austin, 1994; Niederberger, 1996). Mountains were sacred landscapes and the givers of water, rainfall and rivers. The hollowed mountains associated with caves constituted the entrance to the underworld and the interface between life and death. Mountains were holy places where many deities lived, among them those associated to death, fertility and life renewal; thus they were venerated as the givers of perpetual life.

The cult and symbolism of volcanoes and volcanic activity appear in the Purhépecha cosmovision, although this aspect has not been well studied. Archaeological, ethnohistoric and ethnographic evidences show associations of volcanism in the symbolism of natural and holy cycles in the Purhépecha cosmology. There is no evidence of the existence of a holy tree, that would unify the three parts of the Purhépecha universe, as in other Middle American cosmologies. Instead, thermal water vapors, smoke and mists ascending from the Lake of Pátzcuaro were perceived as female substances ascending to the sky, while rainfall was conceived as a male substance descending to the earth and underground world. The interwoven flow of these substances permitted connecting the three parts of the universe and their interactions were assumed to create the forces of fertilization. Rainfall was in the dominion of the sun god (*Curicaueri*) while thermal water vapor and mist were associated to the mother goddess (*Cuerauáperi*) and the moon goddess (*Xaratanga*).

Volcanoes were hollowed places where the flux of masculine and female waters interwoved producing rebirth of plants, humans and maize. Volcanoes were also givers of new water; thus caves and springs were associated to life renewal and venerated with major rituals (Pollard, 1993). The cult of fire was also associated with volcanism. This cult dominates in the ethnohistorical documents, associated with the cult of the sun god and the cult of war (Relación de Michoacán, 1977).

Apparently, bonfires permanently burnt in sacred places and ceremonial centers. Tribute in the form of wood was strictly administrated by bureaucrats and highly appreciated (Caballero, 1982). Huge bonfires were placed on top of the higher mountains surrounding the basin during the most important religious ceremonies, resembling volcanic activity as a symbol of the power held by the patron and warrior sun god. The semi-circular pyramids in Tzintzuntzan, Pátzcuaro and Ihuatzio cities, representing the five cardinal directions and their patron deities, were places for bonfires during the ceremonials. During these rituals, priests used tobacco pipes and the whole ritual resembled the smoke, vapor and fire produced by volcanism.

The association of volcanism in Purhépecha rituals emulated the geomorphic origin of landscapes in the Pátzcuaro Basin. More than 75% of the existing volcanoes in the region were formed during the Holocene; thus, much probably, volcanism was experienced by humans even before the arrival of the Uacúsecha. Saporito (1975) dated seven layers of tephra deposited on the lakebed within the last 3,000 years.

Symbolism of volcanism in the Purhépecha religious cult is also associated with human cremation. The cult of ashes is linked to the veneration of land fertility and the belief that human ashes were givers of rebirth. Ashes were used to fertilize the land. The spread of volcanic ashes over the basin, during the eruption of the Paricutín volcano in the 1940s, was associated to the increase of maize productivity and rainfall, but foremost to the mythic reappearance of the sun god *Curicaueri*. *Curicaueri* is now venerated as the Christian Lord of Miracles (*Señor de los Milagros*).

Other elements that associate volcanism with religious cult and beliefs are:

(a) the meaning of obsidian, a volcanic glass, as the symbol of the Purhépecha Empire;
(b) the settlement of ceremonial centres on lava flows surrounding the basin;
(c) the veneration of moles as deities of the underground world, that build up earth mounds resembling volcanoes, and
(d) the naming of contiguous volcanoes with female and male names as couples. Marriage and gender assigned to volcanoes is associated to fertilization and the cult of the holy couple that created nature.

The symbolic association of volcanoes and social communion is best represented in the daily ritual of food preparation and consumption. The wood oven, consisting of three rounded stones supporting a circular ceramic pan where maize-based food is cooked in any Purhépecha kitchen, synthesizes symbolic associations of fire, smoke, vapor and ashes in the Purhépecha cosmovision. The three rounded stones represent the three parts of the universe, while the circular and concave ceramic pan symbolizes the Pátzcuaro Basin, where people live and produce their staple crops. The kitchen serves as the central place where all household members get together to formalize their kinship ties, symbolizing the communion of the whole Purhépecha society. This ritual is performed near the wood oven that provides food and warmth, resembling the communion between the natural and cultural history of Pátzcuaro. The wood oven emulates the role of volcanoes as the givers of fertility and water and the providers of shelter and well being (Figure 16.10).

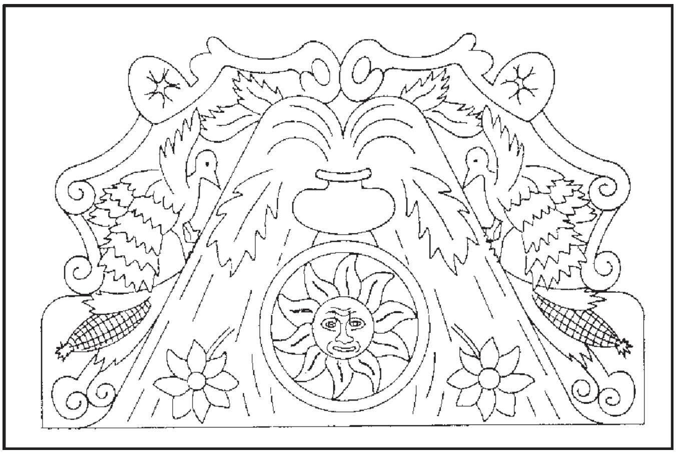


**Figure 16.10.** The holy volcano: giver of water and life. Carved headboard made in San Francisco Pichátaro, Michoacán. **Source:** Avila (1996)

(5) Natural resource management and the state's control of goods and services

During the 15th century, the Purhépecha population living in the Pátzcuaro Basin could not subsist with the sole agricultural and lake production of the basin and required obtaining basic resources from outside the basin. That is why the Purhépecha State developed economic and political mechanisms specific to their empire (Pollard, 1993). The analysis of these mechanisms and how they operated is based on the work of Pollard and collaborators (Pollard and Gorenstein, 1980; Gorenstein and Pollard, 1983; Pollard, 1993, 1994, 1996; Fisher, 2000).

