CHINANTEC SHIFTING CULTIVATION : InTERAcTIVE LANDUSE

A CASE-STUDY IN THE CHINANTLA, MEXICO, ON SECONDARY VEGETATION, SOILS AND CROP PERFORMANCE UNDER INDIGENOUS SHIFTING CULTIVATION

Hans van der Wal

Promotor: Dr. Ir. R.A.A. Oldeman,
Hoogleraar in de Bosteelt & Bosoecologie

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PROPOSITIONS

STELLINGEN,

behorende bij het proefschrift "Chinantec shifting cultivation: ItTERAcTIVE landuse"
door Hans van der Wal,
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1. The difference between industrial and ecological agriculture resides in the degree to which ecological processes are permitted and used to act as sources of variation at near-field scales and as links across scales.

2. Indigenous shifting cultivation is a sequential, iterative form of land-use in which the development of secondary vegetation, soils and crop performance may follow various paths. (THIS THESIS)

3. The iterative and interactive character of indigenous shifting cultivation confers to this form of land-use the potential to become a form of mosaic management, which optimally combines diverse conservation and production goals. (THIS THESIS)

4. Use-history is a useful entry for studying secondary vegetation, soils and crop performance in shifting cultivation. (THIS THESIS)

5. Because indigenous farmers have knowledge of paths of development of secondary vegetation, soils and crop performance and of the factors influencing them, the redesign of locally adapted forms of shifting cultivation cannot be conceived without farmers playing a central role. (THIS THESIS)

6. Developed for industrial agriculture, monitoring methods in "precision agriculture" can greatly enhance knowledge of the complex dynamics in ecological agriculture.

7. According to Brundtlands' (1987) definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs", the sustainability of present development can be increased by enhancing the ability of future generations.

8. Remmers' (1998) observation that biodiversity cannot be conserved, only reproduced, correctly reflects the worldwide human interference in the ecological processes that generate biodiversity.

9. The goal of reproduction of biodiversity is insufficiently integrated in sectoral policies with regards to the use of natural resources.

10. Centralist policies and lack of coordination between government institutions have greatly contributed to environmental degradation in Mexico.

11. In the mountains, straight paths are inclined surfaces. (EMPIRICAL FACT)

12. The "pilot" character of development projects is differently conceived by development agencies' staff and farmers.

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Glossary

agglomerative clustering: a method of clustering in which two most similar groups of species or sites are distinguished in successive steps of analysis.

aggradation phase (Oldeman 1990): a phase of eco-unit development that starts when the canopy is closed. In this phase, trees fight fiercely for light and nutrients. *Potential trees* and *trees of the present* together form the canopy. The aggradation phase ends when the canopy consists of only *trees of the present*. See also: *potential trees* and *trees of the present*.

architecture: the spatial distribution of the interacting components and their forms in a system, expressing its organization. Viewed on the level of a tree, architecture considers the spatial distribution of the organs and their form. Viewed on the level of an eco-unit, it considers the spatial distribution of trees and their form. Viewed on the level of a field, it considers the spatial distribution and form of eco-units within the mosaic in the field . Viewed on the level of a territory, it considers the spatial distribution and form of mosaics in the territory.

basal area: structural parameter used in forestry to indicate the sum of the surfaces of horizontal cuts through the trunks of the trees on a specific area, usually expressed in $m^2 \cdot ha^{-1}$.

biomass: structural parameter indicating the weight of living organisms on an area.

biostatic phase (Oldeman 1990): a phase of eco-unit development in which trees of the present determine the overall architecture. The set of all *trees of the present* in one eco-unit is divided into structural ensembles, which determine layering (Oldeman 1990; Oldeman & Van Dijk 1991). See also: *trees of the present*.

Budowski's rule (as amended by Oldeman 1983): any plant which plays a pioneering role in hospitable environments shows a geographical distribution which includes more inhospitable environments (Oldeman 1990).

chablis: ancient french concept for the uprooting of a tree, the opening in the forest canopy it causes, the uprooted tree itself; the concept includes the event, its causes and its consequences (Oldeman 1990). In the present text, this concept is preferred to the concept "gap", because of the idea of emptiness associated with the latter.

Chinantec: an indigenous Mexican group, probably of Olmec origin.

Chinantla: the region inhabited by the Chinantec, located in the northern part of the Mexican state Oaxaca.

clustering: a mathematical technique frequently used in ecology to group species or samples.

comunero: a member of a community – a village with a communal form of land tenure according to mexican and local customary law, in which unused lands can be freely accessed and used, but cannot be sold – who is recognized as such by the community. Membership brings obligations and rights: to vote in assemblies, to be elected to represent the community, to participate in the maintenance of roads and trails, to use land, to construct a house, etc.

covariable: a variable the contribution of which to the variation in species composition is determined and eliminated for the ordination.

crop performance: the character of the growth and development in the course of the biological cycle of a population of cultivated plants on a field. Productivity in terms of standardized yield and biomass are structural parameters of crop performance.

cropped field: eco-unit of which the organization is determined by cultivated plants.

crown area index: the ratio of crown projection of the trees in a certain area to area.

degradation phase (Oldeman 1990): a phase of eco-unit development that starts when biostasis breaks down due to internal or external causes and that is switched on by senescence of trees or accidents.

disturbance: concept of impact on vegetation used in successional theories, that postulate more or less regular pathways from pioneer to climax stages which are liable to be disturbed.

divisive clustering: in each step of analysis, two most dissimilar groups of species or fields are distinguished.

eco-unit (Oldeman 1983: p. 176): "*the unit of vegetation which started its development at the same moment and on the same surface.*" Or (Rossignol, Rossignol, Oldeman & Benzine-Tizroutine 1998: p. 152): "*one eco-system, developing on one surface, cleared by one impact, from one specific moment on, and by one development process*"

field: patch of land which has been subjected to at least some homogenizing action of man, intended to make possible its use for agriculture and which has the same use-history over its whole surface. In shifting cultivation, fields begin their existence when primary or very old secondary vegetation is cut.

first-order regrowth: secondary regrowth that starts after primary or very old secondary vegetation has been cut.

forest eco-unit (Oldeman 1990: p. 165): "*every surface on which at one moment in time a vegetation development has begun, of which the architecture, eco-physiological functioning and species composition are ordained by one set of trees until the end*".

fragmentation (Oldeman 1990): one eco-unit splits up in several smaller eco-units as a consequence of tree fall or some factor that hampers development in part of the original eco-unit, such as climbers that inhibit the growth of trees. Fragmentation may occur in the innovation phase (early fragmentation), aggradation phase and in the degratation phase (late fragmentation).

holoplexion: the holoplexion is a complete vertical profile of the natural environment. Its layers are called hoplexols (Richard 1989). Note that the dimensions of the holoplexion (space and time) are not included in the definition. Holoplexions can therefore be studied both on the level of an eco-unit or on the level of a mosaic.

huamil: field as a mosaic of eco-units.

innovation phase (Oldeman 1990): a phase of eco-unit development in which the propagule bank is activated. Seeds in the seedbank and meristems on the remains of the former eco-unit (e.g. stumps) become active. When the canopy is closed by shrubs or small trees, the *aggradation phase* starts. See also: *aggradation phase*.

integral shifting cultivation (Conklin 1957: p. 2): shifting cultivation which "*stems from a more traditional, year-round, community-wide, largely self-contained and ritually sanctioned* *way of life.*" Watters' (1971) concept of "*traditional shifting cultivation*" has the same meaning. It is practised by farmers "*belonging to a tribe, a community, whose members are linked by habit and custom dating from time immemorial ... using methods and techniques particular to them and inextricably woven into the very fabric of their family and tribal institutions, frequently also into their beliefs and religious practices*" (Watters 1971: p. 6).

landuse pattern: spatial and temporal regularity in the distribution of the use of fields by a human comunity in their territory. In indigenous shifting cultivation the landuse pattern is based on a broad knowledge of the environment. See also: *use-history*.

lateritic soils: lateritic soils are soils that become hard as a brick when exposed to the air. The term "laterite" includes all the kinds of soil of very strong geochemical weathering, ranging from ferralitic formations to ironstone. Lateritic soils are rich in hydrous alumina or iron oxide, or both, and poor in silica (Stamp & Clark 1979).

lithology: "*the character of a rock expressed in terms of its mineral composition, its structure, the grainsize and arrangement of its component parts; that is, all those visible characters that in the aggregate impart individuality to the rock*" (Walker 1988).

morpho-units: distinct forms of the land that are found on the field-level.

Oaxaca: one of the southern states of Mexico.

order of regrowth: the order of regrowth is the rank number that indicates how many times the development of secondary vegetation has started on a field: after the cutting of primary or old secondary vegetation a first-order regrowth starts to develop; after slashing a first-order regrowth, a second-order regrowth starts to develop. See also: *first-order regrowth, regrowth, second-order regrowth*

ordination: a mathematical technique used in ecology, by which scores are calculated for species and sites, which are then plotted along axes that may (direct ordination) or may not (indirect ordination) represent environmental gradients.

páramo: permanently wet, high mountain regions with small annual and diurnal temperature fluctuations.

physiognomy: description of the aspect of an object, applying terms that do not form part of a hierarchical system of concepts.

polydominance: several dominant species are present with similar numbers of individuals, in contrast to single dominance, with most individuals belonging to only a few species.

potential trees (Oldeman 1974): trees with a potential for crown expansion.

recontextualization: the process undertaken by indigenous groups to think of themselves in a multi-scale context and to act to ameliorate their position in this context. The term contextualization has been borrowed from A.P. Vayda, founder of the journal "Human Ecology". Vayda (1983) refers to progressive contextualization as a procedure of research, which starts by focusing on important people-environment interactions, and then tries to explain them by placing them in progressively wider or denser contexts. The term has been converted here into recontextualization.

regrowth: the secondary vegetation that develops on a field after burning. The term is neutral with respect to species and eco-unit composition. See also: *first-order regrowth, order of regrowth, second-order regrowth.*

schist (Stamp & Clark 1979): a foliated metamorphic rock which can be split into thin flakes or flat lenticles.

secondary vegetation: vegetation that develops after a natural event or a human intervention, which has a great impact on the original vegetation, though it does not completely eliminate all traces of it. Most secondary vegetation results from clearance by man of the original vegetation. It may also result from hurricanes, fires or tree falls.

second-order regrowth: secondary regrowth that starts after cutting a first-order regrowth. See also: *regrowth, first-order regrowth, order of regrowth*

shifting cultivation: a general form of landuse, confined to the tropics, in which fields are prepared for cropping by clearing tracts of forest, usually by slashing and burning; fields are cropped during one or more seasons and then left fallow for periods which are usually longer than the period of cropping.

shifting event (Oldeman 1990, p. 394): natural or artificial event that cause the eco-unit composition of a given silvatic mosaic to change as to its spatial and temporal pattern.

species composition: the distribution of the plants found in a certain area taxonomic species, usually rated for their numerical importance.

standardized yield: yield referring to the horizontal projection of the surface area on which a crop is grown. See also: *surface yield*

structure of vegetation: concept used to indicate a general, average organization of vegetation. The structure of vegetation is detailed by enumerating a set of structural parameters. See also: *structural parameters.*

structural parameters: parameters that indicate an average or summed value of some characteristic of the trees or other compartment of an ecosystem. See also: *structure of vegetation.*

surface yield: yield referring to the real surface on which a crop is grown. See also: *standardized yield.*

sustainable agriculture (wide sense): agriculture in which the social, cultural, economical and natural context are reproduced and/or maintained.

sustainable agriculture (strict sense): agriculture in which the level of productivity is maintained in the course of time.

temperament of a tree (Oldeman & Van Dijk 1990): the set of growth and development reactions shown by a tree towards its environment during its life cycle

tree of the past (Oldeman 1974): a tree with a decaying or damaged crown, destined to run down to its death.

tree of the present (Oldeman 1974): a tree with a crown that has reached its maximal expansion.

use-history of a field: the record of all facts of use that physically and biologically influenced the field. The term refers to the temporal aspect of the landuse pattern on the level of an individual field. The use-history of a field starts when primary or old secondary vegetation is cut. Important parameters of use-history are: period since the cutting of primary or old secondary vegetation; the number and duration of subsequent intercalary periods of development of secondary vegetation; and the duration of the subsequent periods of cropping. In the Chinantla, periods of cropping last six months each.

yield: structural parameter indicating the weight of the harvested product obtained from a plant or an area cultivated with a certain crop. Yields of annuals usually refer to an area; in tree crops yields may refer to individual trees also.

zero-event (Oldeman 1974): the event that creates the surface on which a new eco-unit starts to develop. This notion is opposed to that of 'disturbance'.

Summary

The development of secondary vegetation, soils and crop performance was studied in local variants of shifting cultivation in two villages in the Chinantla, Mexico. In Chapter 1, the institutional, social and political context of the research are presented and the reader is advertised that the scope of the study is limited to the interaction between ecological-productive aspects and the landuse pattern as practiced by the farmers.

In Chapter 2 a conceptual framework is presented. Indigenous shifting cultivation is defined as a general form of landuse, characterized by the continuous recontextualization of a many-sided relation between man and nature, the continuous recreation of knowledge and the making and use of dynamic fields according to a landuse pattern. A great specificity of indigenous shifting cultivation in response to local environmental and socio-economical factors is observed.

The ecology of secondary vegetation is reviewed, paying attention to mountain areas such as the Chinantla. The development of forest eco-units is not a simple, unilinear process, but, on the contrary, a process that can take one of many possible courses, influenced by environmental factors and the use-history of the land. Soils develop as an integral part of eco-units, as has been observed by comparing characteristics of soils in hurricane tracts and eco-units of different ages. The development of secondary vegetation and soils, as related to the landuse pattern for shifting cultivation, leads to variation in the ecological conditions within the mosaic of fields. Consequently, the performance of crops may vary within the mosaic of fields.

In the Chinantla region a large variation in climate occurs due to a wide altitudinal range (Chapter 3). As a consequence, several vegetation types occur. Soils in the area have developed from limestone or sandstone/metamorphic rocks. Chapter 4 describes the variants of shifting cultivation and the landuse pattern in the Chinantec communities Santa Cruz Tepetotutla and Santiago Tlatepusco. Three variants of shifting cultivation were distinguished: shifting cultivation in the area of "selva alta perennifolia de montaña" (the most widely practised), shifting cultivation in the limestone area, and shifting cultivation in the *Quercus*-forests. In all variants maize is the principal crop.

In Chapter 5 the development of secondary vegetation as related to the use-history of fields is studied, concentrating on secondary vegetation in the area of "selva alta perennifolia de montaña". Secondary regrowths were sampled in 28 fields. Ages of regrowths varied from 5 to 50 years, and orders of regrowths – first-order regrowths develop after cutting primary or old secondary vegetation; second-order regrowths after cutting a first-order regrowth – varied from 1 to 4. On each field, data on the trees and shrubs with a diameter at breast-height of more than 2 cm were recorded in four transects, each of 100 m^2 surface area, which were all laid out on steep slopes.

A total of 5691 trees and shrubs, belonging to 229 species, were found on the sampled area. Thirty-seven species comprised 90% of all sampled individuals. Cluster and ordination analysis showed variation of the species composition of secondary vegetation with age, altitude, geographic location, lithology and order of regrowth. Analysis of farmers' information on the relation between order of regrowth and species composition confirmed the results of sampling.

Structural parameters, species composition, tree development and eco-unit development varied between orders of regrowth. Basal area, number of trees and crown area index were high in first- and second-order regrowths, but fell sharply in subsequent regrowths. First-order regrowths were dominated by one or two species. In several second-order regrowths, *Hedyosmum mexicanum* was the single dominant. In other second-order and in later-order regrowths polydominance was observed. Analysis of height-diameter relations in frequent species also indicated a relation between the order of regrowth and the development of the trees of a certain species, demonstrating the flexibility of trees in responding to a changing environment. Whereas first- and second-order regrowths were composed of few eco-units, third- and fourth-order regrowths showed fragmentation of eco-units from early phases of development onwards. The results indicate that the number of consecutive eco-units per time unit diminishes with increasing order of regrowth.

Changes in soils during one cropping season were studied by comparing soil parameters in samples obtained after slashing the vegetation (May), after burning (June) and at harvest (October-November). No significant differences in bases, pH, nitrogen and carbon were found between May- and June-samples on limestone-derived soils. Between burning and harvest, pH and the sum of exchangeable bases increased slightly. In the area of "selva alta perennifolia de montaña" pH and exchangeable bases increased significantly between May and June. During the cropping season (June to October-November), the sum of exchangeable bases declined slightly. No relation of these changes with the use-history of fields was found, possibly due to the small number of sampled fields and burns being partial and heterogenous in the year of sampling (1993).

Sampling of soils in a chronosequence of fields in the area of "selva alta perennifolia de montaña" gave strong indications of an increase of pH and exchangeable bases in the course of several decades, from the cutting of primary or old secondary vegetation onwards. The strongest increase was observed in the quantity of exchangeable calcium. Correlations between use-history parameters and carbon, nitrogen and phosphorus were not significant. A mechanism of soil change based on a combination of physical and biological processes is proposed, wherein an initial increase in pH through the addition of bases triggers of an increased biological activity resulting in a more hospitable soil.

The performance of maize crops in a chronosequence of fields was studied in 1994 by determining several parameters referring to the crops (Chapter 7). Crop performance varied strongly between fields, both in the limestone area and in the area of "selva alta perennifolia de montaña". In the limestone area, yield per square meter sloping surface diminished with increasing number of burns; there was no relation between yield and any of the measured soil parameters. In the area of "selva alta perennifolia de montaña", yields were not significantly correlated with any of the parameters applied to characterize the use-history of fields. However, yields per square meter sloping surface were correlated with several soil parameters: CEC-$BaCl_2$, exchangeable calcium, total phosphorus and the C/N-ratio. At values smaller than 3.9 also pH-KCl was positively correlated with yields. In fertilization experiments the combined application of nitrogen and phosphorus improved yield on a field where without fertilization a low yield was obtained; fertilization had no effect where high yields were obtained without fertilizer application.

The development of secondary vegetation, soils and crop performance in indigenous shifting cultivation in two villages in the Chinantla, Mexico, illustrates the interactive and iterative character of this form of agriculture. This character should be taken as the point of departure for its redesign in such a way that the production of a variety of goods is combined with the production of a variety of services in a complex mosaic of eco-units.

Samenvatting

De ontwikkeling van secundaire vegetatie, bodems en het gedrag van maïsgewassen werd bestudeerd in lokale varianten van zwerflandbouw in twee dorpen in de Chinantla, Mexico. In Hoofdstuk 1 wordt de institutionele, sociale en politieke context van het onderzoek kort besproken en wordt de lezer gewaarschuwd voor het feit dat de thematiek van onderzoek beperkt is tot de interactie tussen ecologisch-productieve aspecten en het landgebruikspatroon zoals toegepast door de boeren.

In Hoofdstuk 2 wordt een theoretisch raamwerk gepresenteerd. Inheemse zwerflandbouw wordt gedefinieerd als een algemene vorm van landgebruik, gekenmerkt door de voortdurende aanpassing en herschepping van een veelzijdige relatie tussen mens en natuur aan haar sociaal-economische en ecologische context, door de voortdurende herschepping van de kennis waarop ze gebaseerd is en door het aanmaken en gebruik van zich ontwikkelende velden volgens een patroon.

De ecologie van secundaire vegetatie wordt kort besproken, waarbij aandacht besteed wordt aan de speciale omstandigheden die zich voordoen in berggebieden zoals de Chinantla. De ontwikkeling van de samenstellende delen van bos-ecosystemen (eco-eenheden) wordt niet gezien als een eenvoudig, rechtlijnig proces, maar, integendeel, als een proces wat potentieel op verschillende wijzen kan verlopen, beïnvloed door zowel omgevingsfactoren als de gebruiksgeschiedenis van velden. Bodems ontwikkelen zich als een integraal deel van de eenheden ecosysteem, hetgeen aangetoond is door het vergelijken van bodemgegevens m.b.t. eco-eenheden in verschillende fases van ontwikkeling, o.a. in door (gedateerde) orkanen nagelaten sporen. De ontwikkeling van secundaire vegetatie en bodems, gerelateerd aan het patroon van landgebruik voor zwerflandbouw, leidt tot variatie in de ecologische omstandigheden in het mozaïek van velden. Dientengevolge kunnen verschillen optreden in het gedrag van het gewas tussen de eenheden (velden) van het mozaïek.