Goods and services flowed through several institutional channels, which fell into two basic classes: (1) local and regional markets, and (2) state-controlled agencies. The state-controlled agencies included the tribute network, official long-distance merchants, state agricultural lands, state forestlands, state mines and official gift exchange (Pollard, 1993). Within the Pátzcuaro Basin, many goods and services flowed through markets, which were associated with subsistence needs and primarily servicing the commoners. Tribute was the most important state institution involved in economic exchange. The tribute system was vast, centralized, hierarchically organized and under total control of the royal family. It included both goods and services, but the most common products were maize, cotton and clothing. Tribute was associated with subsistence and status needs and primarily servicing the elite. Both flows were necessary to the maintenance of the population, but tribute depended on the existence of the state.

In addition to the tribute, the Purhépecha state satisfied its needs in various other ways. One of these ways was the state land held in the basin and used to produce food for the royal family and the administrative and religious elites. This land included some of the most fertile areas in the lacustrine plains and lakeshores. The royal palace had rights to forest products, including lumber, wood, deer and rabbit, and lake products. The ruling elite also controlled long-distance merchants, that provided specialized goods only obtained outside the basin and even outside the territory (Pollard, 1993).

Local production was obtained by subsistence activities performed by commoners in a multi-purpose land management system and the production surpluses were sold on local and regional markets. A proportion of the production was for tributary purposes, fulfilling parts of the Tzintzuntzan elite demand. Imports of goods to fulfill commoners and elite needs were considerably high in quantity (Pollard and Gorenstein, 1980).

Approximately 45% of the maize and 90% of the beans regionally consumed came from imports. Tribute demand and the lack of fertile lands were the main factors requiring food imports to balance the commoners' diet. Local populations were highly dependent on imports. Specialization of production became important in some localities of the basin to fulfill export demands. These types of exchange contributed to more centralized control from the elite and enlarged the unequal relationships between the social classes inside and outside the Pátzcuaro Basin (Pollard, 1993).

An estimation of the maximum population that could have been supported by local resources just before the Spanish conquest shows that the Pátzcuaro population was well above the regional carrying capacity of the basin, according to maize production and consumption patterns (Pollard and Gorenstein, 1980). Estimates show that optimal land-use and consumption rates could support 40,000-50,000 persons in an average year, while the estimated population of the basin was 60,000-100,000 inhabitants in 1519 AD. This means that the population was 10,000-60,000 inhabitants above the carrying capacity. Therefore, the only solution was to import maize.

The paleo-ecological reconstruction for the Late Post-Classic period shows a slightly wetter and perhaps warmer climate, associated with a lake level about 15 m higher than at present (Hutchinson et al., 1956; Pollard and Gorenstein, 1980; Pollard, 1993; O'Hara, 1991; Bradbury, 2000; Fisher, 2000) (Figure 16.11). This would mean that the fertile, permanently or temporarily irrigated lands of the lacustrine plains were less extended than today; thus maize was mainly produced on alluvial soils in the inter-mountainous valleys and on piedmont slopes. These less fertile, rainfed lands account for approximately 45% of the basin. Under these circumstances, the basin would suffer from anthropogenic soil erosion, according to paleo-limnological studies (Street-Parrot et al., 1989; O'Hara, 1991, 1993; O'Hara et al., 1993, 1994).

By the end of the Late-Postclassic period, 32% of the settlements of the basin were located on piedmont slopes and in the inter-mountainous valleys. Under demographic, political and economic pressure, it is suggested that most of these settlements probably caused land degradation, but ethnohistorical documents do not provide information of mass out-migration, famine or extensive land degradation in the basin (Relación de Michoacán, 1977). Moreover, recent studies that combine analysis of sediment cores with archaeological survey at landscape level found no evidence of widespread soil erosion in the southern portion of the basin, however densely populated by that time. On the contrary, archaeological findings suggest relative landscape stability, despite intensive farming (Fisher et al., 1999; Fisher, 2000).

## 16.4. Colonial period: Haciendas, ranchos and indigenous communities

### 16.4.1. Demographic collapse

The conquest of the Purhépecha territory by the Spaniards during the 1520s led to dramatic demographic, cultural, environmental and land-use changes in the Pátzcuaro Basin. Within few months, the Purhépecha State lost its cultural, political and economic independence, becoming subordinated to a wider area now controlled by Spain and its colonial rules and officials. From that moment on, the Purhépecha people living in the Pátzcuaro Basin developed a culture of resistance to oppose the usurpation of their land and territory but also managed to adapt to the forced circumstances. This hybridization process led to constant conflicts and dissents between colonizers and the colonized people. These events caused profound environmental and cultural transformations, that should be traced when analyzing the ecological and socio-cultural problems of the Pátzcuaro Basin at the end of the 20$^{th}$ century.

The most dramatic impact experienced by the Purhépecha in the century following the conquest was sudden depopulation (West, 1947; Castilleja, 1993; Paredes, 1991). As in the rest of Middle America, the European contact triggered massive depopulation of natives, whose lack of immunity rendered them susceptible to Old World diseases or 'virgin soil epidemics' (Crosby, 1986). The population of the basin is thought to have fallen from 100,000 in the immediate post-conquest period to about 30,000 by 1580 (Figure 16.12). Population estimate by 1540 gives some 98,000 inhabitants (Paredes, 1981), a figure, which correlates with an estimate for the Post-Classic period (100,000 inhabitants) (Gorenstein and Pollard, 1983). By 1631, population was estimated at 11,500 inhabitants, which means that 85% of the original population was lost during the 90 years following the first account (Castilleja, 1993).

Depopulation was not only due to the virgin soil epidemics. Sixteenth century official documents reveal the number of Purhépecha slaves, who were forced to out-migrate every eight weeks from Tzintzuntzan to the northern mines of New Spain (Paredes, 1991). Moreover, an important number of natives left the basin and sought refuge in the nearby Meseta Tarasca, a rugged mountainous area. Slower rates of disease transmission in the cooler highlands ensured the survival of indigenous communities, a continued occupancy of the land and hence the maintenance of traditional land-use systems (Butzer, 1992a and b). It was precisely in the highlands that the introduction of Spanish colonization policies and land-use practices would, in consequence, stimulate acute antagonism between Purhépecha and colonizer populations (Endfield, 1998).

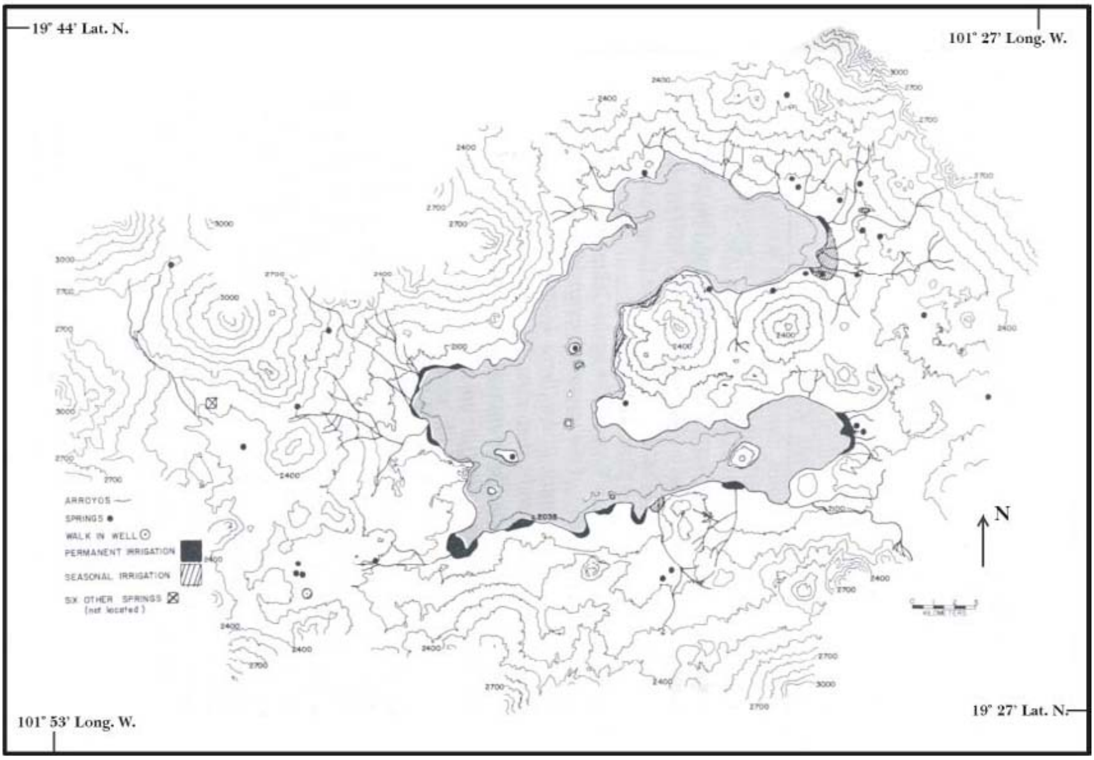



**Figure 16.11.** Post-Classic water level of the Pátzcuaro Lake. **Source:** Gorenstein and Pollard (1983)

### 16.4.2. Settlement and land granting policies

Colonial policies after the military conquest took two main directions. Congregation, relocation and dispersion of local populations were systematically promoted from the 16th to the 19th centuries. In this way, Spanish officials reorganized populations, organized local networks of townships and imposed tribute policies. This allowed better control of colonial territory and local populations, but foremost served to redefine community territories and resource access and, in many cases, it was actually used to remove communities from their means of economic support and livelihood.

Local communities were brought together and relocated in planned settlements. Reduction of indigenous settlements was due in part to depopulation. Forty-one native localities were registerd by 1631, corresponding to 45% of those found during the Late Post-Classic period (Pollard, 1993). Reduction policies were also effective. Twenty-seven indigenous localities were registered within the basin by 1822, accounting for 30% of those reported for the Late Post-Classic period and 60% of those reported in 1631 (Paredes and Piñón, 1984; Castilleja, 1993; Pollard, 1993).

Population dispersion in the form of forced migration as slavery served to fulfill labor demands outside the basin and to reduce possible social unrest inside the basin. Forced migration policies revealed that work force

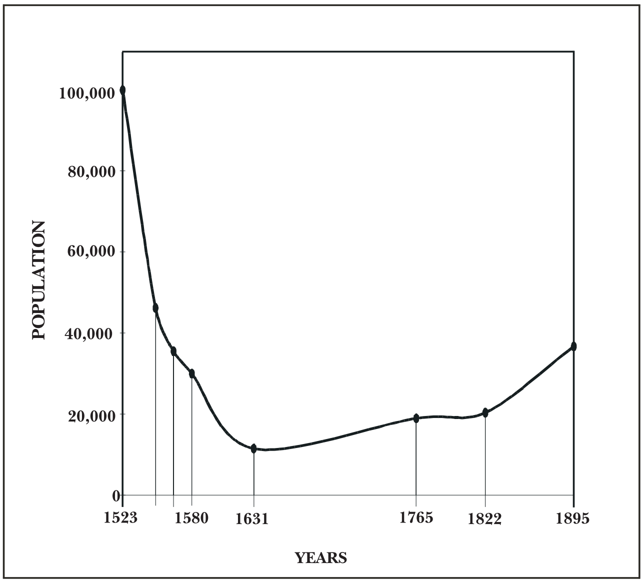



**Figure 15.12.** Population trend in the Pátzcuaro Lake Basin during the 16th to the 19th centuries

was considered the most important source of the basin due to the limited possibilities to develop intensive agriculture because of the reduced tracts of fertile land in the Pátzcuaro lakeshore (Paredes, 1991). Despite the opposition by native populations, indigenous communities were forced to relocate and Spaniards seized their territories (Paredes, 1995; Endfield and O'Hara, 1999a and b).

Colonial settlement policies were encompassed with land granting and tribute policies as engines for a more effective appropriation of land, water and forest within the basin. Tribute-paying natives and their land were granted to a small number of conquerors and officials of the treasury as royal rewards for their duties (*encomienda*). Royal duties took the form of private enterprises, not without conflicts among Spanish officials, civilians and the church, but foremost between Spaniards, Indians and church officials (Garibay, 1996; Endfield and O'Hara, 1997, 1999a, 1999b; Endfield, 1998).