De Chinantla regio kenmerkt zich door een grote klimatologische variabiliteit, gerelateerd aan de grote hoogteverschillen die zich voordoen (Hoofdstuk 3). Dientengevolge vindt men er verschillende vegetatie types. De bodems in een deel van het gebied hebben zich ontwikkeld op kalksteen, in het overige deel op zandsteen en schist. In deze variabele omgeving hebben de Chinanteken in de dorpen Santa Cruz Tepetotutla en Santiago Tlatepusco 3 varianten van zwerflandbouw ontwikkeld, elk gekarakteriseerd door een patroon van landgebruik: zwerflandbouw in immergroen regen-bergwoud, de meest voorkomende variant; zwerflandbouw in het kalksteengebied; en zwerflandbouw in de eikenbossen (Hoofdstuk 4). In alle varianten is maïs het hoofdgewas.

De ontwikkeling van secundaire vegetatie in relatie tot de gebruiksgeschiedenis van velden wordt geanalyseerd in Hoofdstuk 5, waarbij de aandacht wordt gecontreerd op secundaire vegetatie in de meest voorkomende variant van zwerflandbouw in immergroen regen-bergwoud. Deze vegetatie, in leeftijd varierend van 5 tot 50 jaar, werd bemonsterd in 28 velden. De orde van hergroei van de bemonsterde vegetatie – een hergroei van de eerste orde groeit op na het kappen van primaire of oud-secundaire vegetatie; een hergroei van de tweede orde groeit op na het kappen van een hergroei van de eerste orde, etc – varieerde van één tot vier. In elk veld werden vier transecten met een grondoppervlak van 100 m^2 uitgezet. Hoogte, kroondiameter, kroondiepte en stamdiameter werden bepaald van alle hierop voorkomende bomen en struiken met een diameter op borsthoogte van meer dan 2 cm. Ook werd hun wetenschappelijke en lokale naam bepaald.

In totaal werden gegevens bepaald van 5691 bomen en struiken, welke gezamenlijk tot 229 soorten behoorden. Van de gevonden individuen behoorde 90 % tot slechts 37 soorten. Met behulp van klassificatie- en ordinatie-analyse werd aangetoond dat de soortensamenstelling van secundaire vegetatie varieerde met de leeftijd van secundaire vegetatie, de hoogte boven zeeniveau van het veld, het dorp, het moedergesteente en de orde van hergroei. Analyse van door de boeren verstrekte informatie met betrekking tot de relatie tussen de orde van hergoei en soortensamenstelling bevestigde het op bemonstering gebaseerde resultaat.

Struktuur parameters, soortensamenstelling en de ontwikkeling van bomen en eco-eenheden varieerden met de orde van hergroei. Grondvlak, het aantal bomen en struiken en de ratio tussen de gesommeerde kroonprojecties van de bomen en struiken op een zeker oppervlak en dat oppervlak, waren hoog in secundaire vegetatie van de eerste en tweede orde. In secundaire vegetatie van de eerste orde waren meestal één of twee soorten dominant. In secundaire vegetatie van de tweede orde was in verschillende gevallen *Hedyosmum mexicanum* dominant, terwijl in andere gevallen en in secundaire vegetatie van hogere ordes verschillende soorten gezamenlijk het aangezicht bepaalden. Gegevens met betrekking tot de hoogte en diameter van individuele bomen van verschillende, veel voorkomende soorten gaven aan dat hun ontwikkeling varieerde met de orde van hergroei. Dit illustreert dat bomen op een flexibele wijze reageren op een veranderende omgeving. Hergroei van de eerste en tweede orde bestond uit enkele, grote eco-eenheden; hergroei van hogere orde was altijd in een vroege fase gesplitst in meerdere, kleinere eco-eenheden. De gegevens gaven verder aan dat het aantal opeenvolgende eco-eenheden per tijdseenheid vermindert met toenemende orde van hergroei.

Veranderingen in de bodem in de tijd tussen kappen en de oogst van maïs werden bepaald door bemonstering van de bodem in mei (na kappen), juni (na branden) en oktober-november (oogst) van 1993 (Hoofdstuk 6). In het kalksteen-gebied werden geen significante verschillen gevonden tussen de waarden van bases, pH, stikstof en fosfor in mei en juni; tussen juni en oktober-november namen de pH en de som van de hoeveelheden bases licht toe. In het gebied van immergroen regen-bergwoud namen de hoeveelheden bases en de pH tussen mei en juni toe, terwijl de hoeveelheid bases licht daalde van juni tot oktober-november. Er werd geen verband gevonden tussen de grootte van de veranderingen en de gebruiksgeschiedenis van de velden, hetgeen mogelijk te wijten was aan het geringe aantal bemonsterde velden en/of aan de aanhoudende regens, die branden in 1993 bemoeilijkten.

Bemonstering van bodems in een serie velden van toenemende leeftijd, gemeten naar het aantal malen dat de vegetatie gekapt en gebrand was, gaf sterke aanwijzingen dat de pH en de totale hoeveelheid bases toenamen in de loop van meerdere decennia vanaf het moment van kappen van primaire of oud-secundaire vegetatie. Van de uitwisselbare bases werd de sterkste toename gevonden in de hoeveelheid uitwisselbaar calcium. Er werd geen significante correlatie gevonden tussen parameters van de gebruiksgeschiedenis van velden en de hoeveelheden koolstof, stikstof en fosfor in de bodem. Als mogelijke verklaring van de gevonden aanwijzingen wordt een combinatie van fysische en biologische processen genoemd: door branden vindt een initiële pH-verhoging plaats, die een verhoogde biologische activiteit in de bodem mogelijk maakt, waardoor deze verder verrijkt en nog meer gastvrij gemaakt wordt.

Het gedrag van maïs-gewassen in velden van oplopende leeftijd werd geëvalueerd door in 1994 verschillende parameters te bepalen met betrekking tot het maïsgewas (Hoofdstuk 7). Het gedrag van de maïs-gewassen varieerde sterk tussen velden, zowel in de variant van zwerflandbouw in het kalksteengebied, als in het gebied van immergroen regen-bergwoud. In het kalksteengebied verminderde de opbrengst per vierkante meter hellend oppervlak naarmate velden vaker gekapt en gebrand waren, terwijl geen verband gevonden werd tussen opbrengsten en de bepaalde bodem parameters. In het gebied van immergroen regen-bergwoud werd geen significant verband gevonden tussen opbrengsten en de ter karakterisering van de gebruiksgeschiedenis van velden gebruikte parameters. Echter, in dit geval waren de opbrengsten per vierkante meter hellend oppervlak gecorreleerd met verschillende bodem parameters: CEC-$BaCl_2$, uitwisselbaar calcium, totaal fosfor en de C/N-ratio. Bij waarden lager dan 3.9 was ook de pH-KCl positief gecorreleerd met de opbrengst. In bemestingsproeven werd na de gecombineerde toepassing van stikstof en fosfor een hogere opbrengst behaald in een veld waar zonder bemesting een lage opbrengst werd behaald, terwijl op velden waar zonder bemesting een hoge opbrengst werd behaald geen significant effect van bemesting werd gevonden.

De ontwikkeling van secundaire vegetatie, bodems en het gedrag van maïsgewassen in inheemse zwerflandbouw in twee dorpen in de Chinantla, Mexico, illustreert het interactieve en iteratieve karakter van deze vorm van landbouw. Dit karakter zou als vertrekpunt dienen te worden gekozen voor haar herontwerp op een zodanige manier dat de productie van een scala aan goederen gecombineerd wordt met de productie van een scala aan diensten in een complex mozaïek van eco-eenheden.

Resumen

El tema de esta publicación es el desarrollo de la vegetación secundaria, de suelos y del comportamiento del cultivo de maiz en variantes locales de la agricultura de roza, tumba y quema, practicados por campesinos en dos comunidades en la Chinantla, México. En el Capítulo 1 se presenta brevemente el contexto institucional, social y político de la investigación y se advierte al lector de la limitación de la misma a la interacción entre aspectos ecolológico-productivos y el patron de uso de la tierra practicado por los campesinos.

En el Capítulo 2 se presentan conceptos básicos que ayudarán en la ubicación del tema y en el análisis de la información generada. La agricultura indígena de roza, tumba y quema es definida como una forma general de uso de la tierra, en la cual existe una relación múltiple y dinámica entre el hombre y la naturaleza. Esta forma de agricultura se caracteriza por la re-creación contínua del conocimiento en el cual se basa, y por el establecimiento y uso de huamiles dinámicos según patrones definidos. Se observa una gran especificidad de la agricultura indígena de roza, tumba y quema en respuesta a factores ecológicos locales y socio-éconómicas.

Una breve reseña de la ecología de la sucesión secundaria, con énfasis en áreas montañosas tal como la Chinantla, demuestra que el desarrollo de las unidades ecológicas que conforman esta vegetación no es un proceso sencillo y unidireccional, sino que es un proceso que puede tomar uno entre varios posibles cauces, bajo la influencia tanto del entorno ecológico como de la historia del uso de los huamiles. Los suelos se desarrollan como una parte integral de las unidades ecológicas, como ha sido demostrado en el estudio de los suelos en eco-unidades de diferentes edades, como p.e. en áreas afectadas por hurracanes. La dinámica conjunta de vegetación y suelos conduce a una variación en las condiciones ecológicas en el mosaico de huamiles. Como consequencia el comportamiento de los cultivos puede variar al interior de este mosaico.

Existe una ámplia variación climática en la Chinantla debido a la orografía (Capítulo 3). Por ello se presentan distintos tipos de vegetación en la región. Asimismo se presentan distintos tipos de suelos, unos desarrollados a partir de rocas calizas, otros a partir de areniscas y esquistos. En el Capítulo 4 se describen los variantes de la agricultura de roza, tumba y quema y los patrones de uso de la tierra en cada uno de ellos que se detectaron en las comunidades chinantecas de Santiago Tlatepusco y Santa Cruz Tepetotutla. Se distinguieron tres variantes locales de agricultura de roza, tumba y quema. La variante de más ámplia distribución es la que se practica en el entorno de la selva alta perennifolia de montaña, a altitudes de alrededor de 1000 m sobre el nivel del mar. Además se practica un variante de la agricultura en el área de calizas y un variante en los encinares. En los tres variantes el principal cultivo es el maíz.

En el Capítulo 5 se presentan los resultados del estudio de la vegetación secundaria en relación con la historia de uso de los huamiles, prestando atención a (i) la composición específica; (ii) la estructura; (iii) la arquitectura, y (iv) los posibles cauces de desarrollo de la vegetación. Se muestreó la vegetación secundaria en 28 parcelas, que conjuntamente abarcaban una ámplia variación en la historia de uso: (i) la edad de la vegetación secundaria en las distintas parcelas variaba entre 5 y 50 años; (ii) el número de orden de la vegetación secundaria variaba de 1º a 4º, en donde la vegetación de 1º orden es la que se desarrolla después de tumbar vegetación primaria; la de 2º orden es la que se desarrolla después de cortar la del 1º orden, y así sucesivamente. En cada parcela se tomaron datos y muestras de los árboles y arbustos con un diámetro a la altura del

pecho mayor de 2 cm, en 4 transectos de 100 m^2 cada uno. Se determinaron los nombres botánicos y comunes de las especies colectadas.

En total se muestrearon 5691 arboles y arbustos pertenecientes a 229 especies, en una superficie horizontal total de 8282 m^2. Treinta-siete especies abarcaron el 90% del número total de individuos. El análisis de clasificación y ordenación demostró que la composición específica de la vegetación secundaria dependía de su edad, de la altitud sobre el nivel del mar, de la localización geográfica, de la litología y de su número de orden. El análisis de la información proporcionada por los campesinos, sobre la relación entre la composición específica y el número de orden de la vegetación secundaria, confirmó lo anteriormente mencionado.

Parámetros de la estructura de la vegetación secundaria, de su composición específica y del desarrollo de los arboles y de las unidades ecológicas, que se distinguen por su arquitectura en la vegetación en las parcelas, estaban relacionados con la historia de uso de los huamiles. El área basal, el número de individuos y la cobertura tenían valores elevados en vegetación secundaria de 1 º y 2 º orden; en vegetación secundaria con números de orden más elevados estos parámetros disminuyeron sensiblemente. En vegetación secundaria de 1 º orden había solamente 1 ó 2 especies dominantes. En vegetación secundaria de 2 º ó mayor orden, se observó frecuentemente polydominancia, donde un mayor número de especies compartían el dosel. Sin embargo, también se observó que la vegetación secundaria de 2 º orden podía estar dominada por solamente una especie: *Hedyosmum mexicanum*. El análisis de los datos de altura y diámetro de individuos de especies frecuentes indicaba una relación entre el desarrollo de los arboles de cierta especie y el número de orden de la vegetación secundaria, lo cual demuestra la flexibilidad que tienen las especies en responder a los cambios en su entorno. En vegetación secundaria de 1 º y 2 º orden se observaron unidades ecológicas de grandes superficies. En vegetación secundaria de mayor número de orden, se detectó la fragmentación de unidades ecológicas iniciales en varias unidades pequeñas. Los resultados de los muestreos indicaron además que el número de unidades ecológicas sucesivas que se desarrolla en un tiempo determinado, disminuye conforme incrementa el número de orden de la vegetación secundaria.

Cambios en los suelos en el curso de una temporada de cultivo fueron estudiados comparando parametros del suelo en muestras obtenidas después de la tumba (mayo), después de la quema (junio) y a la cosecha del maíz (octubre-noviembre) (Capítulo 6). En los suelos derivados de las rocas calizas no se detectaron diferencias significativas en las cantidades de bases, pH, nitrógeno y fósforo en muestras de mayo y junio. En el periodo entre la quema y la cosecha se observó un ligero aumento en la cantidad de bases y en el pH. En el área de selva alta perennifolia de montaña se observó un incremento significativo en la cantidad de bases intercambiables y el pH de mayo a junio. Entre junio y octubre-noviembre, la cantidad de bases intercambiables disminuyó ligeramente. La magnitud de los cambios no mostraba relación con la historia de uso de los huamiles, lo cual se debe posiblemente al reducido número de huamiles muestreados y/o a las lluvias contínuas en abril y mayo que dificultaron la quema en el año de muestreo (1993).

El muestreo de los suelos en una chronosequencia de huamiles indicaba un incremento en bases intercambiables y pH a lo largo de varias décadas a partir de la tumba de vegetación primaria o secundaria vieja. El incremento más fuerte se observó en la cantidad de calcio intercambiable. No se encontró una correlación significativa entre los parametros de la historia de uso de los huamiles y las cantidades de carbono, nitrógeno y fósforo en el suelo. Con base en los resultados se propone un mecanismo de cambio del suelo basado en una combinación de procesos físicos y biológicos: la adición de bases en la quema resulta en un aumento del pH, lo cual permite una mayor actividad biológica en el suelo. Esta mayor actividad biológica resulta en una mayor incorporación de bases al suelo, volviendo el suelo cada vez más hospitalario.

El comportamiento de cultivos de maíz fue estudiado en 1994 en una chronosequencia de huamiles por medio de la determinación de varios parámetros referentes al cultivo. Se observó una gran variación en el comportamiento de los cultivos entre huamiles, tanto en el área de calizas como en el área de selva alta perennifolia de montaña. En el área de calizas el rendimiento por metro cuadrado de superficie en pendiente disminuyó con el aumento en el número de sucesivas quemas. No se encontró una relación entre rendimiento y parámetros del suelo. Los rendimientos obtenidos en el área de selva alta perennifolia de montaña no mostraron correlación significativa con los parámetros empleados para caracterizar la historia de uso de los huamiles. Sin embargo, en este caso se observaron correlaciones significativas entre el rendimiento por metro cuadrado de superficie en pendiente y varios parámetros del suelo: $BaCl_2$, calcio intercambiable, fósforo total y la relación C/N. A valores menores de 3.9 también se observó una correlación positiva entre pH-KCl y rendimientos. En experimentos de fertilización se encontró una respuesta positiva significativa a la aplicación combinada de nitrógeno y fósforo en un cultivo de bajo rendimiento, mientras que no se obtuvo tal respuesta en cultivos de alto rendimiento.

El desarrollo de la vegetación secundaria, de los suelos y del compartamiento de los cultivos en la agricultura de roza, tumba y quema indígena en dos comunidades en la Chinantla, México, demuestra el carácter iterativo e interactivo de esta forma de agricultura. Este carácter debería de tomarse como punto de partida para su rediseño de una manera tal que se combine la producción de un conjunto de bienes con la producción de un conjunto de servicios en un mosaico complejo de unidades ecológicas.

1 Introduction

1.1 General

Approximately 1400 indigenous groups practice shifting cultivation in tropical rain forest environments (Bahuchet & de Maret 1994). In response to their generally marginal position in national societies, members of indigenous groups have pursued a range of initiatives to diversify and sustain production. Such initiatives usually start from local knowledge of environmental and socio-economic conditions. They may substantially benefit from external knowledge to reinforce locally available options or germs of options.

International development agencies and organizations concerned with the conservation of the rain forests have recognized the importance and value of indigenous resource management. In spite of this recognition, knowledge of indigenous resource management is still limited. In a workshop on traditional Resource Use in Neotropical Forests of the Man and Biosphere Program, it was therefore recommended to carry out more case-studies (Redford & Padoch 1992). An interdisciplinary approach "*that integrates social and biological/natural scientists with indigenous specialists*" is recommended in order to learn more about indigenous resource management (Posey & Dutfield 1997: p. 89).

The present study is intended to be a step towards such an interdisciplinary approach. It was designed to increase knowledge of the influence of landuse in the form of shifting cultivation on secondary vegetation, soils and crop performance and *visa versa*. It elaborates each of these themes on the basis of fieldwork in the Chinantla, Mexico, and places them in a wider context. The goal of the study was to support the redesign of landuse by local farmers' organizations, NGO's and institutions by developing a long-term perspective of the changes that occur within the mosaic of eco-units created through landuse for shifting cultivation and by elaborating on the notion of sustainability.

1.2 Institutional context

Fieldwork was conducted in the context of the "Programa de Aprovechamiento Integral de los Recursos Naturales" at the Laboratory of Ecology of Mexico's National Autonomous University (UNAM). In this program, professionals, students and local farmers' organizations worked together, to define options for sustainable agriculture in marginal areas of four important ecological zones of Mexico (Carabias & al. 1994). In the tropical humid zone, the program worked in the Chinantla, the area inhabited by the Chinantec in Mexico's southern state of Oaxaca. The Chinantla contains tropical lowlands through terrain with altitudes of 3000 m. Farmers usually combine shifting cultivation with coffee culture.

The program's regional team in the Chinantla consisted of anthropologists, economists, biologists, botanists, geologists and agronomists. Attention was paid to the following themes: organization of production, farmers' organization, diversification of production, water, ethnobotany and shifting cultivation (Anta & al. 1992). The investigation of shifting cultivation, which was designed and executed in close collaboration with local farmers' organizations, focused on the relation between the landuse pattern and secondary vegetation, soils and crop performance.

The actual writing of the thesis was done in the context of a *de facto* program on indigenous resource management, directed by Prof. R.A.A. Oldeman, Chair of Silviculture & Forest Ecology at the Department of Ecological Agriculture of Wageningen Agricultural University. In this program, it is attempted to contribute to the development of tailor-made resource management, adapted to local conditions, by combining local indigenous and scientific knowledge.

1.3 Social and political context

The Chinantla is one of the many marginal areas habited by indigenous groups in Mexico. Only in the 20^{th} century the Chinantla integrated in the national society, after strong investments of the central government in infrastructure, basically in the lowlands. In the first half of the century, general deforestation in the lowlands preceded the establishment of tobacco and banana plantations, later followed by extensive animal husbandry and sugar cane cultivation. In the mountain areas, farmers combine shifting cultivation for food production with the production of coffee under shade trees for cash revenues.

In the 'fifties the Comisión del Papaloapan was established with the objective to design a regional plan of development of the Papaloapan Watershed, which includes the Chinantla. The plans envisaged industrial agriculture as the most adequate means of providing the national market with food. Huge areas were deforested and dams were constructed for flood control and the generation of electricity. The dams have resulted in disintegration of Chinantec society, obliging 37% of the population to resettle in new areas.

One of the resettlement areas was Uxpanapa. Here Chinantec farmers were put to work in mechanized rice cultivation. The Uxpanapa resettlement project aroused public controversy between biologists and anthropologists and the technical staff of the Comisión del Papaloapan. The first proposed small, family-based enterprises, which would make a diversified use of the natural resources and where the people would practice agriculture according to their knowledge and culture. The Commission defended industrial agriculture, pointing at the national food production crisis and the need to concentrate population and efforts. Scattered settlement patterns and diverse small-scale enterprises would not contribute to national development in this view.

The debate, which reflects also the international discussions of the era, has continued. National laws on land tenure have been modified to allow the selling of communal and ejidal lands, with the intention to promote private investment in agriculture. Though some government programs support peasant agriculture, their impact has remained limited. Up to this day, indigenous farmers in Mexico live in a position of marginality and poverty.