An allied land grant policy (*composición*) was to assist in the progressive alienation and concentration of the Pátzcuaro Basin lands (Florescano, 1976). In this way, land titling could be confirmed and regularized against a small monetary payment, allowing individuals to effectively appropriate lands that had been formerly designated as indigenous territory by the Spanish Crown (*República de Indios*) or communal pasture land and forest land. Colonial land granting legalized usurpation and illegal invasion of former indigenous territories. Population resettlement and land granting policies, and procedures facilitated the alienation of depopulated Purhépecha communities and their lands, and at the same time allowed landowners and church authorities to accrue vast tracts of land in the Pátzcuaro Basin (Paredes, 1991; Endfield, 1998).

The increase of large agricultural and livestock estates (*haciendas*) and of small private livestock units (*ranchos*) during the 1631-1822 period shows the effectiveness of the colonial policies and procedures. *Haciendas* and *ranchos* increased from 19 to 47, while the indigenous communities substantially decreased in number and population. But, foremost, private landholdings were established on the most fertile tracts of land (Paredes, 1985; Castilleja, 1993). *Haciendas* and *ranchos* were located on the lakeshores and in the lacustrine plains, much probably founded in the irrigated areas formerly controlled by the Purhépecha State (Pollard, 1993). Land tenure changes, associated with the imposition of the Spanish colonial system, had pervasive implications for indigenous land-use systems, resource exploitation and traditional livelihoods (Endfield, 1997). Two of the implications were: (1) the adoption and adaptation of the European agricultural experience into the Purhépecha natural resource management systems, and (2) the increase of conflicts between Indians and private landlords.

### 16.4.3. Agricultural revolution

The introduction of crops, domesticated animals and technological know-how in the local agricultural systems had profound consequences for land-use intensification in the Pátzcuaro Basin. In this way, the Purhépecha multi-purpose land management was benefited in various forms. The introduction of the ox-plow into the rainfed systems and the integration of domesticates into the agricultural activities ensured the increase of land productivity and the decrease of labor allocation under low population rates. Grazing of domesticates on fallow land improved soil fertility, thus reducing fallow. The European agricultural technology, adapted to flatlands with deep soils, favored the opening of agricultural areas in the inter-mountainous valleys without competing with the traditional cropping technologies, adapted to sloping lands and shallow soils, thus permitting diversification of the agricultural systems.

The integration of wheat, barley, oats and fava beans into the *milpa* system favored land intensification. For the first time in the agricultural history of the Pátzcuaro Basin it became possible to crop during the whole year when integrating winter-spring crops. The adaptation of exotic fruit trees, poultry, goats, sheep and pigs in backyards and homegardens also diversified the Purhépecha agro-forestry systems. The overall adaptation of species, tools and know-how would benefit the Purhépecha rainfed production (Alvarez-Icaza and Garibay, 1993; Garibay, 1996).

The adoption of the European agricultural experience in the basin was rapid. Tribute documents of the 16th century account for the amount of wheat, oats, chicken, pigs and new fruits that Indians tributed to Spanish officials (Paredes, 1991, 1995). However, agricultural adoption by Purhépecha farmers was not harmonious. Wheat cropping was forced on communal lands. Indians were prohibited to ride horses and own cattle besides the oxen used to plow, and butcheries were prohibited in the indigenous communities of the Pátzcuaro Basin (Simpson, 1952; Barrera-Bassols, 1995).

The effectiveness of the introduction of the European agricultural experience in the Purhépecha *milpa* system was remarkably high and maintained robust until the late 20th century. Its adaptation permitted recuperating the indigenous population of the basin during the 19th and 20th centuries. However, intensification of rainfed agriculture was basically pursued as a subsistence strategy and for local and regional market needs. West (1947: 33) notes the historical importance of this hybrid multi-purpose land management when asserting that "the Tarascan [Purhépecha] economy is today, and was in pre-conquest times as diversified as that of any large Indian group of North America".

### 16.4.4. Conflicts over land, forests and water

Conflict over land, water and forest between the new landlords and subordinated Purhépecha communities constantly governed the unequal inter-ethnic relationships. These conflicting relations increased at the end of the Spanish rule, during the early 19th century. Conflicts have been well documented (Endfield, 1997, 1998; Endfield and O'Hara, 1997, 1999a, 1999b). Clearly, access to fertile land and resources became a source of contention throughout the colonial period. Indigenous communities found themselves deprived of their territory and natural resources, and it was not only fertile land that became a source of contention at the end of the colonial period. References to apparent land degradation in the region reflect the consequences of these trends at the eve of the Independence period. Depopulation, expropriation and exploitation governed the unequal inter-ethnic relations during colonial times, influencing land management, creating conflicts over natural resources and causing environmental degradation.

## 16.5. INDEPENDENCE PERIOD: INDIGENOUS LAND DISENFRENCHISEMENT AND FOREST EXPLOITATION

### 16.5.1. Rural policies

The post-colonial economy was left in utter disarray following Mexico's independence from Spain in 1821. Three reform policies were implemented to restructure the economy and integrate and modernize the territory of the new Republic. These policies consisted in establishing (a) an administrative reform; (b) an agrarian reform; and (c) a rural modernization program via industrialization and privatization of agriculture, livestock and forest. The implementation of these reforms had profound and detrimental consequences for the indigenous communities located in the Pátzcuaro Basin. The reforms substantially affected landholding regimes, land-use systems and the environment, when the legal status of the indigenous community was disenfranchized.

Competition for land and natural resources paralleled the constant recuperation of the population size during this period (see figure 16.12).

### 16.5.2. Administrative reform

The administrative reform consisted in reorganizing the political division of the country's municipalities. This reform prioritized a new hierarchical division that benefited those settlements with a majority of *Mestizo* populations as the political and administrative centres of the municipalities, thus subordinating indigenous communities to *Mestizo* economic interests and power. This territorial division deepened the unequal relations between *Mestizo* enclaves and indigenous peripheries that evolved during the colonial period.

Some *Mestizo* families had direct kinship ties with Spaniard and *Criollo* landlords; therefore, many of them inherited economic, political and social benefits from early colonists. While possessing the large estates of the Pátzcuaro Basin, they became more involved in political and commercial activities as absentee landlords now ruling the municipality centres. Influenced by *Criollo* nationalism that elevated European blood ties with progress and modernization as the only way to construct the new Republic, they considered themselves the only representative ethnic class for the country's future. As *Criollo* nationalism relegated the indigenous condition as backward and as a reminiscence of the past, ethnocentrism and racism became more acute than during the colonial period. That is why conflict, dissention and violence between *Mestizo* and Indians governed inter-ethnic relations in the 19th century.

### 16.5.3. Agrarian reform

The agrarian reform consisted in the disfranchisement of the rights the indigenous institutions had to commonly possess and usufruct lands in legal terms (Enfield, 1998). The implementation of the Lerdo Law in 1857, which initially served as an attempt to undermine the power of the Catholic Church, by then owning almost 50% of the Mexican territory, aimed to build a broad base of small private property owners by expropriating and commodifying church property. Although the law was considered by their supporters as an attempt to dissuade concentration of land, it also prohibited communal control over the land, undermining the indigenous community. Instead, it fostered land concentration among the wealthy class and foreign enterprises, who were used to making claims over church and indigenous properties and/or negotiating land transactions.

The Lerdo Law favored the expansion of the large estates already owned by *Mestizo* landlords and the acquisition of large tracts of forestland by foreign enterprises in the Purhépecha territory (Friedrich, 1981; Gledhill, 1995). An immediate response and violent outrage emerged among the indigenous communities in the Pátzcuaro Basin (Zárate, 1993; Dietz, 1999). Land concentration by the regional, national and international wealthy classes and dispossession of communal lands intended to allow rural modernization but provoked the upheaval of social conflict at the beginning of the 20th century.

### 16.5.4. Rural modernization

Rural modernization was intended to start once the *Mestizo* settlements had total control of the municipalities and the communal land rights were disenfranchised. Modernization efforts in the rural landscape of the Pátzcuaro Basin took two main directions: (a) forest exploitation in the mountains, and (b) expansion of livestock estates in the lacustrine plains. However, the Purhépecha communities were strongly organized, thus capable to partially overcome land dispossession, and rural modernization had to adjust to the prevailing social circumstances.

Forest exploitation was promoted by foreign enterprises in the Pátzcuaro Basin and the nearby Meseta Tarasca. As indigenous communities' unrest limited land privatization on their territories, forest exploitation on their lands was promoted as temporary concessions of wood resources and agricultural lands. Forest exploitation concessions served for the construction of the railroad linking Mexico City to the Western portion of the country (Brand, 1951). Extensive logging served for the maintenance of rail services and for export, while agricultural lands served to maintain captive labor force.

The expansion of livestock raising by *Mestizo* landlords appeared to be the only activity that could generate substantial profits in the lowlands of the basin, while augmenting private control over communal lands. Privatization of forest and pasturelands undermined the indigenous community capacity to maintain their subsistence strategy. As a consequence, social conflict between private owners, commoners and rural forced labor inaugurated the revolutionary upheaval in the region (Friedrich, 1981; Paulson, 1999, 2001; Dietz, 1999).

Conflict over space and natural resources in the Pátzcuaro Basin increased during the late 19th century, leading to land-use changes and environmental degradation. The constant recuperation of population size and the weakening of the Purhépecha community influenced an unequal competition for the land resources. At the beginning of the 20th century, the majority of the population living in the Pátzcuaro Basin experienced extreme poverty and land dispossession, coupled with a series of short-term drought periods that severely affected their livelihood. These were the prime movers of social unrest in the basin.

## 16.6. Modern period: land reform, rural modernization and demographic explosion

### 16.6.1. Land reform

During the 20th century, the Pátzcuaro Basin experienced drastic changes affecting the population, regional economy, cultural setting and land-use systems. The political consequences of the Mexican Revolution (1910-1921) and the foundation of the modern Mexican State drove changes that transformed the rural landscapes and livelihoods of the basin. A social programme of land restitution to indigenous communities and land granting benefiting dispossessed farmers and localities, took place during the four decades following the war (1930-1970). This period was followed by a 'modernization via development' period, that included stabilization of private property in rural areas, industrialization subsidized by agricultural innovation and rapid urbanization in the 1970-1990s. The last period is ongoing since the beginning of the 1990s, led by neoliberal policies consisting in structural adjustment reforms, such as the disenfranchisement of social land property rights, the end of subsidized agriculture and agricultural internationalization.

These policies were presumed by the Mexican officials to resolve the historic imbalance inaugurated since the 16th century, repositioning the country as an independent modern nation capable to interact with the rest of the world in a well-standing position. Since the 1940s, cultural, economic and political programmes were established as 'pilot efforts' to resolve the historical problems of the indigenous territories in Mexico. The Pátzcuaro Basin served as an 'experimental laboratory for development' for several governmental agencies, being the first one experiencing systematic efforts to modernize the indigenous landscapes of Mexico (Toledo and Barrera-Bassols, 1984; Garibay, 1996). However, the implementation of these policies caused new socio-cultural imbalances, economic disparities and environmental degradation in the basin. The evaluation of these programmes shows that most of them failed and were detrimental to the environment of the basin and to the social well being of the Purhépecha community (PNUD, 1996).

An agrarian reform was implemented in the basin via land granting and land restitution. Major vindications of the local populations during the revolutionary upheaval were the expropriation of the large estates controlled by *Mestizo* elites and the restitution of communal lands lost during the late 19th century. Land granting and land restitution were implemented not only to fulfill farmers' vindications, but also to establish a new social contract between the Mexican State and the rural social sectors, aiming to incorporate them as main political allies of the revolutionary government. However, land reform was also pursued to maintain the privileged political and economic relations with the local and regional elites that supported the revolutionary movement. This ambiguous reform policy led to the establishment of a heterogeneous and conflicting landholding regime in the basin that subsists until today.

Land was restituted to indigenous communities according to local political agendas, creating conflicts among farmers of the same community and between communities. Land granting as social property (*ejido*) was implemented in areas formerly owned by indigenous communities, thus in practice creating rivalries among the social rural sectors. On the other hand, large tracts of the most fertile land were restituted to private owners, but limiting the size of the landholdings (Zárate, 1993; Dietz, 1999). Land restitution, endowment or expansion to the social and private sectors and the creation of new settlements initiated social stratification, land conflicts and land-use specialization in the Pátzcuaro Basin.