The responses of indigenous farmers to this situation have been diverse. In some regions or villages, independent organizations have taken in their hands the marketing of products like coffee and have been searching for possibilities to diversify production, to produce end-products on the local level and to educate their members in taking responsibilities beyond the family level. In other regions and villages, people adapt to the regional power structure, negotiating temporary advantages in a system of clientelism. Government plans with respect to agricultural development have so far generally played a part in the latter line of action, though exceptions to this rule have occurred. In this context, local independent organizations have had to fight difficult battles in order to grow and consolidate, as they challenge the basis of the regional power structure with its extensions to the national level.

The local situation in the Chinantla is thus embedded in a larger context, which co-defines the local ecological context. Local farmers act in both contexts. They continuously rebuild their social structure along old and new patterns. In parallel and concomitantly, they rebuild their relations with the natural resources. In this sense, natural resources have a social life (Appuradai 1986), their state being intimately related with the organization of society.

Social and political life in Santa Cruz Tepetotutla, a village in the Chinantla, was determined by casiquism until the mid-seventies. The local casique dominated coffee production and commerce. Wages were low, if paid at all. "Tequio", traditionally a form of collective labor to the benefit of the village as a whole, was used as a mechanism to increase personal power and wealth. It was so frequent, that people fell short of time to grow their own food crops. Cohesion was maintained by force: villagers were not allowed to leave the community. Some of them, however, managed to escape to other villages.

At the death of the casique there was no successor. At this moment, a local cooperative was formed, with outside help from independent activists. After an initial period of massive affiliation, differences of opinion arose: one faction longed for the old ways and days; the other faction tried to implement change on the basis of mobilization and action. Differences were polarized through targeted interference from the regional power centers: a competing organization was formed, which was temporarily provided with abundant financial resources.

In spite of social pressure, the cooperative managed to consolidate itself as a minoritarian organization within the village. This was possible thanks to internal democracy of the organization, which was constructed from day to day by sharing responsibilities in the organization and by focussing on internal education in organizational skills. In the consolidation of the organization, external advice played an important role. The social cost of the process included gossip campaigns against cooperative members and denial of their right to speak in village assemblies.

With time it became clear that the majoritarian conservative faction could not offer economically attractive alternatives in the sphere of production. This became obvious, when the prices of coffee fell to a historical minimum in 1993 and 1994. Monetary returns from coffee production became so low, that farmers did not even bother to weed and harvest their plantations. As a consequence, the prospect of diversification of production became more attractive. In this sense the cooperative took the lead with several activities: bee keeping, small scale milk production, weaving and the production of wooden furniture for the regional market. This was later complemented with the planting in coffee plantations of *Chamaedorea tepejilote*, a palm with an edible and marketable inflorescence.

In the situation of internal polarization, an academic investigation started into the options for the management of the villages' natural resources. Because the investigators had been invited by the cooperative, the villagers supposed that they had made an explicit choice for one of the contending groups. This placed the investigators as well as the contending groups in a complicated situation. The investigators responded to this by informing the villagers at any moment of their research activities. Evidently, the local conflict could not be resolved on the short term. In order to escape from polarization, it seemed wise to try to contribute to a regrouping of factions on the medium term. Within the cooperative, discussions started to make its infrastructure accessible to other villagers than members only.

1.4 Scope

The present study centers upon the long-term changes in soils, vegetation and performance of maize on lands used for shifting cultivation in the Chinantla, Mexico. It is based on fieldwork in two Chinantec villages with communal land tenure, where a pattern of landuse is followed and where general rules concerning the use of community lands are defined in village assemblies. In the communities, shifting cultivation will probably remain an important form of landuse.

The landuse pattern developed by the Chinantec starts from and results in a mosaic of eco-units, *i.e.* small ecosystems (see Section 2.2.1), in their territories. The mosaic is the object of management and regulations by the community as a whole, whereas individual farmers' families act upon a fraction of the mosaic. In this study, the mosaic is seen as the most convenient level of aggregation, because it connects well to the level of local management of natural resources. To arrive at this level of aggregation, change is studied in a sample of fields selected on the basis of information of the landuse pattern. The present study aims at supporting local management by providing information on change of the ecosystems as inflicted by use according to the local pattern.

Such information is a necessary element, though certainly not the only one, that is required for redesigning landuse in such a way that a desired composition of the mosaic of eco-units is obtained and maintained. Such a desired composition should permit the cultivation and the use of a variety of products and constitute an alternative for economic dependence on a few products only. It should also contribute to maintain biological diversity.

As landuse for shifting cultivation is embedded in complex natural and socio-economic dynamics, it would be unrealistic to claim that this study, which concentrates on ecological aspects, would provide a complete and sufficient outline for future actions in the Chinantla, or other regions with similar conditions. Such actions can only be designed as a part of the broader process of "recontextualization" which indigenous groups continuously undertake themselves, i.e. the effort to strengthen their position in society. However, scientific knowledge can be of help for redesigning local alternatives in production, when favorable social conditions arise; its generation may also contribute to establish such conditions by offering options for uniting people around common ideas and goals.

2 Concepts

2.1 Indigenous shifting cultivation

Shifting cultivation is a form of fallow agriculture: in between periods of cropping, fields are fallowed. Its many variants have as a common element the shifting of fields and a generally practised sequence of activities that includes burning, sowing or planting, weeding and harvesting. Apart from these very general common elements, each variant of shifting cultivation has its own specific characteristics. Although a classification could be made of all specific local variants of shifting cultivation, such an exercise would necessarily be based on simplifications. The role of specific circumstances in shaping the local variant would not enter into the picture (Neugebauer 1986).

Detailed descriptions of local variants of shifting cultivation show the flexibility of the system and the continuous change that fields go through. A cycle of fixed duration of cropping and fallowing is rarely found. Also the type of cropping may vary in time. De Schlippe (1956) argued that in systems of shifting cultivation in Africa, the pattern of crops over time on a single field is better described as a sequence rather than a rotation; the regularity that the word rotation suggests is not found. Though Conklin (1957) describes an "average swidden cycle", it is also clear from his illustration that many "deviations" exist (Figure 2-1). In fact, "deviations" are the rule in long-term sequences of many uses, including such diverse activities as hunting and gathering, the careful building of diverse homegardens and the cultivation of annual crops (Anderson 1990; De Jong 1995). This is also the case in natural forest dynamics (Oldeman 1990).

Indigenous peoples all over the world continuously integrate new economic activities in their way of living, and make changes in the sequence of uses that fields go through. At present, changes go extraordinarily fast. In many situations the environment has changed so much in the last decades, that the multiple use of ecosystems is threatened. *As a consequence, the coming decades are the very last in which farmers' knowledge of rhythms and patterns in a complex environment can guide the redesign of landuse: alternatives are still ecologically possible and a sufficient base of knowledge is still present at the local level.*

In the following, the term "*indigenous shifting cultivation*" will be used to indicate a general form of landuse by indigenous groups, in which land is not cultivated annually, where agricultural practice is to an important degree guided by knowledge of local ecological conditions and where the legacy of former practices and ecosystems still permits the redesign of the multiple use of ecosytems.

The concept "indigenous groups" refers to population groups that have inhabited their land for a long time and whose culture is intimately interwoven with their environment. According to the International Group for Indigenous Affairs (IWGIA) there are worldwide between 4000 and 5000 indigenous peoples, comprising a total population of at least 250 million (Posey & al. 1997). According to Bahuchet & de Maret (1994) there are 1400 indigenous peoples who live in an intimate relation with tropical rain forests; they represent a total population of 12 million.

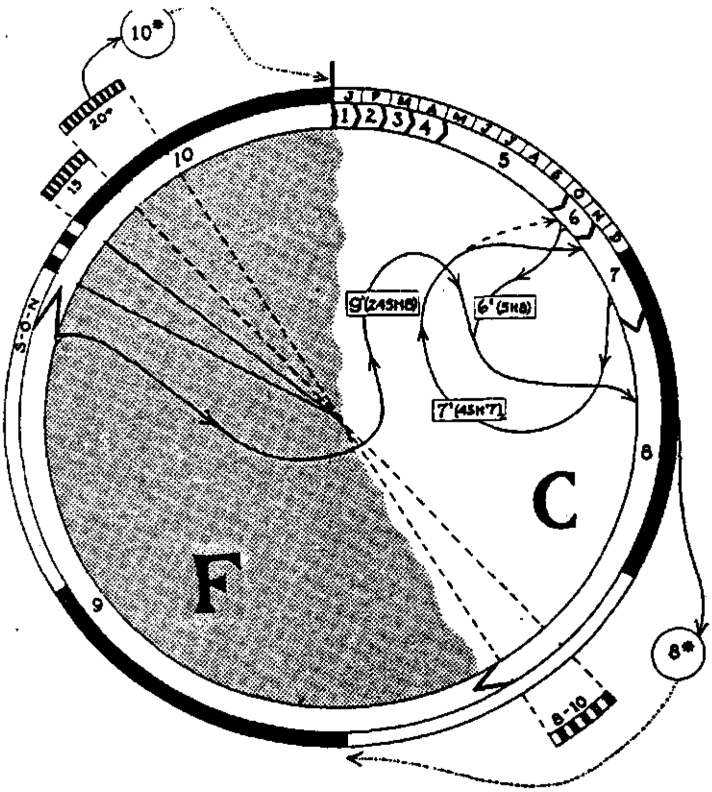

Figure 2-1. Hanunoo shifting cultivation: "cycles" or "sequences"? The inner circle represents stages of the "normal" swidden cycle. The outer circle represents time in years. The "normal" cycle lasts 6–10 years. Several lines cross the inner part of the circles. They indicate possible "deviations" from the "normal". The wedges indicate possible extensions of the "normal" cycle, which may vary from 8–20 years. Some fields, represented by small circles, are withdrawn from the "normal" cycle. Exceptions seem to be the rule. After: Conklin 1957.

Indigenous shifting cultivation is characterized by three main aspects:

- *continuous recontextualization of a many-sided relation*
  All over the world indigenous shifting cultivators are trying to make a living and to resolve population pressure through integration with the market economy, through participation in the sectors of services, industry, agriculture, and through migration and engaging in wage labor. Small industries based on specific products develop, sometimes using prime materials from secondary or primary vegetation. The basic strategy is to maintain as much as possible self-sufficiency in food production and to purchase other necessities on the market with cash. Production may shift to encompass new products for specific markets (e.g. organically grown coffee). In this process, fields under shifting cultivation may absorb new functions and/or be transformed in permanent fields containing perennial crops. The many-sided relations between man and natural resources are thus continuously being updated; in fact the role of

natural resources is subjected to change; new forms of "riding" (Richards 1985) on natural processes are created at the grassroots level, along lines which are difficult to discern by outsiders, not least because of the long-term character of the processes involved (Fairhead & Leach 1994; Padoch & al. 1998).

- *recreating indigenous knowledge*
  Indigenous knowledge is the principal tool for building a new coherence from the remnants of local forms of integral shifting cultivation. In this process multiple use of natural resources can be combined with the conservation of nature and local/regional economic and socio-cultural development. Local knowledge of natural resources and agricultural production is still an important element of many indigenous cultures (Toledo 1992). It includes such varying domains as phyto-practices applied to individual plants for better yields or easier cultivation (Hallé 1996), ecological knowledge of the relations between distinct vegetation types (Van der Wal 1996) and the interplay of cultural, legal and socio-economical factors (Brouwer 1998). A crucial element of indigenous knowledge concerns the use-history of natural resources. In this respect Appuradai's (1986) coined the term "*social life of resources*", indicating the biography of resources in the context of their use by man in society. Local farmers generally know the use-history of fields, who cultivated them and the results. This, along with their botanical knowledge, makes it possible for the farmers to evaluate the impact of landuse on the long term (over decades) and to choose between management options.

- *dynamic fields in a landuse pattern*
  In indigenous shifting cultivation farmers make new fields and return periodically to previously established fields *according to a pattern*, which among others, is based upon detailed inspection of the conditions of fields and their phase of development in the sequence of phases that they go through. Farmers consider fields as a whole. This is indicated by the use of local concepts, such as the Nahuatl term "huamil", which includes organisms as well as dead matter, vegetation as well as soil, in a similar way as in Richard's (1989) *holoplexion* (Figure 2-2) and Oldeman's *eco-unit*. The development of holoplexions and eco-units is not completely predetermined and fixed. As complex entities, their development is subject to many factors and events, from the distribution of bats to particular sequences of torrential rains. As a consequence, holoplexions and eco-units follow paths of development, rather than lines. The difference, as indicated by Oldeman and Vester (in press), is that a path has width, representing the variation that development may display during its course.

The present study concentrates on a part of the complex reality of indigenous shifting cultivation, *i.e.* the development of secondary vegetation, soils and crop performance as influenced by landuse according to locally developed patterns.

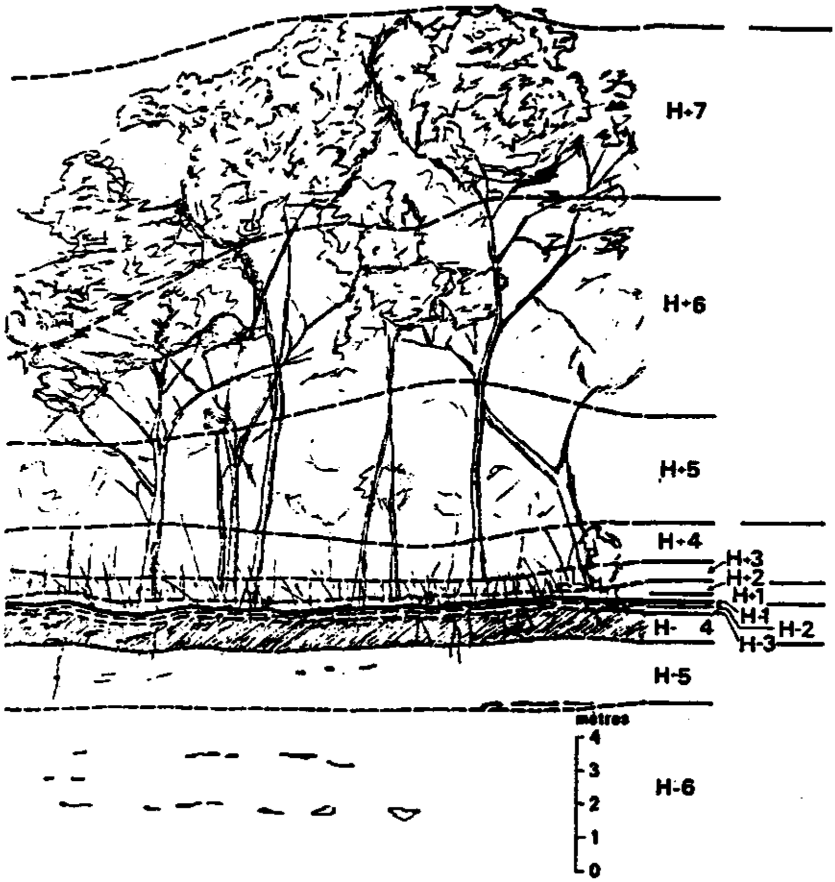

Figure 2-2. Holoplexion. Within the ecosystem, Richard (1989) distinguishes volumes, according to the organization of the composing elements: rocks, structural elements of the soil, dead organic matter, trees. The integration of the volumes or "hoplexols" makes the holoplexion. Drawing by J.C. Filleron, published in Richard (1989). A holoplexion that started its development on one moment on the same surface is a eco-unit.

2.2 Secondary vegetation

2.2.1 Definition

Secondary vegetation is the vegetation that develops, in the process of secondary succession, after natural or anthropogenic impacts upon the original vegetation. Secondary vegetation has been studied from the points of view of population or community biology (Budowski 1963; Bazzaz 1996; Gómez Pompa & Vázquez-Yanez 1981) and the architecture of ecosystems (Oldeman 1974, 1983, 1990; Vester 1997; Rossignol & al. 1998). In the latter, units are spatially bounded, whereas this is not the case in community theory. In community theory, numerical techniques are used for comparing communities and for relating the composition of vegetation to environmental or management variables. In architectural theory, analysis is based on scale-drawings of transects and/or maps.

2.2.2 Development pattern of secondary vegetation

Oldeman (1974, 1983, 1990) has developed a theory of the genesis of forest architecture, or sylvigenesis. The central concept in this theory is the forest eco-unit, defined as: *"every surface on which at one moment in time a vegetation development has begun, of which the architecture, eco-physiological functioning and species composition are ordained by the same set of trees until the end"* (Oldeman 1990: p. 165) Forest eco-units are the entities that together build the forest as a mosaic. They are generated by events, called "zero-events". Oldeman (1990) deliberately does not use the term disturbance, as nothing is "disturbed" if the old is replaced by the new.

The self-supporting frame of an eco-unit consists of three sets of trees: the set of *potential trees*, which includes trees that still have the potential to expand their crowns; the set of *trees of the present*, including trees that have reached their maximum crown expansion; and the set of *trees of the past*, which includes trees with decaying crowns. The sets are indicative of the phases that eco-units go through. Four phases of eco-unit development are distinguished, not to be confused with the stages of eco-unit succession in a mosaic:

- *innovation phase*: phase of eco-unit development in which the seedbank and meristems on remains of former eco-units are mobilized. This phase ends when the canopy is closed by shrubs or small trees (see glossary).
- *aggradation phase*: phase of eco-unit development from closure of the canopy by trees of the present and potential trees to the moment that the canopy consists of only trees of the present (see glossary).
- *biostatic phase*: phase of eco-unit development during which the set of trees of the present determines the organization of the eco-unit, suppressing potential trees. The biosatic phase ends when crowns start to decay (see glossary).
- *degradation phase*: phase of eco-unit development during which crowns of trees decay (see glossary).

After degradation, the eco-unit is succeeded by one or more other eco-units, so we can also speak of succession of eco-units. Succession in this context "*was clearly stated to be a sequence of eco-units replacing eco-units, and not species replacing species within a developing eco-unit*". And "*Eco-unit development is treated as a subprocess in 'succession'* " (Oldeman 1990, p. and p. 166).

The eco-unit concept not only includes patches of modest sizes, but extends to all deforested surfaces where forest started to develop at one moment in time, e.g. clear-cuts, and cleared and abandoned lands (Oldeman & Van Dijk 1991). Biotic "remanence", i.e. the living remains of the previous situation, and "contagion", i.e. the relations between eco-units, are essential elements in the building up and succession of eco-units (Oldeman 1990).

In the succession of eco-units, the old continental forester's concept of temperament of trees, defined "*as the set of growth-and-development reactions shown by a tree towards its environment during its life-cycle*" (Oldeman & Van Dijk 1991), plays an important role. The eco-unit that first develops on an open site is partly built by species with a very early hard-gambler temperament (Vester, 1997); these species grow fast and die when overtopped. They frequently do not reach their maximum crown expansion. After their death, their place in the eco-unit is taken over by trees with a more patient temperament. With the decay of trees with full crown expansion, a new eco-unit is born.

Together, eco-units at different phases of development in an area with one similar lithology and one similar climate build the forest as a silvatic mosaic (*cf.* Figure 2-3). In mountain areas, the eco-unit composition of the natural (not anthropogenic) silvatic mosaic is fine-grained. There are many small eco-units, due to the frequent toppling over of trees. This eco-unit composition can be modified by events that act upon the mosaic, called "shifting events" (Oldeman 1990). Examples of such shifting events in mountain conditions are landslides and hurricanes, and also landuse for shifting cultivation, which adds comparatively large eco-units to the mosaic.

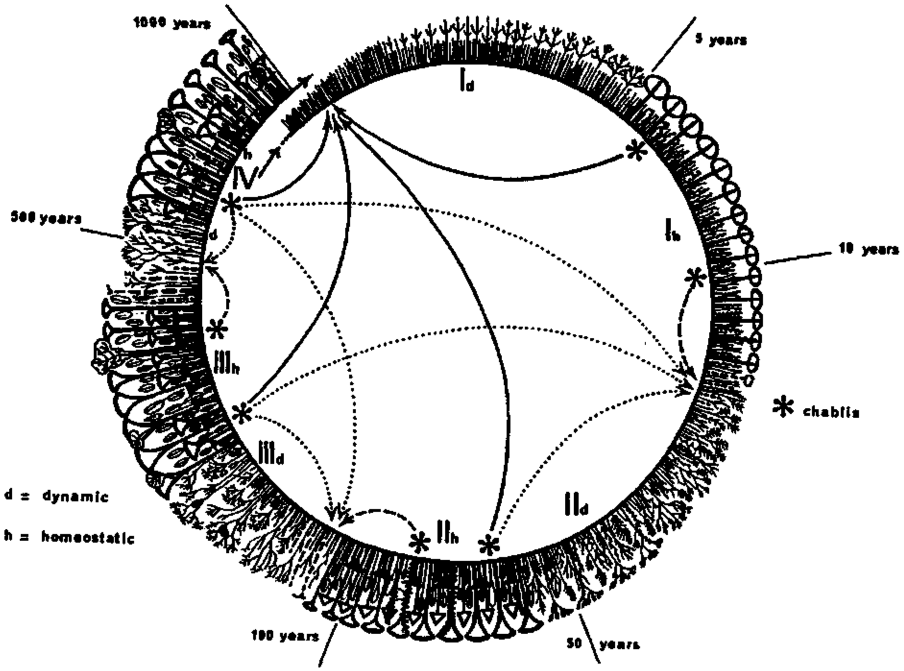

Figure 2-3. Sylvigenetic cycles. In sylvigenesis – the process of generating a forest – successive phases may be distinguished, each with a dynamic (d) and a biostatic (h) phase. Transitions between phases of forest development may occur according to the long, very exceptional, period of classical succession (the cycle) or by shortcuts (arrows) initiated by some impact (star). The length of the period required for development from the pioneer phase to mature forest by classical succession is indicated logarithmically. After: Hallé & al. 1978.