Corruption, complicated procedures, the lack of an independent agency for conflict solution, and the monopolization of land granting by the government and the political party ruling during this period, led to permanent struggle over the land among indigenous communities and between private and social rural sectors. These conflicts increased during the 1970-1980s, when the population size of the basin reached its pre-Hispanic maximum (see figures 16.1 and 16.12). Land-use specialization divided local natural resource management in three main types: (a) the multi-purpose land management based on rainfed maize systems, forest exploitation and fisheries within the indigenous communities; (b) irrigation and rainfed maize systems on *ejido* lands; and (c) irrigation systems and livestock raising on private lands.

### 16.6.2. Rural development

The analysis of the governmental policies and mechanisms implemented to modernize agriculture, stock raising, forest exploitation and fishing activities shows mainly negative impacts (Toledo and Barrera-Bassols, 1984; Esteva, 1995; Garibay, 1996; Dietz, 1999). Several rural development programmes were established in the basin since the 1970s, once land restitution and endowment had effectively impacted both the social and private sectors. Agencies in charge of the agricultural sector intended to increase land productivity in both rainfed and irrigation systems by innovation via substitution.

#### (1) Agriculture

Irrigation schemes in the lacustrine plains were modernized with the introduction of Green Revolution technologies by the Mexican state. Mechanization, HYVs and chemicals were introduced on the *ejido* and private lands. The overall financial and technological investment in these areas was superior to that invested for the modernization of the rainfed systems. Favoring the commercial agriculture created disparities between commercial and subsistence sectors.

Indigenous communities on the less favored *ejido* lands carried out rainfed systems based on maize. Multicropping, the use of organic fertilizers and manual labor functioned in complex ways for subsistence needs and local markets until the 1970s, when the introduction of Green Revolution technologies partially modified local production schemes and institutions. These innovations had major effects on land management. The shift from multicropping to monocropping was largely promoted. A first substantial but ephemeral increase of maize productivity as monoculture made farmers dependent on financial investment and market accessibility. Farmers' dependency on external inputs made them economically fragile and easily exposed to political control. Officials channeled loans, technological investment and market accessibility according to their political agendas; therefore, the social rural sector was rapidly incorporated into the political and economic spheres of the ruling elites.

A second major unfavorable effect for the rainfed systems was the gradual but effective displacement of maize production, encouraged by the government since the 1980s. Rural modernization discouraged *milpa* production when inducing land-use changes to favor commercial crops for export and livestock raising. *Milpa* production was rapidly substituted for avocado, coffee and walnut plantations in favorable agricultural lands near the basin (Paulsson, 1999; Klooster, 2001). Agricultural lands in Pátzcuaro are not favorable for the variety of crops that are globally demanded. Thus, the economic policies designed to integrate the Mexican agricultural sector into the global economy did not benefit local subsistence farmers. Moreover, the cancellation of subsidies for rainfed agriculture discouraged small farmers from producing staple crops. Changes in agricultural policies paralleled the failure of Green Revolution technologies to substantially increase land productivity in the basin. The reduction of multicropping and the political economy of food production in the rainfed systems led to the partial abandonment of agriculture in the indigenous communities at the beginning of the 1990s. Since then, maize prices have fallen by more than half and the effective income of maize harvest has also fallen.

(2) Livestock raising

Agricultural intensification promoted by the Green Revolution resulted in the disruption of the traditional combination of cropping and livestock raising as a single system. This symbiotic system was efficiently adapted for the maintenance of soil fertility on marginal lands, while buffering cash availability and thus rendering in a well-established subsistence strategy. This production integration was the center of the multi-purpose land management strategy adapted since the 16th century.

The disruption of the intimate relation between crops and animals was promoted by innovation as substitution. Wire fences were introduced to prevent cattle invasion into the agricultural parcels as a mandatory technical adjustment for loan availability, but fences also served as an initial step towards land privatization on communal territories (Linck, 1994). Livestock development in the basin encouraged land-use specialization and social stratification within the indigenous community and between the social and private sectors thus stimulating conflicts over loans and lands.

Livestock was mainly promoted for the private sector, while the introduction of cattle in the indigenous communities was limited and selective, benefiting those members who were economically capable to initially invest in such commodity and reliable to maintain production for commercial purposes. The reduction of communal pasture and fallow lands led to (a) land-use specialization for private extensive stock raising; (b) the decrease of agricultural lands; (c) the specialization of crop production for fodder; and/or (d) the expansion of pasture land via deforestation of communal forests.

(3) Forest exploitation

Practically, most of the forestland lies within indigenous communal lands (Alvarez-Icaza et al., 1993; Klooster, 2000, 2001, 2002, 2003). However, the total governmental control on forest resources exploitation, together with the administrative and commercialization policies, undermined this ecological and economic advantage for the Purhépecha localities. State monopolization of forest exploitation has basically benefited the *Mestizo* political and economic elites of the basin, leading to forest over-exploitation and inter- and intra-communal conflicts for forest resources.

Corruption at all levels began since the late 19th century, when foreign forest concessions monopolized logging. Private concessions subsisted until the 1930s, when the government canceled them and decreed an ephemeral logging ban (1934-1939), reactivated since the 1950s until today. Although commercial logging and woodcutting are still officially banned in the Pátzcuaro Basin, this legal measure is not enforced against small woodcutters but in reality denies indigenous communities the opportunity to benefit from logging their own forests. The logging ban also removes economic incentives for them to actively protect their forests from outsiders (Klooster, 2001). At the same time, the logging ban allows exceptions for sanitary cuts to remove diseased and fire-damaged trees. This lubricates corruption between the forest bureaucracy and *Mestizo* sawmill owners at the same time that it desempowers community forest owners (Garibay, 1996; Dietz, 1999; Klooster, 2000).

Clandestine exploitation is generalized and increased with the use of chain saws. Forests supply wood to more than a thousand band saw workshops, sawmills and wood chippers for cellulose, and about 10,000 small pottery and carpentry workshops (Reyes, 1993; Masera et al., 1998; Klooster, 2001). The reduction of agricultural opportunities has led many indigenous households to specialize in pottery and carpentry while illegal logging benefits private enterprises. Thus, forest exploitation augmented social stratification and deforestation leading to environmental degradation in the Pátzcuaro Basin.