2.2.3 Development of secondary vegetation and environment

In secondary succession in temperate regions, the sequence of populations of different species is not so rich as is frequently observed in humid tropical lowlands. This is due to the annual periods of environmental stress between growing seasons in temperate regions (Gómez Pompa & Vázquez-Yanes 1981).

Obviously, in tropical regions environmental stress may also influence secondary succession. This aspect has not received due attention in most studies of secondary vegetation, which concern the humid tropical lowlands, even though these account for less than a third of the total land surface (Budowski 1965; Gómez Pompa & Del Amo 1985; Jones 1955; Jordan 1989; Purata 1986; Sarukhán 1965; Saldarriaga & al. 1988; Souza 1965; Uhl 1987; Vester 1997). Studies of secondary succession in humid tropical highlands and mountain areas are relatively scarce, but have been conducted by Ewel (1980), Sugden & al. (1985), Van Valkenburg & Ketner (1994), Grubb & al. (1963), Tanner (1980), Byer & Weaver (1977), Kellman (1969) and Kappelle (1995). Ewel (1980) stressed that, just as environmental heterogeneity in the tropics contributes to a broad array of primary communities, there is also a tremendous variety of secondary communities. On a general level this can be observed from data on biomass accumulation in different life zones (Table 2-1). Also within life zones a wide variation in standing biomass exists between patches of similar age, which, among other factors, is related to the use-history of fields (Brown & Lugo 1990).

Table 2-1. Biomass and other structural parameters in 13-month-old secondary forest in 5 life zones sensu Holdridge (1967). After Ewel (1980). LAI = leaf area index, i.e. the total surface area of the leaves of the plants, divided by the surface of the area on which they stand. Species probably refer to higher plant species, though this is not mentioned explicitly.

Life zone	Biomass ($g \cdot m^{-2}$)	Average height of 3 tallest plants (m)	No species on 18 m^2	LAI
Tropical wet forest	1159	4.7	36	4.5
Tropical dry forest	951	2.4	30	2.7
Subtropical wet forest	634	2.0	31	4.5
Subtropical dry forest	459	1.6	32	2.4
Tropical montane rain forest	135	0.7	23	1.2

Several studies in mountain regions (Byer & Weaver 1977; Kappelle 1995; Sugden & al. 1985) show that in areas with strong environmental stress there is no differentiation between primary and secondary species: all species are present from the zero-event (see glossary) onwards. In general, few successional stages are expected in stressful environments as compared to well-drained humid tropical lowland (*cf.* Oldeman 1990, his figure 6.1). In especially stressful situations, succession is limited to the development of one eco-unit dominated by one species. Such a case was observed in *Quercus* forests in the Chinantla, Mexico (Van der Wal 1996).

Kappelle (1995) found large similarities in species composition between primary upper (2800 m altitude) and lower (2300 m altitude) montane forests and their secondary communities in Talamanca, Costa Rica. Secondary succession appeared to be a gradual, progressive process leading to a structurally more complex and mature forest phase. No differences in species diversity were found between phases of succession, as species from the cold paramos migrated downslope and invaded the early successional stages, as predicted by Budowski's rule (see glossary).

When site degradation occurs in warm, low-altitude sites, second growth typical of colder or drier sites invades the warmer system. In general, site degradation leads to the expansion of species typical of secondary vegetation in stressful environments into areas of less stressful environments. Budowski's rule indeed also applies to anthropogenic secondary vegetation. This rule reflects that species from harsh environments occupy pioneer niches in more favorable environments subjected to stress.

The foregoing means that the natural geographical separation of harsh and favorable environments, and of vegetation types, is replaced by a degree of spatial integration when excessive stress is exerted on the original environment.

2.2.4 Secondary vegetation and vegetation in chablis

Secondary succession induced by man is related to the regeneration of vegetation in chablis in primary vegetation, as indicated by Richards (1996): "*the secondary successions reproduce on a larger scale the changes which occur in normal regeneration of a primary forest, in which gaps formed by the death of larger trees are temporarily colonized by the same fast growing, easily dispersed species that dominate secondary forests*". Hallé & al. (1978) also relate succession in man-made clearings to the natural regeneration in chablis in the forest.

The area of recent chablis, up to several decades old, in tropical rain forest may be considerable. Hallé & al. (1978) calculated that as much as 50% of the sloping forest area at approximately 400 m altitude on Mt. Galbao, French Guyana, was covered by chablis. In general, natural tree fall is favored by asymmetric crowns, especially on soaked soils. As crowns on slopes tend to be asymmetric, in response to shading by higher standing trees, vegetation dynamics in this situation are intense (e.g. Figure 2-4). Obviously the frequency of formation of chablis and their area varies among sites and regions. In mountain areas it is expected to be fine-grained: many small chablis are expected instead of few large ones.

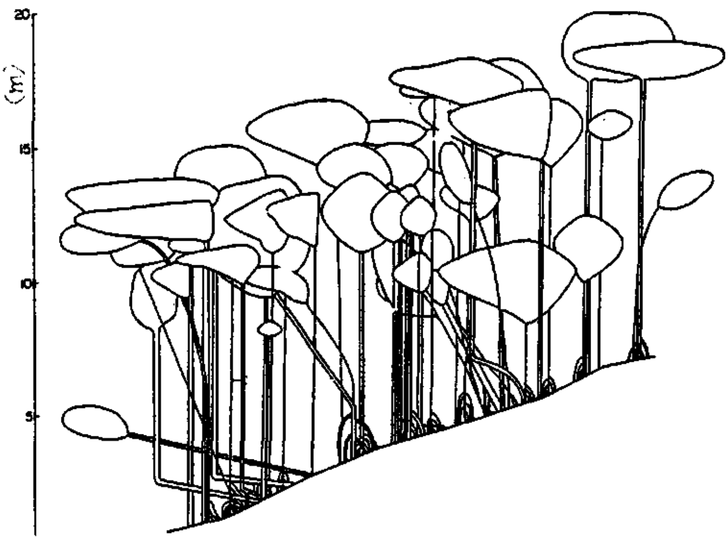

Figure 2-4. Asymmetric crowns on mountain slopes. Reaching for light, asymmetric crowns topple over. Frequent tree fall results in a fine-grained pattern of eco-units. After: Bruynzeel 1993.

Though *similar*, the secondary vegetation in man-made clearings is not *identical* to that in chablis. Herwitz (1981, cited by Richards 1996) compared the tree flora in clearings after abandonment and in chablis in Costa Rica. Species of mature forest were capable of germinating and establishing themselves and filled the chablis to a large extent, whereas only few trees of the genera *Trema* and *Cecropia* played a role. According to Alexandre (1977), the differences between succession in chablis and on clearings are a matter of degree. Vester (1997) showed that the light climate in chablis is more like the light climate in advanced successional stages than in early successional stages. Succession on the edge of fields bordering primary forest is therefore more like forest regeneration in chablis than succession in the center of fields.

2.2.5 Shifting cultivation and secondary vegetation

Different forms and intensities of landuse result in different courses of secondary succession (Figure 2-5). Similarly, different landuse patterns by shifting cultivators also lead to numerous different pathways of secondary succession. This contributes to variation in secondary mosaics, depending on local practice.

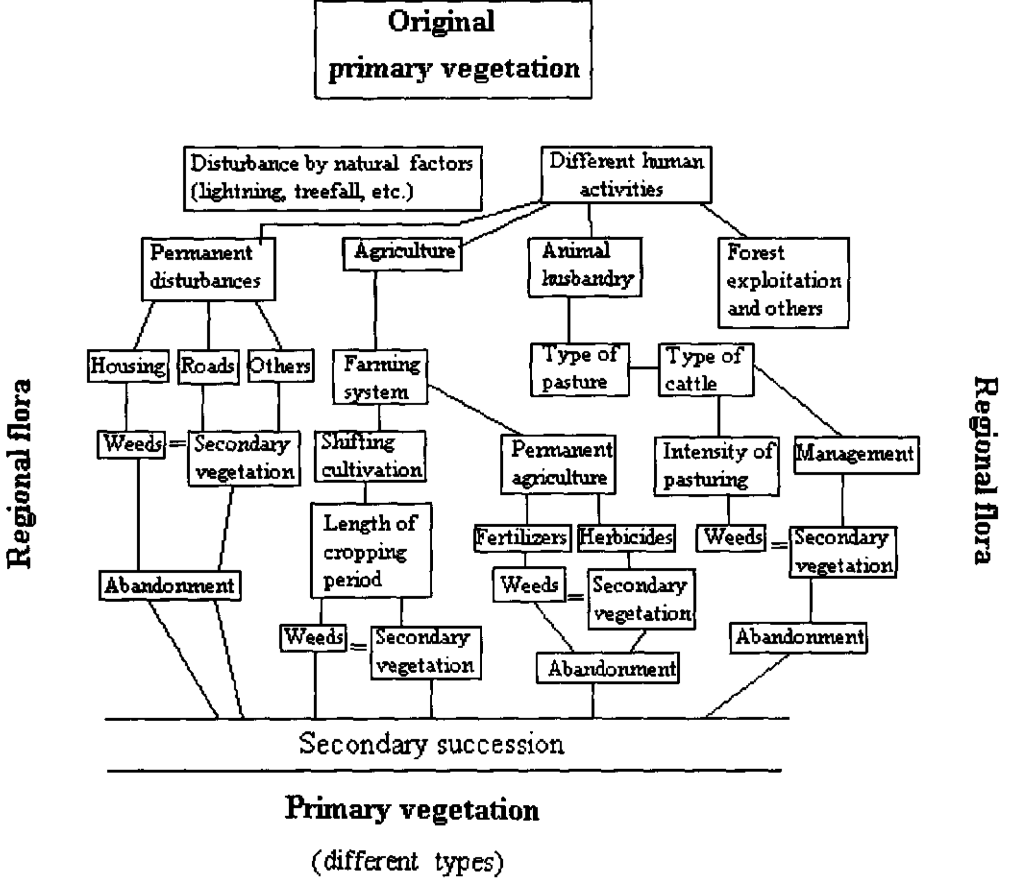

Figure 2-5. Landuse and secondary succession. Paths of secondary succession are influenced by the character and intensity of human activities. After: Gómez Pompa 1971.

Variation of secondary succession may be related to the impact of landuse on the seedbank. The availability of seeds, which varies with the distance of swiddens to primary vegetation, was found to influence the course of secondary succession in Los Tuxtlas, Mexico (Purata 1986). In South-Eastern Mindanao, the species composition in secondary stands on swiddens was related to the intensity of weeding, the number of burns and stand age (Kellman 1970).

2.3 Soils

2.3.1 Definition

The upper soil layer is the interface between living organisms, minerals, remains of dead organisms, air and water. It exists as a part of an ecosystem and houses complex networks of elements of the mentioned compartments.

2.3.2 Development of soils

Soils are not static entities, but develop in the course of time (Jenny 1941; Duchaufour 1984). Regretfully, this development has seldom been studied in relation to the development of eco-units. An exception in this respect is the work of Bernier (1995), who showed that the development of the humus profile – that part of the soil of which the structure is determined principally by biological activity – parallelled eco-unit development in spruce (*Picea abies*) forest in the French Alps. Under the herbaceous cover of eco-units in the innovation phase, a mull type of humus was built by burrowing earthworms (*Lumbricus* sp.). During intense growth of trees in eco-units in the aggradation phase, the worms disappeared and organic materials accumulated, forming a moder type of humus on top of the A1-horizon. In eco-units in the biostatic and degradation phase, worm activity increased again to arrive at a maximum during the innovation phase.

The relation between eco-unit development and soil development offers options for the study of changes in soils under shifting cultivation. For example, the changes that occur in soils in chablis are likely to resemble in some respects the changes that occur in swiddens, especially in situations where burning is incomplete due to climatic limitations.

Soil characteristics in chablis and in biostatic eco-units were compared in La Selva, Costa Rica, on rich volcanic soils. No large differences were found in soil nitrogen and phosphorus availability (Vitousek & Denslow 1986). In Amazonia, soil carbon content, bases and pH were higher in chablis than in biostatic eco-units (Akker & Groeneveld 1984). In tracts of forest thrown over by hurricanes in Puerto Rico, soil characteristics changed during more than a century after hurricane impact (Scatena & Lugo 1995). Soil carbon and nitrogen contents increased with increasing age of the regrowths, whereas pH and exchangeable calcium and magnesium decreased (Table 2-2). It is not impossible that the carbon content of the mineral soil increased during the first decades after treefall and that the total quantity of carbon in the mineral soil and on the forest floor continued to increase as carbon accumulated on the forest floor in the course of the development of the forest after the zero-event. However, this is not directly substantiated by the data set.

In forest ecosystems in the eastern Sierra Nevada Mountains, USA, soil carbon content after harvest of trees increased if slash was masticated and spread over the field. If not, carbon increased on some and decreased on other sites. If nitrogen-fixing trees were present in the regrowths, both carbon and nitrogen contents of soils increased. It is suggested that this increase is due to the formation of stable compounds containing nitrogen (Johnson & Henderson 1995). If similar processes occur on swiddens, increases in carbon are expected after partial burns and/or where nitrogen-fixing trees take part in secondary regrowths.

Table 2-2. Parameters in samples of the upper 60 cm of the soil-profile under regrowths belonging to 3 age-categories in Luquillo Mountains, Puerto Rico. SOM = soil organic matter in $Mg{\cdot}ha^{-1}$, including organic materials on the forest floor; N = nitrogen in $Mg{\cdot}ha^{-1}$; P = phosphorus in $kg{\cdot}ha^{-1}$; K, Ca, Mg, Na, Fe and Mn in $cmol{\cdot}kg^{-1}$; AC = exchangeable acidity in $cmol{\cdot}kg^{-1}$; BAS/SOM = (K+Mg+Ca+Na)/SOM, in $cmol{\cdot}kg^{-1}$. R^2 = square of the correlation coefficient, indicating the fraction of the variation in a parameter that is explained by age. *P* indicates the significance level.

Category	SOM	N	P	K	Ca	Mg	Na	Fe	Mn	pH	AC	BAS/ SOM
>120 yr (n=22)	203	9.0	40.7	4.4	0.53	0.46	0.29	4.91	0.29	4.8	4.1	53
60-120 yr (n=33)	184	8.4	46.7	4.1	1.36	1.55	0.27	3.28	0.53	5.0	3.8	204
<60 yr (n=28)	135	6.8	44.9	4.2	2.25	1.56	0.31	2.30	0.78	5.1	3.2	261
R^2	0.15	0.11	0.01	0.001	0.23	0.16	0.005	0.14	0.17	0.13	0.06	0.23
P	0.009	0.036	0.005	0.36	0.005	0.003	0.427	0.02	0.008	0.018	0.61	0.0009

2.3.3 Shifting cultivation and soils

In shifting cultivation, the development of eco-units starts with the cutting of primary or old secondary vegetation, after which trunks, branches and leaves are spread rather unevenly on the soil (Figure 2-6). From then on, a variety of organisms starts to transform the organic materials and to integrate them into the mineral soil. After some weeks or months, a burn transforms part of the organic materials in ashes, charcoal and gases (CO_2, NO_x). Fine materials – e.g. leaf litter – are affected more than coarse materials, such as trunks (Figure 2-7). Roots remain largely untouched by fires.

The impact of burns depends on preceding climatic conditions: they are most complete after long dry spells and far from complete in their absence. According to Seiler & Crutzen (1980), only 25% of the slashed above-ground vegetation is burnt in wet and moist tropical forests; Silva (1978) estimated that 20% of the above-ground biomass is converted to ashes; according to Ewel & al. (1981) 20% of dead biomass is converted to charred wood and 10% to ashes.

During cultivation and development of first-order and higher-order regrowths, the biological transformation and translocation of the remains of primary or old secondary vegetation continues (Figure 2-8). Whereas leaves are transformed completely in less than a year, trunks and stumps of trees with a large diameter may persist for decades. When every year 11.5% is decomposed, as reported by Odum (1970), after 10 years still 33% of the original biomass remains. Lang & Knight (1979) calculated a decay rate of $46\%{\cdot}yr^{-1}$ for boles of tropical trees in Panama. Buschbacher (1984), cited by Hall & al. (1985) estimated decay rates from 10.9 to $14.6\%{\cdot}yr^{-1}$. In the Chinantla, rests of trunks and stumps of some trees cut approximately 50 years before were observed. Also the biological transformation of the root mat may take more than a decade (personal communication Pedro Osorio, village authority of communal lands in Santa Cruz, 1994).

Figure 2-6. Eco-unit at the start of the innovation phase, after cutting primary vegetation . A thick layer of fresh organic materials covers the soil.

Figure 2-7. Eco-unit at the start of the innovation phase, after burning primary vegetation. Note that the fire did not consume many large trunks.

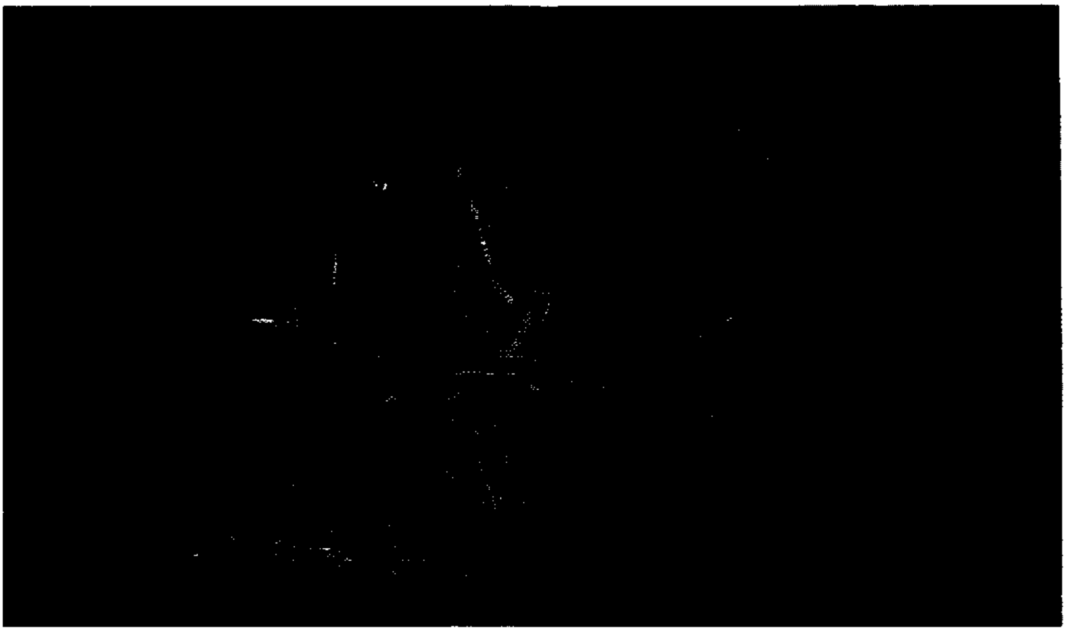

Figure 2-8. Overlapping transformation of rests of primary and secondary vegetation. The charred trunk at the right is a remnant of old secondary vegetation; the slender trunks at the left are remnants of the recently cut young secondary regrowth.

Burns of fine, well distributed materials are more complete than those of coarse, irregularly distributed materials (*cf.* Figure 2-9 and 2-7). In Côte d'Ivoire, only 15% of above-ground biomass was burnt on a site with a 20-year-old secondary regrowth and 45% on a site with a 4-year-old regrowth (Van Reuler 1996). With increasing order of regrowth, *i.e.* the number of times that vegetation on a field has been cut (see glossary), biomass and the proportion made up by trees diminish (Buschbacher & al. 1987), whereas the relative importance of herbs increases. Due to the fine texture of the organic materials burns are complete, whereas the quantity of organic materials that is integrated to the soil by biological activity diminishes.

Increases of pH, exchangeable bases and available phosphorus have been reported as short-term effects of landuse for shifting cultivation on soil characteristics (Van Reuler 1994; Nye & Greenland 1960; Zinke 1970; Stromgaard 1984; Kyuma & al. 1985; Tulaphitak 1985). These changes are found to revert under continuous cropping, though at varying degrees and rates. In Pará, Brasil, the calcium content of soils after high-intensity landuse during a decade was still higher than under primary forest (Buschbacher & al. 1987). After 8 years of continuous cropping in Aiyinasi, Ghana, pH was still higher than under primary forest in spite of a loss of 1100 kg calcium from the 20 cm topsoil (Nye & Greenland 1960). In Benin, soil calcium content after 11 years of cropping, following clearing and burning of 50-year-old secondary forest, decreased in the top 15 cms of the soil profile, but increased by 540 kg in the top 45 cms (Kowal and Tinker, reported by Nye & Greenland 1960). Reported changes in soil carbon also vary between sites: decreases in 9 and increases in 2 out of eleven cases reported by Nye & Greenland (1960, p. 100-101) after cutting and burning primary or old secondary forest.

Figure 2-9. Eco-unit at the start of the innovation phase after slashing secondary vegetation. Note the fine and homogeneous distribution of the fuel.

Few reports on long-term changes in soils under shifting cultivation exist. Lawson (1984) compared the long-term effect of different fire regimes – not shifting cultivation – on soil carbon content in savanna conditions at Olokemeji Forest Reserve, Nigeria. Carbon content in plots burnt early in the dry season was higher than in plots protected against fire. This was attributed to enhanced production of biomass. Similar information from humid or perhumid environments is not available.

2.4 Crop performance

2.4.1 Definition

Cropped fields are *eco-units of which the organization is determined by cultivated plants.* They include several compartments besides that of the cultivated plants: fungi and all kinds of micro-

organisms, insects, earthworms, non-cultivated plants, snakes, mammals and birds. During cropping, the development of non-cultivated plants is contained by cultivation practices such as weeding. Upon cessation, non-cultivated plants take over the organization of the eco-unit.
Crop performance is *the character of the growth and development in the course of the biological cycle of a population of cultivated plants on a field.* Crop performance in indigenous shifting cultivation is a *complex* performance, in which a series of interacting events, natural processes and human actions play a role. Shifting cultivators "ride" on natural processes (Richards 1985), such as secondary succession and biological transformation of organic materials. The courses of the processes taken influence the possibilities for successful cropping. Whether these possibilities are realized or not depends to a certain degree on the human activities undertaken during cropping and their timing, much like the steering of a boat in a wild water river. In this respect crop performance in indigenous shifting cultivation is different from that in industrial agriculture, which depends to a large extent on external inputs such as fertilizers and biocides and man-made physical infrastructure.

Complexity of performance is interwoven with the goal of indigenous shifting cultivation: farmers administrate labour to adapt the available natural and biological infrastructure in such a way that a favourable crop performance is likely to occur, spread in time over a series of fields. By their landuse pattern, farmers try to make optimum use of their environment on the long run. Considerable knowledge and wisdom are required to determine the character and timing of activities to steer the performance of crops and the development of vegetation and soils in rain forest environments (see f.e. De Schlippé 1956; Neugebauer 1986; Nyerges 1997; Padoch & al. 1998; Posey & Dutfield 1997; Richards 1985; Toledo 1992).

2.4.2 Course of crop performance in fields

Nye and Greenland (1960), in their general account of processes in soils under shifting cultivation, observed that changes in soils under shifting cultivation are not necessarily the same everywhere and that (p. 9) "*in addition to analyzing the effects of shifting cultivation on the soil we have also to consider how far the nature and response of the soil accounts for the pattern of farming in the different regions*". Similarly, we should consider *how far the nature and response of the vegetation accounts for the pattern of farming in the different regions* and *how far changes on the long term in the performance of crops account for the pattern of farming in the different regions.* The wide variation in patterns of landuse, observed when studying local practice of shifting cultivation in different regions, indicates that indeed in these respects – response of soil, vegetation and crop performance – wide variation and feedback among the diverse factors occur.

Like soils and secondary vegetation, both part of eco-units, crop performance on a certain field may be expected to change along a certain path in the course of time. Indications of this are found in literature, where yields obtained in shifting cultivation are stated to decrease in the course of time due to weed and/or fertility problems (Nye & Greenland 1960; Ruddle 1974; Watters 1971). In the Chinantla, Mexico, farmers consider that indeed the performance of maize in fields changes on the long run. Maize grown immediately after cutting the primary forest mostly gives a low yield. The second crop, obtained after cutting and burning the first-order secondary regrowth, usually yields better. Best yields are generally obtained in third and fourth crops. Thereafter good yields can be obtained, depending on the course of development of the "huamil" taken (personal communication Pedro Osorio; Ibarra Th. 1995).

2.5 Synthesis

Many different landuse patterns exist in the humid tropics, each responding to specific local natural and social conditions. They lead to specific mosaics of eco-units, with a certain spatial and temporal distribution of eco-units, which are all characterized by a certain development of secondary vegetation, soil and crop performance. Farmers try to define *when* and *where what* can be done best and to spread efforts and harvests according to their posibilities and needs.

The change of fields in shifting cultivation is not always motivated by yield decline, either by soil fertility or weed problems. Other motives play a role, such as changes of aptitude of fields on the long term and prospections of a family's needs and posibilities. For example, farmers may establish a coffee plantation on fields where good yields of foodcrops can still be obtained without much effort, because they want to take advantage of a particular stage of development of the ecosystem; or adapt landuse to the availability of labour within the family.

The foregoing originates that landuse patterns practiced under indigenous shifting cultivation are usually sequential and iterative, i.e. the conditions of ecosystems and families, the decision making units, change in the course of landuse; parallelly the use of particular fields is modified taking into consideration these changed conditions.

Indigenous knowledge, concerning the paths of development of ecosystems which are possible under specific conditions, still exists and provides a valuable toolbox for redesigning landuse and management adapted to present natural, social and economic conditions. It can be complemented with existing scientific knowledge of long-term changes in soils, vegetation and crop performance in shifting cultivation. Both kinds of knowledge can be of help for the identification of interesting paths of development of ecosystems and to design the management that favours such paths.

3 The Chinantla: ecological context

3.1 Geography

The Chinantla is the geographical area inhabited by the Chinantec, located in the Oaxacan part of the Papaloapan watershed in southeastern Mexico (Figure 3-1 and 3-2). About 80% of its total area of 3000 km^2 is located on the windward side of the southward prolongation of the Sierra Madre Oriental , facing the Gulf of Mexico. The terrain is extremely rugged, rising from 50 m to 3000 m altitude over a horizontal distance of less than 50 km in a southwesterly direction.

In socio-economical and political terms the Chinantla *was* and *is* a marginal area (Bevan 1938; Carabias & al. 1994). The density of roads is very low; footpaths and mule-trails interconnect villages. The road system was recently extended and the larger villages are now connected to the region's political and economical centres. State education and health services are of limited extent and quality (Stebbins 1986). Though communication is limited, politically and economically powerful regional groups strongly influence the exercise of power in the villages. The total population is calculated to be roughly 110 000, based on estimates of 43 700 in 1959 (Wolf 1959) and 54 000 in 1980 (Ewell & Poleman 1980) and assuming an 3% annual increase.

3.2 Geology

Three different geological domains can be distinguished: Coastal Plains, Sierra Madre Oriental and Sierra Madre del Sur. The Sierra's form the Mountain System of North Oaxaca, dominated by the Sierra Juarez (Salas 1977; Estrada 1995). The small fraction of the Chinantla in the Coastal Plains was covered during the Pliocene and Pleistocene with alluvial deposits from the Sierra Juarez. These materials contain rounded stones of quartz, schists and gneiss with a high content of micas. In the Holocene these materials have generally been covered by new alluvial deposits (Cuanalo & Aguilera 1970).

Southwest of the Coastal Plains, hills of claystone and mountain ranges of limestone, both of mesozoic origin, form the prolongation of the Sierra Madre Oriental, south of its interruption by the Transversal Volcanic Range and ending in the Istmo de Tehuantepec (Figure 3-1). These sediments overlay the Todos Santos Formation, which consists of conglomerates of quartz, sandstone and siltstone (Estrada & Urbán 1995a). This formation of Triassic and Jurassic origin (Salas 1977) dominates the landscape between the limestone ranges and the higher parts of the Sierra Juarez, at altitudes from 100 to 1000 m. At higher elevations, metamorphic rocks of Paleozoic origin, mostly schists, dominate the landscape. These rocks contain principally micas, but also biotite, muscovite, quarzite, chlorite and sericite. At some places, intrusive rocks of neutral composition occur at the surface (Estrada & Urbán 1995a).

The area has been subjected to intense tectonic movement, resulting in subsequent increases and decreases in areas that emerged from the sea (Figure 3-1) during the Jurassic and Cretaceous. The upheaval of the Sierra Madre Oriental during the Cenozoic (Eocene) resulted in today's extremely rugged area, with the fairly regular sequence of lithologies on the regional level described above (Estrada & Urbán 1994). Locally, mass movements in the form of landslides and block-fall have modified the ideal sequence.

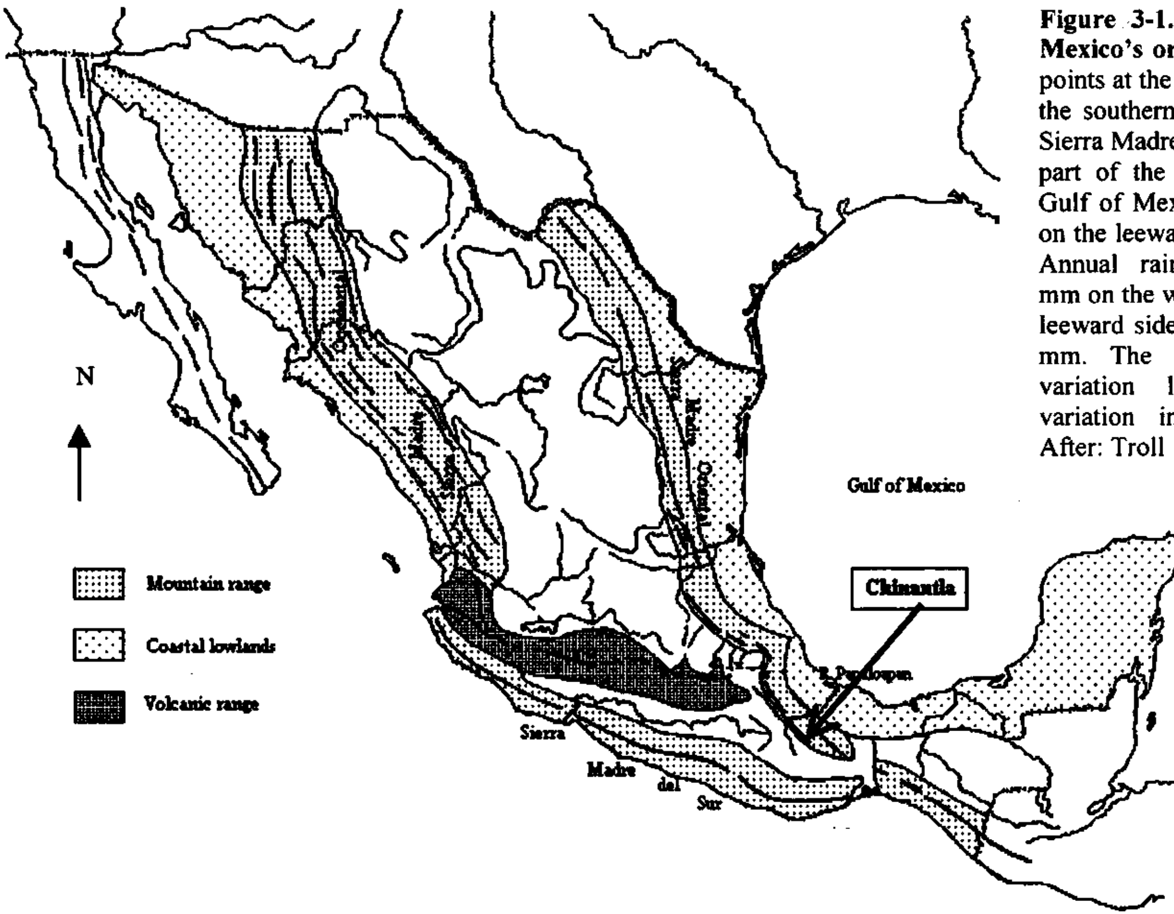

Figure 3-1. The Chinantla in Mexico's orography. The arrow points at the Chinantla, located in the southern prolongation of the Sierra Madre Oriental. The major part of the Chinantla faces the Gulf of Mexico. Some 20% lies on the leeward side of the Sierra. Annual rainfall exceeds 4000 mm on the windward side; on the leeward side it is less than 2000 mm. The wide climatological variation leads to a wide variation in vegetation types. After: Troll 1957.

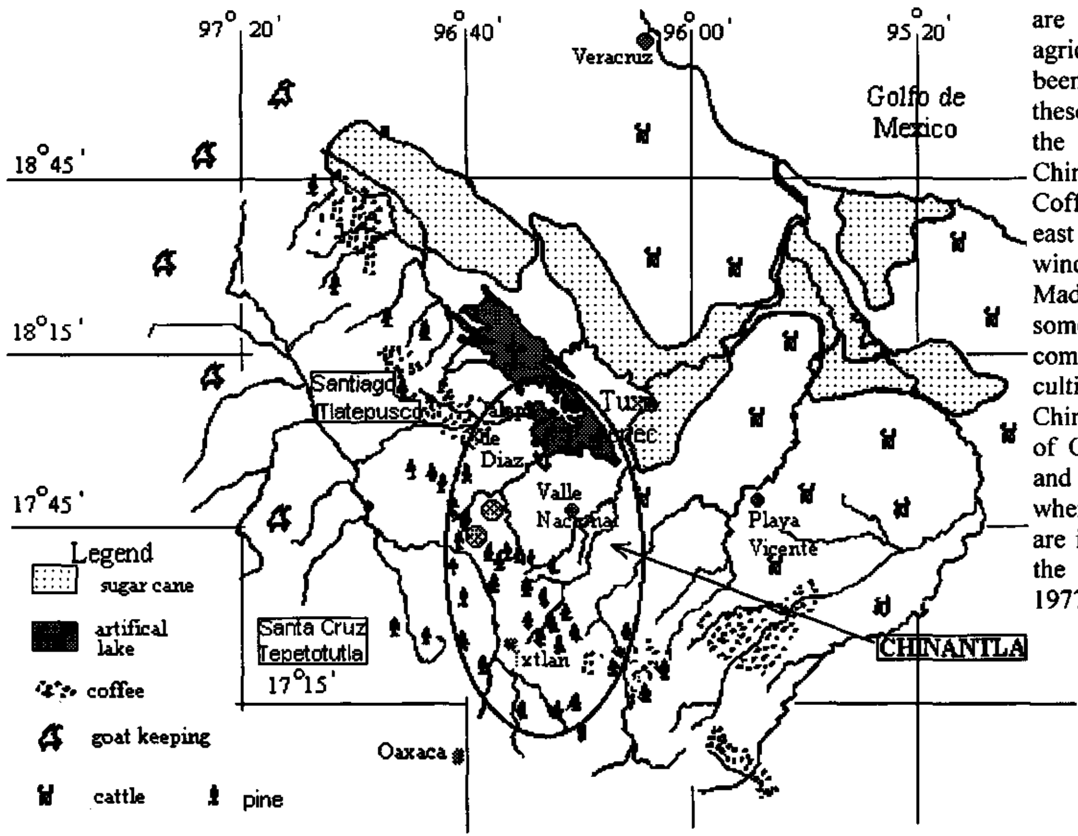

Figure 3-2. The Chinantla in the regional context. The Chinantla is part of the Papaloapan river basin. North of the Chinantla, animal husbandry and the cultivation of sugarcane are the most important agricultural activities. Dams have been constructed a to protect these areas from floods. Hence, the most fertile lands of the Chinantla are now inundated. Coffee is cultivated in a south-east to north-west fringe on the windward side of the Sierra Madre Oriental, up to altitudes of some 1600 m. Coffee culture is combined with shifting cultivation. In the south, the Chinantla borders on the Valley of Oaxaca. Santiago Tlatepusco and Santa Cruz Tepetotutla, where the fieldwork was done, are in the central-western part of the Chinantla. After: IMRNR 1977.

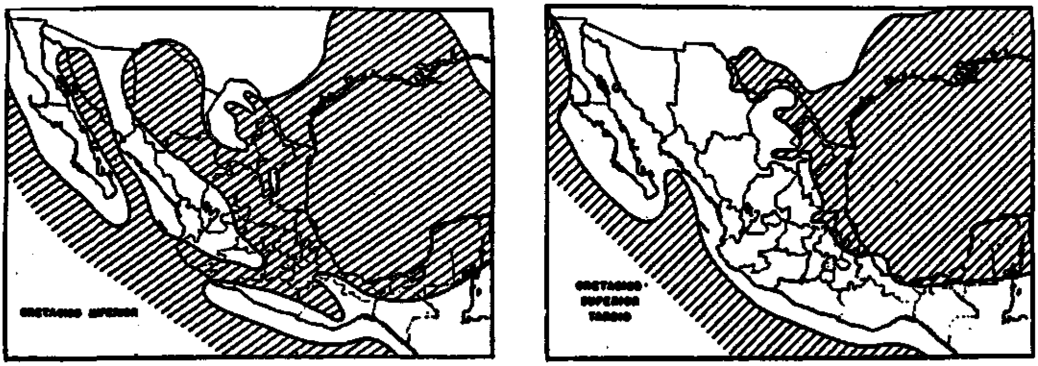

Figure 3-3. Mexico's paleogeography. Large parts of Mexico were below sea level during the early Cretaceous (140 million years ago), as shown at the left. During the late and Tertiary Cretaceous (80 to 45 million years ago) these parts emerged. Figure from Kellum 1944, published in Rzedowski 1981.

During the lifting up of the Sierra Juarez, the rocks in the mountain area have been subjected to a gradient of pressure, visible today as a gradient of metamorphism: sandstone gradually merges into schists, moving South-to-Southwest from the lowlands to the mountains (Figure 3-4).

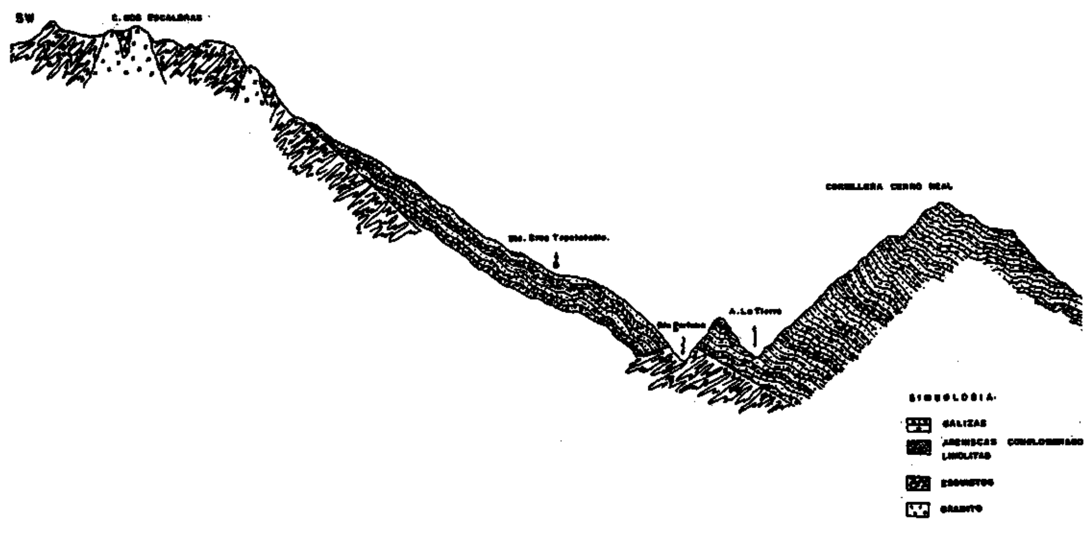

Figure 3-4. Geological profile in NNE direction in the Chinantla. The profile crosses to a large extent the territories of the communities of Santa Cruz Tepetotutla and Santiago Tlatepusco.

A dense superficial drainage network characterizes the area of schists and sand/siltstone, in contrast to the limestone area, where drainage is subterranean (Estrada & Urbán 1994). Steep slopes are the dominant landform on schists and sand/siltstone. Slopes are generally convex near the ridges, straight in the middle and end with a concave colluvium near the affluents to the main rivers (Estrada & Urbán 1995b). On the slopes, accumulation of fine materials proceeds faster than removal, resulting in generally deep soils. Weathered stones with a high proportion of quartz are found in the soil profile and sometimes on the surface.