(4) Fisheries

Land reform was promoted to benefit *Mestizo* landholders in the lacustrine plains and lakeshores of Pátzcuaro (Toledo and Barrera-Bassols, 1984; Rojas, 1993; ORCA, 1997; Dietz, 1999). Most of these fertile tracts of land are now owned by private individuals or are endowed as *ejido* lands. Thus, the indigenous communities located on lakeshores or islands had no choice but to specialize in fishing. The number of fishermen increased since the 1940s and over-exploitation of the endemic fish stocks began during the 1980s when the Pátzcuaro Basin was promoted as a tourist destination. Since then, a drastic decrease of fish stocks led to a seasonal fishing ban imposed by the government, intending to prevent over-exploitation in similar ways as the logging ban. The seasonal ban sanctions fishing during the ovulating and first-growing periods (April-September), ignoring thus the fact that fishermen are totally dependent on this activity for their income. Moreover, commoditization of fish resources for tourist purposes disrupted subsistence fishing activities and local markets.

Production specialization and social stratification arose among fishermen. Those individuals who were benefited by loans, technological innovation and political relations were capable of maintaining or even increasing their production and income, while the majority of local fishermen lost their capacity to obtain an income and maintain their self-sufficiency. Besides, illegal fishing for commercial purposes increased because the highest tourist affluence and Catholic religious festivities in the region overlap with the six-month ban period. Besides, the anthropogenic eutrophication of the lake influenced fish productivity and quality. Traces of pesticides considered as high risk for health have been found in the aquatic fauna, lake sediments and lake water (PNUD, 1996).

(5) Education and cultural development

Education, urban planning and infrastructure development programmes accompanied rural modernization in the Pátzcuaro Basin. Education development in the Purhépecha communities became important since the 1940s, consisting in governmental efforts to integrate the indigenous populations into the emerging modern Mexican society. The image of the modern Mexican society as the union of the indigenous past with the European and *Criollo* experiences that the *Mestizo* represented, was elevated to a national symbol of the *Mestizo* ideology. The integration of the indigenous 'remnants of the past' into the modern social melting pot became central for the avenue of education programmes in the indigenous territories of the country.

The whole Purhépecha territory, including the Pátzcuaro Basin, became the most prominent indigenous area of the country where cultural change planning (*indigenismo*) was promoted since the 1940s (Reyes, 1993; Dietz, 1999). Several reasons lie behind these integrative cultural and educational programmes. Despite land reform efforts to incorporate the social rural sector into the political sphere of the Mexican State, the Purhépecha community remained strong and somewhat autonomous and resistant to change. Communal landholding, language, traditional livelihood and catholic syncretism were cohesive cultural elements strongly defended by Purhépecha populations. Monolingual Purhépecha people accounted for almost 50% of the Indian population and almost all land controlled by indigenous localities was already restituted in a communal regime by the 1940s.

Perhaps, the most prominent effort to integrate the Purhépecha community into the *Mestizo* nationalistic ideology was promoted by formal educational projects. This program consisted in the construction of primary and secondary schools (basic education) in almost each indigenous locality. School training for the young Purhépecha generations was carried out mainly by bilingual schemes (Spanish-Purhépecha), but instruction acquired by youngsters was strongly influenced by the *Mestizo* ideology, thus negatively impacting the maintenance or reinforcement of the Purhépecha cultural control. Language-shifting became an important cultural issue induced by images of modernity and progress. Young generations are now reluctant to learn or speak their native language as a result of the urban, western and national oriented formal education. Nevertheless, the official educational effort carried out during the last 60 years did not meet the overall reduction of illiteracy.

Almost 20% of the regional population older than 15 years is illiterate, while almost 30% of the same population did not finish the basic educational program. Twenty percent of the population between 6 and 14 years do not attend school, and the average number of formal training years per individual is only 4.5. Moreover, illiteracy is much higher within the indigenous population. Illiterate Indians account for 30% of the total population.

### 16.6.3. Urban development and demographic explosion

Urban planning and infrastructure construction reinforced rural and educational modernization in the Pátzcuaro Basin. Both policies and mechanisms were strongly influenced by demographic, political and economic factors. An explosive demographic growth took place in the urban areas of the basin during the 1940-1990s (see figure 16.1). Urban growth was stimulated by several factors: (a) centralization of political, economic and bureaucratic decision-making; (b) rural-urban migration within the basin; (c) the emergence of the region as a tourist destination; and (d) the impoverishment of the rural populations due to rural development failure in the region.

Demographic growth was paralleled with the construction of an all-year road network, that communicates almost the totality of the rural settlements of the basin with the urban localities. Road infrastructure allowed fast transportation of the goods produced within and outside the Pátzcuaro Basin and permitted the flow of services and commodities in more efficient ways. The *Mestizo* localities in each municipality were now in the position for a more efficient control of the indigenous communities and the strategic goods and services they provided. Cheap labor, wood and fish resources, and handicrafts became major indigenous commodities.

The partial breakup of the local rural economies, the consequent massive out-migration accounting for 30% of the economically active population and over-exploitation of forest and lake resources, led to the increase of environmental degradation in the basin during the last decade. Conflicts over land, water and wood resources became political arenas of massive discontent between indigenous communities and the private rural and urban sectors. Social discontent nurtured the emergence of a new political movement, with ethnic and agrarian components surpassing the regional level and encompassing the national indigenous movement that Mexico is facing today (Dietz, 1999).

## 16.7. CONCLUSION

The long occupation of the Pátzcuaro Lake Basin had modified its natural setting in such ways that landscapes must be considered as social constructs, including the lake. Socio-political, economic and cultural processes have been prime movers for landscape transformation since the early establishment of rustic societies. State intervention, internal and external economic demands, demography and inter-ethnic relationships are the specific factors that molded social institutions and human activity in the long span.

Unequal socio-cultural relations have always driven the political economy of the basin while the political ecology has always been molded by contrasting perceptions about nature and its appropriation. Human activity evolved embracing tensions between communal, private and state interests. Power relations transformed land-use systems, local livelihoods and the environment according to each historical epoch. Socio-political settings and natural events largely affected indigenous communities and small farmers.