3.3 Climate

Most of the Chinantla belongs to the subtropical rain forest life zone *sensu* Holdridge (1967). Several climatological types and subtypes of Köppen's classification, as adapted by García (1988) to the distribution of vegetation types in Mexico, succeed one another in fringes roughly parallel to the height lines: Am(e) in the coastal plain; Af(m)(e) in the lower mountain areas (below 1400 m altitude) and (A)C(fm) up to the watershed of the Sierra Juarez; on the leeward side, the drier and colder Cm climate predominates (Comisión del Papaloapan 1975).

Height differences cause wide climatic variation (Figure 3-3). The mountain ranges force warm, vapor-laden airmasses to rise. Average annual rainfall increases with altitude on the windward side of the Sierra. At Vista Hermosa, located at 1500 m altitude, average annual rainfall is nearly 6000 mm; in Usila, located at 150 m altitude, annual rainfall totals 3700 mm. The number of days per year with more than 1 mm rain is as high as 218 in Vista Hermosa and only 162 in Usila (Comisión del Papaloapan 1975). The number of hours of sunshine diminishes with increasing altitude because of clouds and fog. In the relatively dry season (January to May) rainfall is also considerably higher in Vista Hermosa than in Usila. The average diurnal variation in temperature is approximately 10 °C. The difference between the average temperature of the warmest and coldest month is 7 °C.

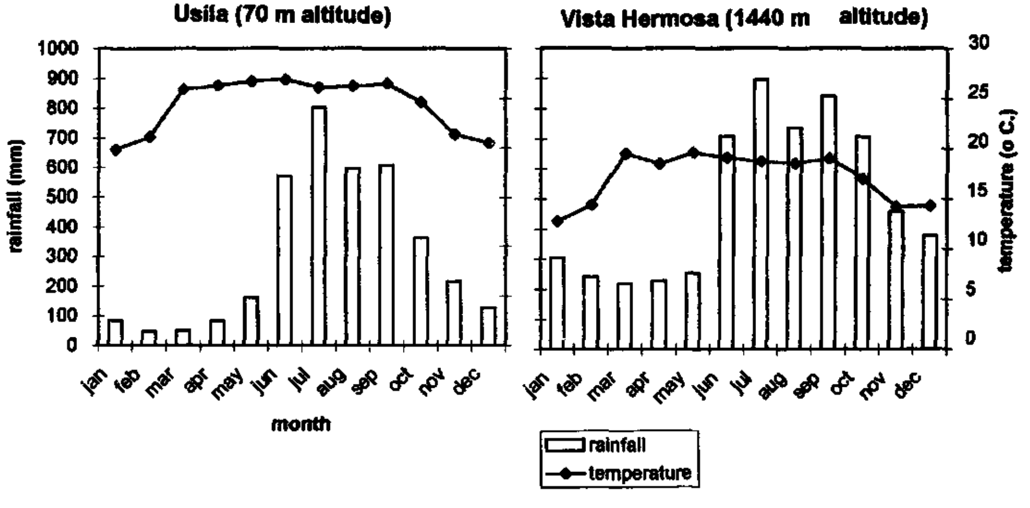

Figure 3-5. Average monthly rainfall and temperature in Usila and Vista Hermosa, Chinantla. The diagrams illustrate the wide variation of climate in the mountains. In the Chinantla, altitudes up to 3000 m are attained. At 2000 m above sea level night frosts occur.

3.4 Vegetation

In terms of Rzedowski's (1981) classification, the following types of vegetation occupy large areas of the Chinantla:

- bosque tropical perennifolio
- bosque de *Quercus*
- bosque mesófilo de montaña.

The category "bosque tropical perennifolio" includes Breedlove's (1973) categories of tropical rain forest, lower montane rain forest and part of the category semi-evergreen seasonal forest. It is generally found below 1000 m, although in Chiapas, southern Mexico, it reaches altitudes of 1500 m (Rzedowski 1981). *Terminalia amazonia*, the species that dominated the eastern tropical lowlands before massive deforestation throughout the 20th century, has been found at altitudes of up to 1000 m in Santa Cruz Tepetotutla.

Quercus forests (probably *Q. sororia* and *Q. glaucescens*, see: Gómez Pompa 1973) cover extensive areas on sandstone in the altitudinal range from 0 to 800 m. This rather open type of forest marginally protects the soil from the impact of rain; it offers even less protection after fires, which occur periodically. Soils are hard and remain poorly developed because of erosion; they retain little water.

Rzedowski's (1981) category "bosque mesófilo de montaña" combines three categories distinguished by Breedlove (1973): montane rain forest, evergreen cloud forest and pine-oak-*Liquidambar* forest. The area covered by "bosque mesófilo", or cloud forest, is restricted to humid tropical montane climates and characterized by frequent fogs and high rainfall, generally more than 1500 $mm \cdot y^{-1}$. The cloud forest of the Chinantla is part of a fringe running from the depression in the Istmo de Tehuantepec northwards (Figure 3-1). It is usually found above 1000 m altitude. Miranda & Sharp (1950) described various associations of cloud forest on different sites in the Sierra Madre Oriental, among them associations dominated by *Liquidambar styraciflua*, *Weinmannia pinnata* with presence of *Ternstroemia sylvatica*, and *Engelhardtia mexicana* at about 1600 m altitude. Stands of *Liquidambar styraciflua* may be of secondary origin (Miranda & Sharp 1950) and reflect Budowski's rule. Meave & al. (1994) distinguished four different associations of cloud forest in Santa Cruz Tepetotutla: those dominated by *Liquidambar macrophylla, Lauraceae, Engelhardtia mexicana* and *Ternstroemia sylvatica.*

Meave & al. (1994) reintroduce the category of "selva perennifolia de montaña", or montane rain forest, as a distinct vegetation type at altitudes between selva alta perennifolia (tropical rain forest) and cloud forest. This vegetation type is found at elevations ranging from approximately 900 m to approximately 1400 m in the Chinantla. Ibarra Manríquez & al. (1993) suggested *Coccoloba hirtella* as an indicator species for "selva perennifolia de montaña". According to Breedlove (1973) montane rain forest occurs between 900 and 2200 m altitude in Chiapas. This author observed *Brunellia mexicana* and *Hedysosmum mexicanum* among the species in the canopy layer of 25–35 m height.

Sarukhán (1964) studied the early development of secondary vegetation on a red-yellow lateritic soil (Cuanalo & Aguilera 1970), formerly occupied by "selva alta perennifolia" with *Terminalia amazonia* as a dominant. On the study site the primary vegetation had been cut and burnt in 1943 and the 16-year-old secondary vegetation underwent the same sort in 1959. At the start of the study, 2-year-old vegetation was cut and removed (not burnt). At 22 months of age, the shrubs and trees in the third-order regrowth had attained a height of 5 m; many of the highest trees had originated from sprouts. *Trema micrantha*, though present, was not among the dominant species at 22 months. In Uxpanapa, Veracruz, with a similar climate and located at 150 km distance from Tuxtepec, *Phytolacca rivinoides*, *Trema micrantha* and *Cecropia obtusifolia* were the dominant species in a 10-months-old second-order regrowth, where primary vegetation had been cut 8 years before. In a 7-year-old first-order regrowth *Heliocarpus appendiculatus*, *Cecropia obtusifolia* and *Cassia doylei* dominated (Williams Linera 1983).

Sousa (1964) studied young secondary vegetation on sites with different types and associations of primary vegetation. Groups of secondary species on red-yellow lateritic soils formerly occupied by *Quercus* forest or "selva alta perennifolia" dominated by *Terminalia amazonia* were significantly different from groups of secondary species on sites formerly occupied by "selva alta perennifolia" dominated by *Robinsonella mirandae* and "selva alta subperennifolia" dominated by *Brosimum alicastrum* on calcimorphic soils.

3.5 Ethno-ecology of the Chinantec

The Chinantec in the village of Santiago Comaltepec consider climate, agriculture, forests and soils as one unified whole (Martin 1993). They use the term "guoo" to express both the concept of climate and of soil, and the term "jee" for both cultivated fields and forests. Cultivated fields are seen as a stage in a succession of plant communities, as are shrublands and forests (Figure 3-6).

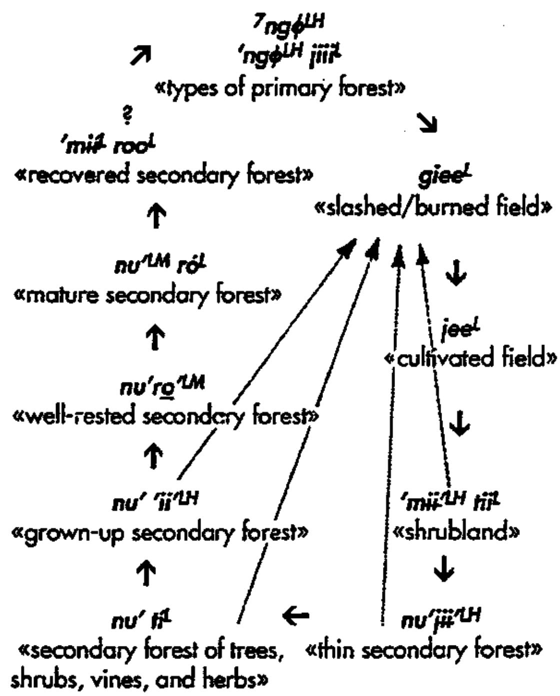

Figure 3-6. Holoplexions in the humid climate distinguished by Chinantec farmers. Many different sequences are possible. After: Martin 1993.

Succession is known to follow different paths, related to previous landuse. Among other things, its course depends on whether the site has been slashed and burnt or simply cut. For instance, trees of *Ticodendron incognitum* and *Pseudolmedia oxyphyllaria* regenerate amply on cut sites, but not on burnt sites. Further differences in species composition, structure and architecture arise from diverse natural conditions throughout the wet mountains and piedmont.

Many of the secondary species in the Chinantla are also found in mixed plantations of coffee and/or vanilla (*Vanilla planifolia*) and/or cacao (*Theobroma bicolor* and *Theobroma cacao*) (Hernandez & Mújica 1992). *Pimenta dioica* and the edible palm *Chamaedorea tepejilote* can also be grown in the shade of late secondary species. Also *Aechmea magdelanae*, a traditional fibre-crop, can be cultivated in these conditions. At present, farmers in the region are experimenting with the mentioned crops.

4 Landuse for shifting cultivation in two Chinantec communities

4.1 Introduction

Chinantec shifting cultivation was studied in the communities Santa Cruz Tepetotutla and Santiago Tlatepusco, in the municipality of San Felipe Usila, Oaxaca. Together, both communities cover an area of 17000 hectares, ranging from altitudes of 70 m to 2500 m. Land tenure is communal: "comuneros" have the right to use land, but they do not own it and cannot sell it. However, they can sell the right to use particular fields after investing in them, for example by planting coffee. Areas covered with primary vegetation and frequently cropped fields can be selected freely for cultivation. Only fields with first- to third-order regrowths are reserved in principle for the comunero who invested in the cutting of the primary or old secondary vegetation.

In both villages, comuneros grow maize and minor crops under shifting cultivation and coffee under shade-trees. Maize is principally grown in the rainy season, from June to November. In the limestone area of Santiago Tlatespusco and on a few sites with residual humidity in Santa Cruz farmers raise a second maize crop from January to May. The cropped area in the dry season is, however, quite reduced. Though secondary vegetation covers extensive areas in both communities, considerable areas remain covered with primary vegetation: selva alta perennifolia, oaklands and bosque mesófilo (Table 4-1). The savanna area in Santiago Tlatepusco is probably anthropogenic, considering its location in the immediate vicinity of the village.

Table 4-1. Population and landuse in Santiago Tlatepusco and Santa Cruz Tepetotutla in 1996. Areas (hectares) were estimated on the basis of aerial photographs. Population figures were obtained from the 1980 census and extrapolated, using a 3% rate of population increase.

	Santa Cruz Tepetotutla	Santiago Tlatepusco
Total population	705	578
Number of comuneros	138	114
Total area of the community	12300	5600
Invaded area	2000	300
Area cultivated with maize	330	200
Area with secondary vegetation	3000	1800
Area with coffee	350	200
Area with pastures	220	100
Savanna	-	300
Oaklands	500	2000
Selva alta perennifolia de montaña	1000	1000
Bosque mesófilo	6900	-

In 1990, population density in Santiago Tlatepusco was similar to that in the 'twenties. A minimum of 234 persons was reached in 1950. From this year onwards population has increased steadily. In Santa Cruz, the total population amounted to 183 persons in 1940; thereafter it increased steadily.

4.2 Landuse

The village of Santiago Tlatepusco lies on the margins of the Santiago River, at about 120 m altitude. Most coffee plantations are located below 500 m altitude, bordering the river's affluents. Maize is principally grown in the higher parts of the catchment areas, but is also found near the gallery-forests in the altitudinal range from 200 to 500 m. In the limestone area in the northeast of the communal territory, each year an area of 100 ha is cropped with maize.

The village of Santa Cruz Tepetotutla is located on a ridge at 1200 m altitude. Maize is mostly grown at similar altitudes, though sometimes as low as 500 m. Most coffee plantations are near the village at less than an hour walking distance. In principle, the varied climatological conditions permit a certain variation in the timing of agricultural activities. These possibilities are fully exploited after bad harvests, when the need of an early harvest compels the people to exploit the lower range of altitudes in spite of the extra transportation efforts entailed.

An annual production of aproximately two tonnes of grains of the staple food maize can meet the needs of an average family of 5 persons. Additionally, maize is required for domestic animals, such as mules, pigs and chickens. To meet these needs, each family cultivates 1 to 2 hectares each year. Different local varieties are grown, which are distinguished according to the color and consistency of the grains: "white hard" and "white soft", "yellow hard" and "yellow soft", "black hard" and "black soft", and "colorado", a hybrid. Varieties differ in ecological demands and in the time required to reach maturity. Selection of ears for seed takes place after harvesting, considering their length and health.

Vegetation is cut between January and May depending on labor availability and the character of the vegetation to be cut. Primary or old secondary vegetation is cut early in the year, so that the trunks and branches have the time to dry. Secondary regrowths consisting of herbs can be slashed until May. Farmers time the burns according to the expected distribution of the first rains and, among other signs, use the appearance of ants as an indicator. They burn as late in the season as posible to assure an advantage of the maize plants over other plants, generally at the end of May.

In Santiago Tlatepusco, "yellow soft" and "white soft" maize are the most cultivated local varieties of maize. "Yellow soft" maize, less demanding, is grown in the sandstone area; "white soft" maize in the limestone area. Sowing starts at the end of May in the limestone area and at the beginning of June in the sandstone area, after the first rains. In Santa Cruz Tepetotutla, "white hard" and "yellow hard" maize are the most cultivated local vartieties. Sowing is habitually done at the beginning of June.

At sowing, 4 to 6 grains are deposited in 10 cm deep holes made with a dibble stick. Distance between holes is more than a meter and varies between fields. The number of plant holes varies between fields from 5000 to 8000 in a hectare of sloping area, the number of plants from 17000 to 37000 (Table 4-2). Farmers adjust plant density to their preference and sometimes to the characteristics of fields, using wide spacings where low yields are expected. Within fields, spacings are seldom varied. Due to the wide variations in spacing between fields, farmers do not measure the area of cultivated land, but the volume of seed sown. This was formerly measured in "jicaras", recipients of *Crescentia cujete*. At present it is measured in litres or kilogrammes and "maquilas". A maquila is equivalent to 5 kilogrammes of seed. On average, one maquila of maize is equivalent to 0.30 hectares of sloping area.

Table 4-2. Surface area of fields and spacing of maize plants in fields in the limestone area and in the area of selva alta perennifolia de montaña. The areas in the second column refer to the surface area of fields cropped by the farmers mentioned in the first column. Kg maize = the quantity of maize sown on the area in the second column. This quantity has been distributed over plant holes, the number of which on a hectare basis is recorded in the fourth column. Area/kg is the surface area expressed in m^2 that was sown with 1 kilo of maize; n plt/mt = number of plants per plant hole; n plt/ha = number of plants per hectare. In both areas a wide variation in all parameters is observed. Farmers may grow maize on several fields.

Name farmer	Area (m^2)	Kg maize	Plantholes/ha	Area/kg	n plt/mt	n plt/ha
LIMESTONE AREA						
Francisco M.	2880	5	7800	576	4.71	36738
Genaro G.	2730	6	7500	455	4.01	30075
Jacinto L.	1370	3	7680	457	3.55	27264
José R.	1670	2	6100	835	4.34	26474
Valentino M.	9310	15	7330	621	4.91	35990
Average	*3592*	*6*	*7282*	*589*	*4.30*	*31308*
AREA OF SELVA ALTA PERENNIFOLIA DE MONTAÑA						
Ciriaco J.	16200	25	7830	648	4.68	36671
Ciriaco P.	13780	25	7830	551	3.97	31059
Francisco T.	17640	22	6800	802		
Juan M.	23200	32	7870	725		
Abel P.	2920	5	7300	584	4.48	32704
Albino O.	19590	22	6770	890	5.13	34753
Alfonso H.	10400		7230		4.34	31378
Andres J.	18750	34	7230	551	3.62	26149
Casimiro G.	8100	11	8500	736		
Gabino H.	7800	13	7130	600	4.38	31253
Hipolito L.	16600	24	6400	692	3.76	24033
Ignacio P.	12000	17	7230	706		
Jaime O.	25600	36	6670	711	5.18	34573
Jorge O.	9360	16	6770	585	5.07	34301
Laurentino H.	3750		7200		4.32	31100
Maximino O.	3840	6	5230	640	3.41	17850
Pedro O.	7800	12	5800	650	3.63	21073
Raymundo O.	12150	20	6630	608	4.28	28399
Average	*12749*	*20*	*7023*	*667*	*4.30*	*29664*

Weeds are cut with a machete, pulled out by hand or killed by using herbicides. Weeding starts 3 weeks after sowing and ends at 10 weeks after sowing. The required efforts vary between fields. In recently established fields one weeding is sufficient, while in other fields 3 weedings may be necessary.

In Santiago Tlatepusco, immature ears ("elote") are gathered in September, whereas harvest of the mature ears is done in October in the limestone area and in November in the sandstone area. In Santa Cruz, immature ears are cut in October, whereas harvest may extend to January. At harvest, well-formed and deformed or damaged ears are treated separately. Well-formed ears are stored with the inner leaves of the husk, whereas the grains of damaged ears ("molcate") are separated from the cob as soon as possible to minimize post-harvest losses. "Molcate" is frequently fed to chickens and pigs in the court yard. Maize yields are counted in "zontles", each zontle containing 400 well-formed ears, approximately equivalent to 50 kg of dry grains. Yields vary widely between years and between fields. In both villages, average yields are approximately 1400 kg per hectare.

Maize as a staple food is complemented with beans (*Phaseolus vulgaris*) and other minor crops: yucca (*Manihot esculenta*), sweet potatoes (*Ipomoea batatas*), chili peppers (*Capsicum annuum*), the local crop "huasmol" (*Renealmia* sp), tomato (*Solanum lycopersicum*), mustard shoots (*Brassica nigra*), tepejilote (*Chamaedorea tepejilote*) and sugar cane (*Saccharum officinarum*). Tomatoes, mustard and some bean varieties are grown in polyculture with maize. Sweet potatoes are usually grown on the edge of the maize fields. Beans, yucca, "huasmol" and sugarcane are usually grown on separate small fields.

Plantains (*Musa* sp.) make up an important part of the diet; occasionally they are used as a substitute for maize, as is the stembase of an unidentified fern species. A range of fruits is consumed: orange (*Citrus sinensis*), mandarins (*C. reticulata*), limes (*C. limetoides*), avocados (*Persea* spp.), peach (*Prunus persica*), zapote negro (*Diospyros ebenaster*), mamey (*Pouteria mammosa*), mango (*Mangifera indica*), guava (*Psidium guajava*), chico zapote (*Achras zapota*), pomarosa (*Eugenia jambos*), coconuts (*Cocos nucifera*), nanche (*Byrsonima crassifolia*) and pineapples (*Ananas comosus*).

Because of strong price fluctuations of coffee, farmers have started alternative economic activities, such as carpentry for the regional market, baking bread and growing typical crops, such as *Chamaedorea tepejilote*, *Renealmia* sp. and *Aechmea magdelanae*.

4.3 Variants of shifting cultivation

Different variants of shifting cultivation are practised in the communities: shifting cultivation in selva alta perennifolia de montaña; shifting cultivation in the limestone area and shifting cultivation in the oaklands. Transitional forms between variants exist. The use-history of fields of the most extended variants was investigated in 1994 and 1995, when farmers were asked about the localization and the use-history of their cropped fields. Among other things, they were asked when primary or very old secondary vegetation was cut; how many times secondary vegetation had been slashed; and what the age of secondary vegetation was at the time of slashing.