The analysis of the historical relations between nature, culture and society in the Pátzcuaro Basin shows two distinct ways of perceiving and managing natural resources. Indigenous communities and small farmers have perceived the basin as their primordial territory and have managed their surrounding landscapes in multi-purpose ways to complement their needs. Colonizers, landlords, officials, foreign enterprises and governmental agencies have perceived the basin as a natural region to be exploited via extraction and land-use specialization to fulfill individual, national and/or international needs.

These contrasting worldviews resulted in tensions between *Mestizo* and indigenous communities, urban and rural populations, and among rural localities. Subordination/domination relations dominated these tensions where the rural and indigenous populations acted in resistance as subordinated actors. The outcome of these tensions has also impacted land-use systems, land tenure regimes and the natural dynamics of the basin.

The maintenance of a vigorous Purhépecha community, the prevalence of the communal land tenure regime and the multi-purpose natural resource management strategy show the effective resistance of the indigenous population until today. The presence of *Mestizo* and urban populations, private land tenure regimes and commercial production show a highly hybridized and complex social system. The overlapping of the social system with the natural heterogeneity of the basin mirrors the long adaptation of contrasting interests in a fragile mountainous landscape. That is probably why the basin remains as one of the most preserved lake catchments in the most populated and industrialized region of Mexico.

The historical analysis presented in this chapter reveals distinct patterns of landscape evolution:

(1) Rustic agrarian pattern

Low *et al.,* population pressure and local decision-making influenced landscape evolution. Agricultural intensification was carried out by communities increasingly competing for land resources without the intervention of the State. Early agricultural adaptations may have caused localized environmental degradation, but agricultural intensification was supported by high labor supply, therefore reducing environmental risks. Short-term lake level fluctuations may have caused competition for fertile lands. Settlements were founded on lakeshores and islands.

(2) Purhépecha State pattern

Landscape evolution was influenced by agricultural intensification under high population pressure and centralized state intervention. Competition for land and water resources may have led to social unrest, but the implementation of alliances and a common dominating ideology and religion helped elites control natural resources and social sources. Social stratification and tribute dominated the flow of goods and services in symbiotic ways. The emergence of urban localities controlling rural populations and land and water resources, and the establishment of the Pátzcuaro Basin as the geopolitical core of the Purhépecha State had large consequences on landscape transformations. Food carrying capacity of the basin was well below population demands; therefore, the expansion of the territory outside the basin increased inter-ethnic relations and commercial flows, and induced production specialization within localities of the basin. Apparently, territorial expansion was promoted by the ruling elites to overcome good limitations, thus buffering environmental risks. Short-term unfavorable climatic events may also have triggered territorial expansion. Environmental degradation may have caused territorial expansion and social unrest at the eve of the Spanish conquest. A large majority of settlements was located on the lakeshores, islands and low piedmonts of the basin.

(3) Colonial pattern

Landscape evolution was influenced by agricultural intensification under low population pressure and by the implementation of colonial land granting and tributary policies, largely affecting the diminished local populations. Apparently, forced labor was the major regional source demanded by Spanish officials, but adaptation of the European agricultural experience had impacted landscape transformations in the long term. Urban and rural populations were differentiated by ethnic grassroots. Spaniard, *Criollo* and *Mestizo* communities largely dominated urban localities. Indigenous populations prevailed in the rural peripheries. Indigenous land dispossession and land monopolization by colonists governed inter-ethnic relations and economic demand. Large private estates were established in the most fertile tracts of land, while indigenous communities were relocated in the less fertile lands, including sloping lands and the inter-mountainous valleys. Unequal relations between colonists and the colonized populations inaugurated a long-term struggle for land, forest and water resources. Social unrest was also triggered by short-term unfavorable climatic events therefore exacerbating inequality and dissent. Depopulation, agricultural intensification and unequal access to land resources may have caused environmental degradation.

(4) Independence pattern

During Independence period but especially during the last 40 years of the 19th century, landscape evolution was influenced by forest overexploitation under increasing population growth and by the state deregulation of indigenous communal lands and re-municipalization. *Mestizo* populations controlled vast tracts of lands as absentee landlords and urban localities as administrators. Forest over-exploitation was carried out by foreign enterprises controlling land and human resources. Private land tenure regimes dominated, thus triggering emigration and rural poverty, especially in the indigenous sector. Land-use intensification was promoted by stock raising and irrigation schemes, with the use of large labor supply. Land dispossession, extreme poverty and forced labor governed social dissent and unrest at the end of this period. Natural resource over-exploitation, emigration and unequal access to land triggered environmental degradation and the avenue of the revolutionary movement in the basin.

(5) Modern pattern

Landscape evolution was influenced by intensification of the rural production under explosive demographic growth and by centralized state intervention. A complex land tenure regime was promoted, but the social land property largely dominates at the end of the 20th century. Rural modernization was intended to increase land productivity via monocropping, fishing and stock raising specialization. Agricultural intensification was promoted by substitution. Forest exploitation and administration was monopolized by the Mexican State. Land-use specialization partially disrupted the multi-purpose land management strategy carried out by indigenous communities and *Mestizo* private smallholders. These policies and mechanisms were paralleled with cultural programmes largely controlled by the Mexican State. Cultural programmes aimed to integrate indigenous populations into modern standards dominated by the *Mestizo* worldview, undermining the cultural control of local communities by language-shifting. Inter-ethnic unequal relations, economic inequality and social conflicts have dominated during the last 20 years. Discouragement of maize production and social land property deregulation deepened rural poverty, therefore triggering mass emigration and natural resource over-exploitation. The current socio-political context led to environmental degradation at regional level and to economic disparities between urban and rural populations. Environmental degradation and economic inequalities have been also triggered by short-term dry and warm climatic events.

Landscape evolution during the last 4,000 years has been triggered by different nature-culture-society patterns. These patterns were guided by agricultural intensification under two main processes: (1) intensification under low population pressure and the absence of or limited state intervention policies as in the case of the rustic and colonial patterns, and (2) intensification under high population pressure and centralization of decision-making by state policies, as the in case of the Purhépecha, Independence and modern patterns.

The analysis of social and natural events in the long term permits a better comprehension of landscape evolution, environmental degradation and human adaptation to variable and adverse circumstances. To which extent environmental degradation affected human activity during the long span and how land degradation is perceived by different scientific agendas, thus influencing the ways to analyze the role that the indigenous communities played and could play in landscape evolution, are discussed in Chapter Seventeen.