4.3.1 Shifting cultivation in "selva alta perennifolia de montaña".

Shifting cultivation in the area of "selva alta perennifolia de montaña" is characterized by a landuse pattern which is similar to that described by Martin (1994) for the community of Santa Maria Comaltepec (Figure 3-4, Section 3.7). Cultivation starts with the cutting of primary or very old secondary vegetation. After burning, a maize crop is grown during 5 to 6 months. Thereafter the field reverts to secondary vegetation, during a period of generally 5 to 10 years (Figure 4-1). After cutting and burning this first-order regrowth, another cropping period follows, after which the second-order regrowth starts to develop. Fields with regrowths of an order higher than 7 are generally not slashed, but left fallow for approximately 50 years (Figure 4-2). Fields under a long fallow may be converted for other uses, such as mixed coffee plantations under the natural shade of basically late secondary species, or just await new cultivation with annual crops.

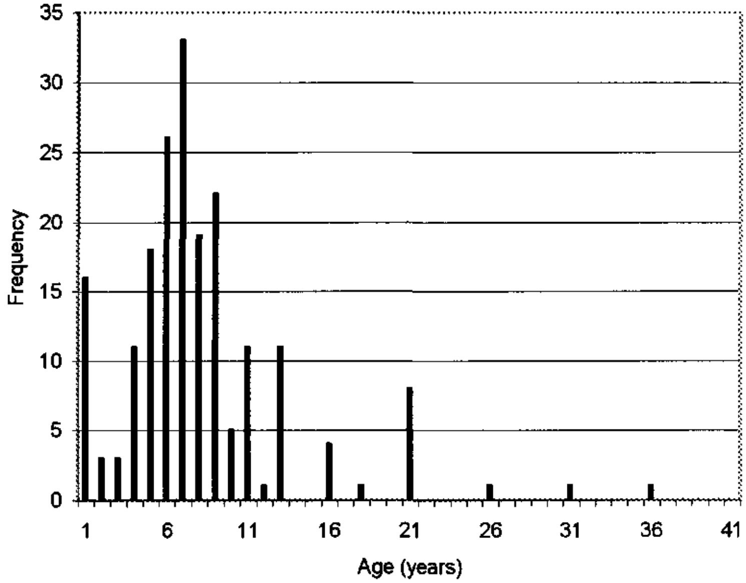

Figure 4-1. Frequency of ages in a sample of regrowths in Santa Cruz Tepetotutla (n=195). Most secondary regrowths are 5 to 6 years-old when slashed for maize cropping.

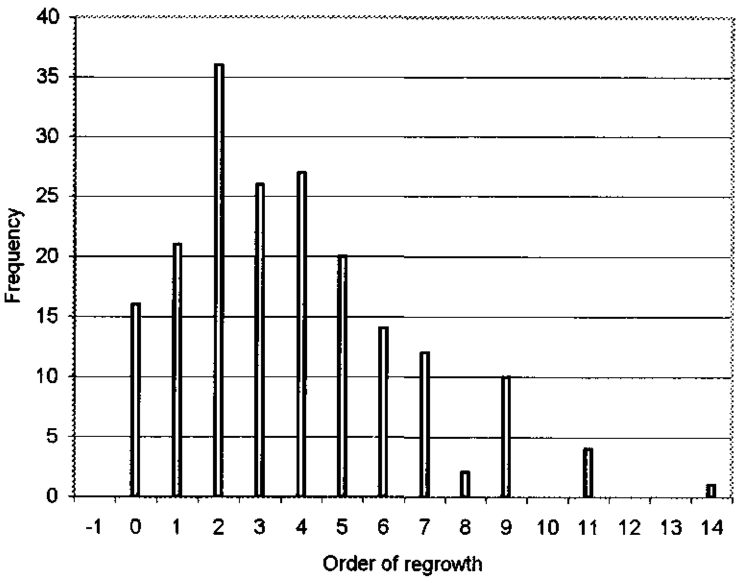

Figure 4-2. Frequency of order of regrowth in a sample of fields in Santa Cruz (n =190). Few regrowths are of a higher order than five. Zero-order regrowths represent primary or old secondary vegetation.

Fields are located on slopes, never on ridges. Most fields, occurring in clusters, are located at more than 5 km distance from the village. Cultivated fields rarely border on other fields being cultivated in the same year. Clusters are distributed over the comunal territory (Figure 4-3). The relative importance of sites, as measured by the number of fields located on them, shifts between sites in different years. In 1994 most fields were located in Monte Pan, in 1995 in Monte Tierra (Table 4-3). In both years most fields were located in the elevation interval between 1000 and 1500 m.

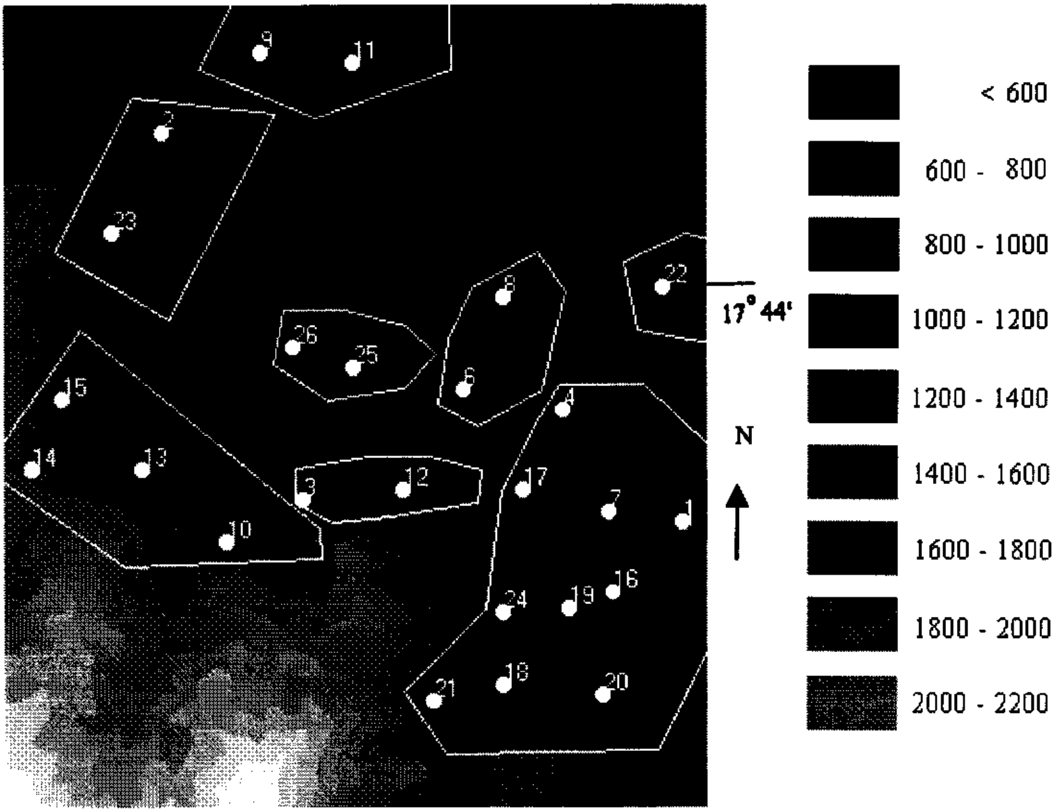

Figure 4-3. Geographical sites with clusters of fields in Santa Cruz Tepetotutla. The numbers on the map correpond with the numbers and names in Table 4-2. The number of cultivated fields on the sites fluctuates from year to year.

Four groups of sites can be distinguished in Santa Cruz, according to distance, position with respect to the village and elevation: a group of sites in the northwest, with low elevation; a group of sites at the west of the village; a group of sites located within 2 km distance from the village; and a group of fields at the East (see Figure 4-3 and Table 4-3). These groups are indicated in the following as North-West, West, Village and East.

Farmers showed a preference for fields located in East in 1994 and 1995. The number of burns of fields varied between East and West (Figure 4-4). On average, fields in West had been burnt less frequently and showed a smaller range in the number of burns. This demonstrates that the preference for East in 1994 and 1995 is not an isolated fact, but dates back to at least some decades ago. Fields in Village had been burnt significantly more often than fields located in West and East, while the age of secondary regrowths was higher in Village than in East. The number of years since the cutting of primary or old secondary vegetation was greater in fields in Village than in East and West.

Table 4-3. Geographical distribution of fields cropped in 1994 and 1995 in Santa Cruz Tepetotutla. Site numbers correspond with those in Figure 4-3. Sites can be grouped in 4 broad groups: North-West (sites 5, 9 and 11); West (sites 2, 23, 15, 14, 13, 10); Village (26, 25, 8, 6, 3, 12); and East (22, 4, 17, 7, 1, 19, 24, 16, 21, 18, 20). In 1994 most fields were in Monte Pan; in 1995 most fields were in Monte Tierra.

site number	site name	Number of fields in 1994	Number of fields in 1995	Percentage of fields in 1994	Percentage of fields in 1995
1	Arr. Algodon	2	0	4%	0%
2	Arr. Del Derrumbe	0	7	0%	9%
3	Camino a la Sierra	1	3	2%	4%
4	El Charco	0	1	0%	1%
5	La Boca	3	0	6%	0%
6	Loma de Sangre	2	7	4%	9%
7	Loma del Gavilan	3	3	6%	4%
8	Loma del Grillo	0	2	0%	3%
9	Loma del Sol	0	2	0%	3%
10	Loma Trampa	0	2	0%	3%
11	Mah Kein	1	0	2%	0%
12	Mi Djoh	1	0	2%	0%
13	Monte Calabaza	4	4	8%	5%
14	Monte Frio	3	5	6%	7%
15	Monte Guitarra	0	4	0%	5%
16	Monte Gusano	2	1	4%	1%
17	Monte Hierba	3	1	6%	1%
18	Monte Malangar	1	0	2%	0%
19	Monte Pan	14	3	26%	4%
20	Monte Perfume	0	2	0%	3%
21	Monte Perro	2	3	4%	4%
22	Monte Peste	2	2	4%	3%
23	Monte Tejon	4	4	8%	5%
24	Monte Tierra	3	17	6%	22%
25	Pueblo	0	3	0%	4%
26	Pueblo Viejo	2	0	4%	0%
	SUM	53	76	100%	100%
	EAST	32	33	66%	44%
	WEST	11	26	22%	36%
	VILLAGE	6	15	12%	20%
	SUM	49	75	100%	100%

As a result of the traditional landuse pattern, a diverse mosaic of secondary vegetation was maintained, with patches of vegetation of varying architecture, structure and composition. At present, this landuse pattern is being abandoned as a general practice, among other reasons because the use of herbicides makes it possible now to return more frequently to the same fields. However, the traditional pattern has not yet been completely overruled, as can be observed from remaining patches of very old secondary vegetation. Many farmers still apply the knowledge and wisdom which sustained the traditional system and associate the presence of species with orders and ages of regrowths. At the same time, the farmers conserve a fairly detailed knowledge of the use-history of fields.

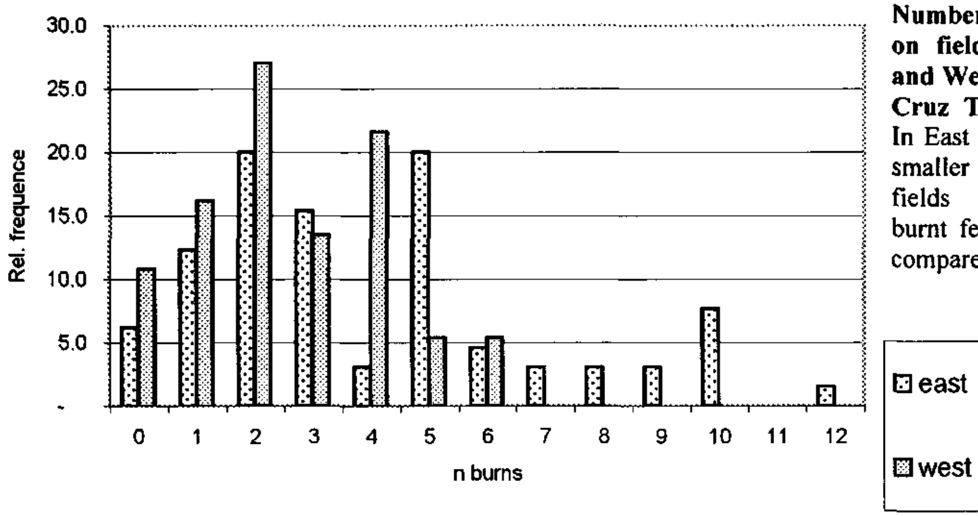

Figure 4-4. Number of burns on fields in East and West in Santa Cruz Tepetotutla. In East a relatively smaller number of fields has been burnt few times as compared to West.

In Santiago Tlatepusco most fields are situated in the altitude interval from 400–900 m. Originally, these areas were covered by a transitional type of vegetation with characteristics of both "selva alta perennifolia de montaña" and "selva alta perennifolia". Fields are generally cultivated once every 7 to 10 years. In contrast to Santa Cruz Tepetotutla, patches of primary rain forest are seldom cut. As a result, fields have been more frequently cultivated.

4.3.2 Shifting cultivation in the limestone area

This variant originates from a conflict about land titles. Part of the lands in the limestone area have been invaded by comuneros of a neighbouring village. As a customary rule states that fallowing fields may be taken freely for cultivation, intensive use of fields in the disputed area is a form of defence of communal lands. The comuneros of Santiago therefore crop their fields frequently, as cropped fields will not be taken by other farmers. As a consequence, secondary vegetation can develop only during short periods, mostly no more than 2 years (Figure 4-5). At this age it is principally made up of herbs. At present, most fields have been cropped frequently (Figure 4-6). The resulting weed problems have made the use of herbicides compelling.

Fields in the limestone area are mostly situated between 200 and 700 m altitude on moderate to steep slopes. They form one large cluster and frequently contiguous fields are cropped in the same year. Ridges may be cultivated, though natural terraces with moderate slopes are preferred.

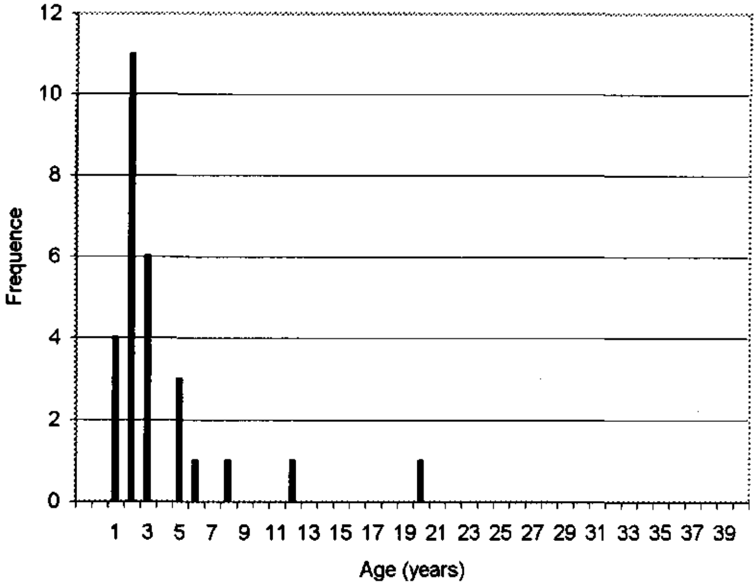

Figure 4-5. Frequency of ages in a sample of regrowths on limestone (n = 28). Most regrowths are cut when 2 years old, *i.e.* 1.5 year after harvest of the previous crop.

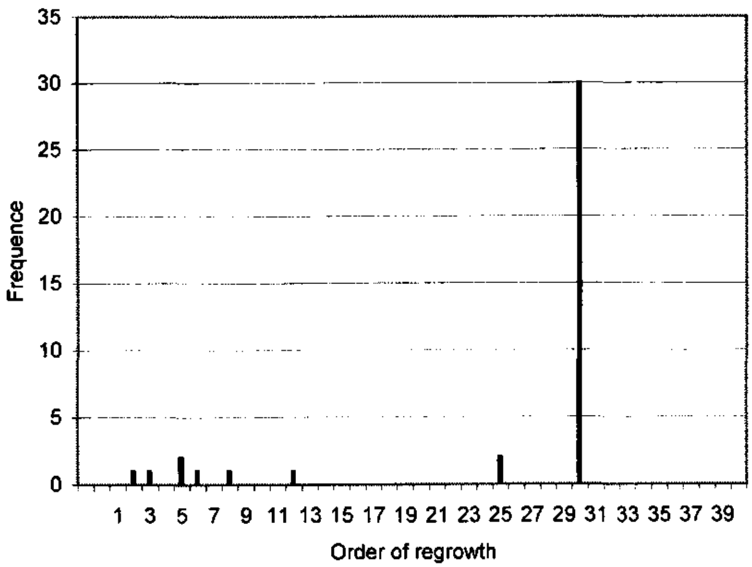

Figure 4-6. Frequency of orders of regrowths on limestone (n = 28). Most of the fields have been cropped many times since the start of the conflict on land titles with a neighboring village.

4.3.3 Shifting cultivation in *Quercus*-forests

The variant practised in oaklands illustrates how specific indigenous shifting cultivation is. The variant is an example of "riding on" the natural process of invasion of oaklands or woodland savannas by rain forests. This variant is characterized by the fact that fields cannot be cultivated immediately after cutting the primary vegetation. The soil is considered too hard, too dry and too poor for a maize crop, which would not yield more that a few hundred kilos of maize per hectare. In order to ameliorate the fields' conditions, the secondary vegetation proper of the selva alta perennifolia is induced, by ringbarking the oaks.

The ringbarking only makes sense on selected sites, where species of the secondary forest of selva tropical perennifolia are already present in the undergrowth. On sites where this is not the case, the ringbarking would lead to a renewed oakforest. Oaklands with the desired secondary species in the undergrowth occur usually on the lower parts of slopes near tracts of gallery forest, which act as refugia of species of the selva (Meave & al. 1991). After ringbarking, vegetation is left to develop during a decade or more. The intensely rooting trees and herbs contribute to a better aeration of the soils; organic materials are increasingly integrated in the soils, ameliorating its general properties. Maize cropping can start after cutting and burning the induced vegetation (Van der Wal 1996).

4.4 Conclusions

Even within the territory of two communities, a considerable variation in local forms of shifting cultivation was observed. This variation responds to social and natural factors. Three variants can be distinguished, with different landuse patterns. On limestone, cropping periods of half a year are followed by short fallow periods, sometimes of only half a year. Many fields have been cropped 20 or more times. In the variants in the area of *Quercus* forests and in the area of selva alta perennifolia de montaña, fallow periods after cropping periods of half a year last several years. After cutting primary or old secondary vegetation fields are not cropped with maize more than 10 times before letting revert the vegetation to old secondary vegetation.

5 Chinantec shifting cultivation and secondary vegetation

5.1 Introduction

This chapter presents goals, methods and results of the study of secondary vegetation on fields under Chinantec shifting cultivation. In draws upon fieldwork that was done in 1994 and 1995.

5.2 Objective

The general objective was to study the influence of the local landuse pattern on the development of secondary vegetation, and so generate baseline information for the redesign of a diverse mosaic of secondary vegetation which would support a diverse production.

More specifically, the study set out to find answers to the following questions:

- Which are the species that play a role in secondary succession?
- Is the development of secondary forests related to temporal aspects of the landuse pattern (landuse history), paying attention to species composition, structure and architecture?
- Is the composition and structure of secondary forests related to altitude?
- Is the composition and structure of secondary forests related to lithology?
- Is architectural eco-unit development related to landuse history?
- Is secondary succession on fields related to secondary succession in chablis?

5.3 Methods

5.3.1 Field selection

In 1994 and 1995, information on the landuse pattern in the villages of Santiago Tlatepusco and Santa Cruz Tepetotutla was gathered through interviews with the farmers (Van der Wal & Caudillo 1995; Chapter 4). In the interviews, the use-history was recorded of the fields that were cropped in 1994 and 1995. On the occasion, farmers were also asked to mention the most important plant species on their fields by their local names, in order to establish an approximate relation, if any, between use-history of fields and species composition of secondary vegetation.

Based on the knowledge of use-history, fields were selected in order to sample their secondary vegetation. The selection principally included fields that represented the most important local variant of shifting cultivation, i.e. shifting cultivation in "selva alta perennifolia de montaña". The selected fields covered a range of ages of secondary regrowths and a range of the orders of regrowth. Two fields were located in the limestone area; the other fields were located on sandstone and schists (Table 5-1). More data on the selected fields are presented in ANNEX 1. Secondary vegetation in chablis was also sampled for comparison with secondary vegetation after shifting cultivation.

Table 5-1. Use-histories of sampled fields. Information on the use-history was obtained from the farmers. On Field 2 and 12, vegetation was sampled in chablis. This vegetation was cut in the case of Field 2; the vegetation on "Field 12" was not cut, and therefore no farmer's name was recorded. Very old secondary vegetation grew on Field 14. It was not known who had cleared the field, approximately 50 years ago, nor could information be given by the farmers on the order of regrowth and the year of cutting the primary forest.

Name farmer	Field no.	Age (years) of secondary regrowth	Order of regrowth	Years since primary forest was cut	Name farmer	Field no.	Age (years) of secondary regrowth	Order of regrowth	Years since primary forest was cut
Jorge	1	12	4	30	Maximino	15	5	1	5
Alfredo	2	-	-	-	Justiniano	16	5	4	20
Leopoldo	3	5	1	5	Benito	17	5	3	17
Francisco	4	20	1	20	Jorge	18	12	2	16
Romeo	5	17	2	30	Lorenzo	19	7	1	7
Francisco	6	16	1	16	Gabino	20	12	2	22
Jaime	7	6	2	12	Joel	21	5	2	15
Maximino	8	6	2	12	Pedro	22	7	3	21
Sotero	9	5	5	50	Pedro	23	14	2	21
Luis	10	5	2	20	Andres	24	20	2	40
Andres	11	12	1	12	Aniceto	25	6	2	12
-	12	-	-	-	Anselmo	26	12	4	60
Leandro	13	5	4	40	Pedro M	27	7	4	30
?	14	50	?	?	Anacleto	28	5	4	30

5.3.2 Sampling

Sampling was done by a team consisting of a local farmer, who was assigned by the community, a botanist and two agro-ecologists. Slope angle, aspect and altitude were recorded. Geographic coordinates of sites were determined in the field. This information was digitized on screen in IDRISI (Figure 5-1), a geographic information and image processing software system.

On each field, 4 transects were laid out on straight steep slopes, with their longest side in the direction of the slopes. Transects were 25 m long and 4 m wide. Border areas of fields were excluded from sampling. If secondary vegetation within a field consisted of physiognomically different patches, then transects were assigned in approximate proportion to the area covered by patches.

Three variables of individual trees and shrubs with a diameter at breast height above 2 cm were recorded:

- circumference of trunk at breast height
- height of tree and length of branch-free trunk
- two perpendicular crown diameters.

The circumference of the trunks was measured using a metric tape. The other parameters were estimated, using a 2-m-long stick for comparison. All estimates were made by the same person.

Positional coordinates of the trees with respect to the length- and width-axes of the transects were determined by measuring with a tape.

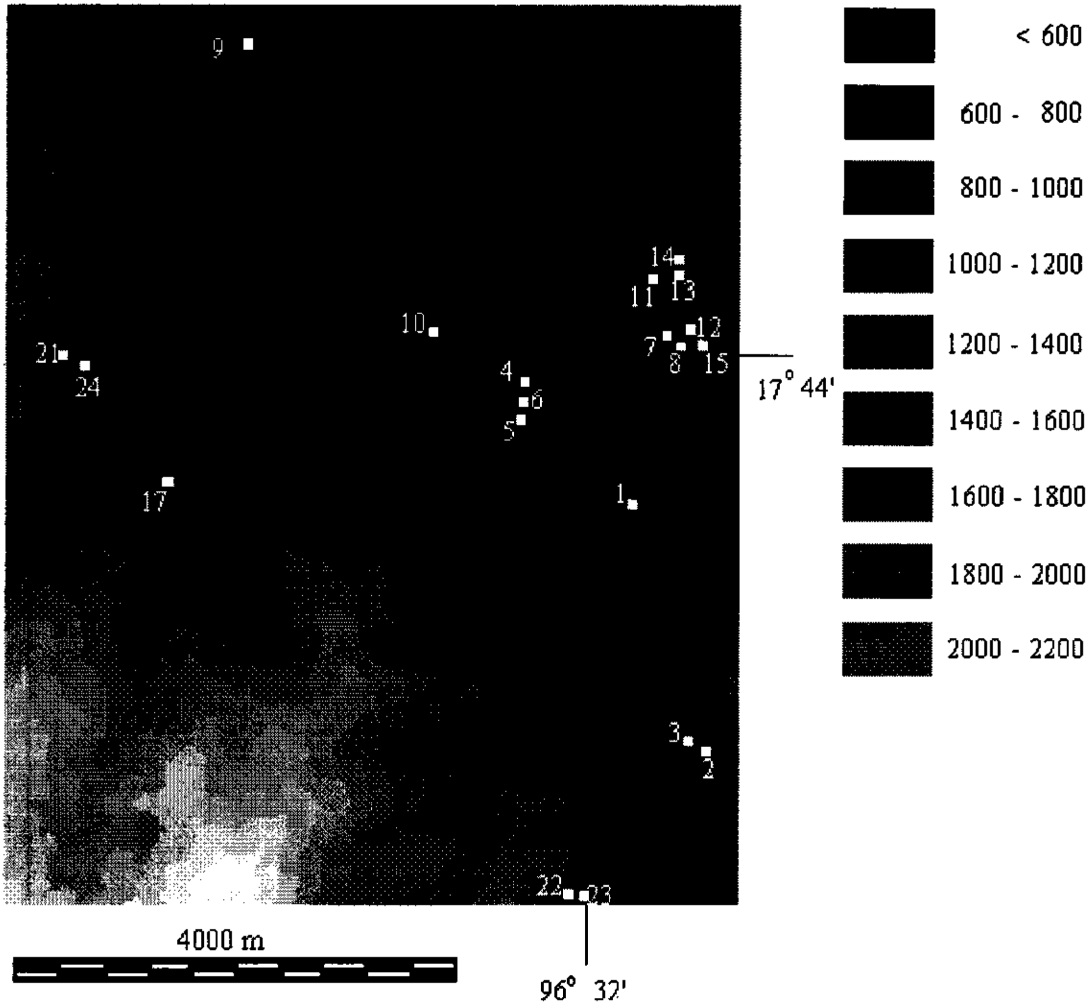

Figure 5-1. Location of sampled fields in Santa Cruz Tepetotutla. The numbers correspond with the field numbers in Table 5-1. Only the fields in Santa Cruz Tepetotutla appear on the map. The altitude of fields is in the range of 700 to 1500 m above sea level.

Sampling was done from March to November 1994 (17 fields) and from March to August 1995 (11 fields). If known, Chinantec and Spanish names of trees and shrubs were recorded. Voucher specimens of all tree and shrub species in each plot were collected, excluding common species that had been found earlier on the same working day. Generally three transects were sampled per day. Voucher specimens were treated in the village with a 1:1 water/alcohol mixture and enclosed in polyethylene bags. After transport and drying they were identified at the Laboratory of Ecology and at the Institute of Biology of the Universidad Nacional Autónoma de México (UNAM) by Dr. Ibarra Manríquez and BSc. Romero Romero, kindly supported by specialists. Nomenclature follows Cronquist (1981). A species list was elaborated and a local herbarium was made; vernacular names were translated into scientific names.

5.3.3 Data processing

Information on the relation between the order of regrowth and the composition of secondary vegetation, gathered by interviews with farmers, was analyzed by determining frequencies of species for different orders of regrowth. Data on woody species composition of sampled fields were first analyzed by clustering methods. Relationships between environmental parameters and landuse history and species composition were analyzed by ordination methods. The relation between structural data and landuse history was analyzed by comparing data for different orders of regrowth. The relation between landuse history and the development of eco-units was analyzed by studying the drawings of selected transects.

Field data were originally captured in Lotus Spreadsheet and thereafter treated in a FORTRAN application to compile vegetation tables comprising numbers of individuals and the summed values of basal area and crown projection for all species in each transect. The surface area of transects was reduced to their horizontal projection for the calculation of structural parameters.

For further analysis, data on crown projection were converted to classes using the relational database program OPNAME 2 (Pot 1998). Classes were defined by the boundaries presented in Table 5-2. Slope aspect, measured in degrees with respect to North, was converted to values from 0 to 1, applying the following conversion: x -> {cos[aspect (x) – 30°] +1}/2.

Table 5-2. Conversion of values to classes of crown projection. Crown projection of the trees was determined in the transects and then calculated in $m^2 \cdot ha^{-1}$.

crown projection	0–100	100–200	200–400	400–800	800–1600	1600–3200	3200–6400	>6400
class	1	2	3	4	5	6	7	8

Computer files containing data on presence/absence of species, crown projection and environmental parameters were transformed to the Cornell Condensed and Full Format applying the program OPNAME 2 (Pot 1998). Data were then analyzed with the divisive clustering program TWINSPAN (Hill 1979) to determine which fields had similar vegetation. The program CANOCO (Ter Braak 1991) for correspondence analysis was used to determine whether relations existed between parameters of the landuse pattern (spatial and temporal) and species composition.

Structural data on secondary vegetation of similar age, though of different orders of regrowth, were compared. Data of trees in transects were transformed into drawings by means of the program TREEDRAW (Leersnijder 1997) to study the development of eco-units.

5.4 Species composition and distribution

5.4.1 Introduction

Data on woody species composition obtained by the sampling of transects can be analyzed by different methods, such as indirect and direct gradient analysis. By these means the relation between management or ecological factors and species composition can be investigated. This will be done in the following sections.

5.4.2 Species, genera and families

A total of 5691 trees and shrubs, belonging to 229 species (ANNEX 2), were recorded on a total sample area of 8282 m^2. Fourteen species were exclusively found in chablis in primary vegetation. Fifty-two species were represented by only 1 individual, 28 species by 2 individuals, and 27 species by 3 individuals. The low species diversity (in the sense of polydominance) of secondary vegetation is demonstrated by the fact that 90% of the total number of recorded trees and shrubs comprised only 37 species (Figure 5-2).

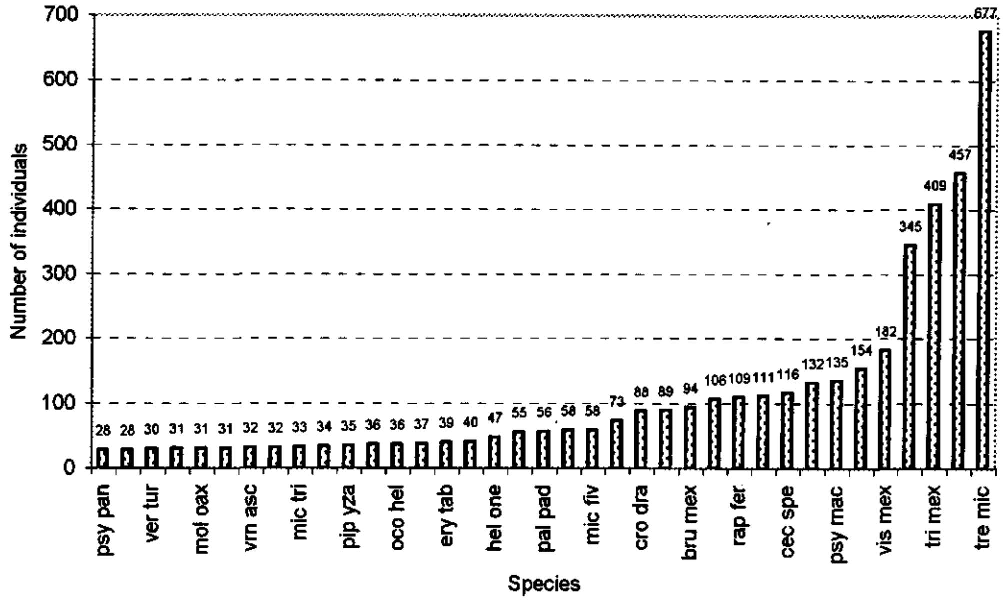

Figure 5-2. Number of occurrences of most frequent species. *Trema micrantha, Heliocarpus appendiculatus, Trichospermum mexicanum* and *Hedyosmum mexicanum* were found most. Legend: tre mic = Trema *micrantha*; hel app = *Heliocarpus appendiculatus*; tri mex = *Trichospermum mexicanum*; hed mex = *Hedyosmum mexicanum*; vis mex = *Vismia mexicana*; vrn pat = *Vernonia patens*; psy mac = *Psychotria macrophylla*; sau asp = *Saurauia aspera*; cec spe = *Cecropia* sp. ; ing lat = *Inga latibracteata*; rap fer = *Rapanea ferruginea*; sip and = *Siparuna andina*; bru mex = *Brunellia mexicana*; alc lat = *Alchornea latifolia*; cro dra = *Croton draco*. For explanation of other codes: ANNEX 3.

The number of woody species varied with age and order of regrowth. In young, first-order regrowths on Fields 3 and 19, 20 species were found; in the third-order regrowth on Field 17, 34 species were found, and 30 species were found in the second-order regrowth on Field 21. In spite of the small number of trees in the fourth-order regrowth on Field 16 (less than 25% of that in first-order regrowths), the number of species was only slightly lower than in first-order regrowths. Similarly, 23 species were found in the 12-year-old, first-order regrowth on Field 11; 36 species were found on Field 20, with a second-order regrowth; and 32 species on Field 1, with a fourth-order regrowth. When considering regrowths of similar age, the number of woody species *increases* from first- to second- and third-order of regrowth.

Woody species belonged to 108 genera (ANNEX 4) and 55 families (ANNEX 5). The genera *Eupatorium, Piper, Miconia* and *Saurauia* were represented by most species. The families represented by most genera were Leguminosae (12), Asteraceae (8) and Rubiaceae (8). The families represented by most species were Leguminosae (23), Melastomataceae (21), Asteraceae (21), Rubiaceae (18) and Lauraceae (16).

Farmers distinguish many different plant species. Common trees have generally both a Spanish and a Chinantec name (ANNEX 6). Whereas farmers could name most secondary species in Spanish and Chinantec, species in primary vegetation frequently could not be named.

5.4.3 Species distribution as influenced by management and ecological factors

The grouping of fields obtained by the divisive clustering program TWINSPAN was compared with data on use-history. Groups of most dissimilar fields are separated in each of the consecutive divisions that the program makes on the basis of species scores and field scores.

In a first run, presence/absence data of woody species were used as input. With presence/absence data species are given equal weight, independently of their importance as measured by, for example, the number of trees or the crown projection. The clustering of fields gives a first impression of similarities and dissimilarities (Figure 5-3). Fields 9 and 10 were excluded from the analysis because of doubts on the correctness of data on use-history. Fields were weighted according to the number of transects: Fields 5, 8 and 15 were given weight 0.25 and Field 17 was given a weight of 1.5.

In the first division, old secondary and primary vegetation were separated from secondary vegetation younger than 20 years. In the second division, fields of low altitude in the community of Santiago Tlatepusco were separated from fields of higher altitude in Santa Cruz Tepetotutla. The fields of low altitude in Santiago Tlatepusco were characterized by the presence of the following species: *Calliandra houstiniana, Casearia sylvestris, Rondeletia villosa, Cupania glabra, Spondias radlkoferi, Inga aestuariorum, Tabernaemontana alba* and also *Croton draco* and *Verbesina turbacensis.* In the fields of higher altitudes, *Brunellia mexicana, Hedyosmum mexicanum, Saurauia aspera, Miconia trinervia, Rapanea ferruginea, Vismia mexicana* and *Palicourea padifolia* were frequently found.

In the following divisions, 12 to 20 year-old regrowths on fields 1, 4, 5, 6 and 11 were separated from younger (5 to 7 year-old) regrowths. In 12 to 20 year-old regrowths *Alchornea latifolia, Ocotea helicterifolia, Psychotria panamensis, Piper calophyllum* and *Miconia trinervia* were frequently found. High-order 5 to 7 year-old regrowths on Fields 13, 16 and 17 were distinguished by the presence of *Vernonia patens, Solanum schlechtendalianum* and, to a lesser degree, *Inga latibracteata.*

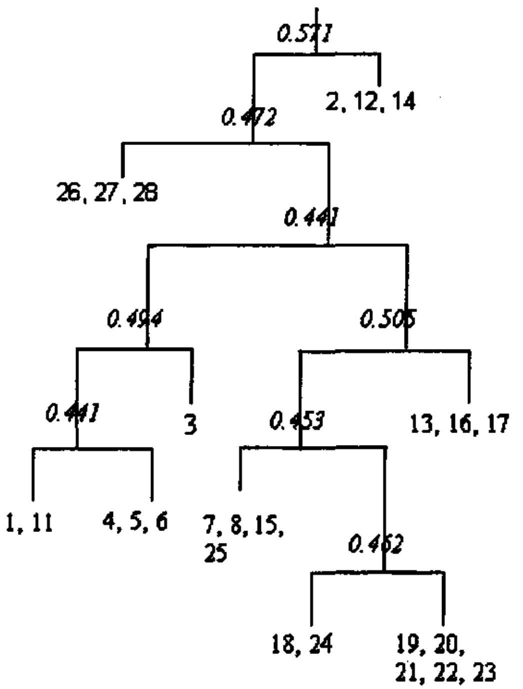

Figure 5-3. TWINSPAN-clustering of fields based on presence/absence data. Numbers in italics represent eigenvalues, a measure of the efficiency of the division. As a rule of thumb an eigenvalue of 0.3 or higher is considered acceptable. Numbers 1 to 28 refer to field numbers as mentioned in Table 5-1 and ANNEX 1.

First-order regrowths on Fields 3, 15 and 19 were separated from each other in the third and fourth division. This shows that if species are given equal weight, independent of abundance, no effect of use-history is observed. Careful examination of the TWINSPAN-table (ANNEX 7; species codes are explained in ANNEX 3) shows that separation is largely due to little frequent species. The table further shows a weak segregation of species along the upper left-lower right diagonal, illustrating the wide distribution of many species, such as *Cecropia* sp., *Trema micrantha, Hedyosmum mexicanum* and *Heliocarpus appendiculatus.*

In an additional TWINSPAN run, species were weighted according to class of crown projection. Clustering was based only on the most important tree species, i.e. only species with coverage classes higher than 4. Fields 2, 12 and 14, with primary or old secondary vegetation, were excluded, together with Fields 9 and 10. Weighting of fields was as in the previous run.

In the first division, Field 4 with a 20 year-old first regrowth was separated from the rest because of strong dominance of *Alchornea latifolia, Costus pictus* and *Miconia trinervia* (Figure 5-4 and ANNEX 8). In the second division, fields in Santiago Tlatepusco were grouped together with Fields 7 and 16. Field 16 was frequently used, while vegetation on Field 7 was heterogeneous and open, probably because of grazing by beasts of burden. *Croton draco* was very abundant in all fields in Santiago Tlatepusco, as well as *Vernonia patens*. Further divisions showed no consistent clustering according to age or order of regrowth, indicating that other factors also play a role. However, first-order regrowths remained together in the same cluster until the last division.

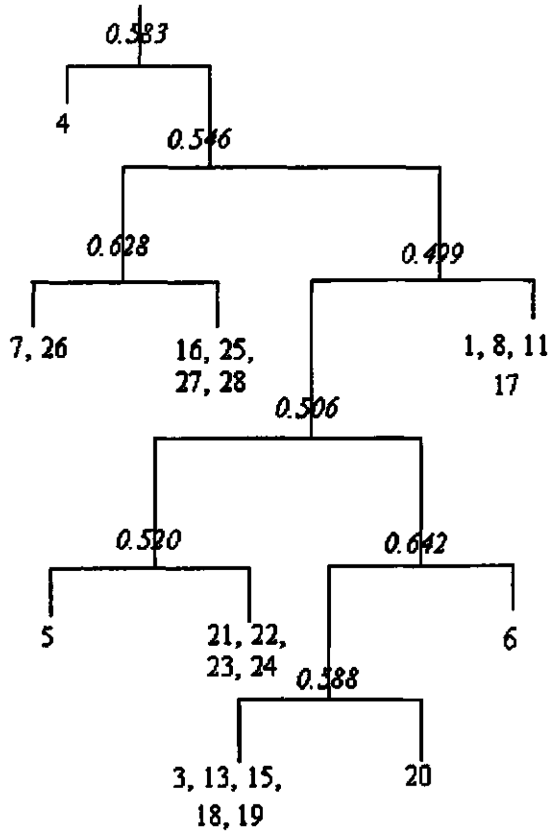

Figure 5-4. TWINSPAN clustering based on crown projection data. Numbers in italics represent eigenvalues. Numbers 1 to 28 correspond to field numbers of Table 5-1 and ANNEX 1.

A powerful method of direct gradient analysis, which can be used to determine whether environmental or management variables are related with species composition, is correspondence analysis. This analysis was therefore applied, using the program CANOCO (Ter Braak 1991), with data on crown projection as the vegetation input; altitude, lithology, village and slope-aspect as environmental variables; and "age of regrowth", "order of regrowth" and "number of years since primary vegetation was cut" as management parameters.

As "time since cutting of primary vegetation" was significantly correlated with both "age" and "order of regrowth" ($r = 0.66$ and $r = 0.49$, respectively), it was not taken into account for further analysis. Though "order of regrowth" was significantly correlated with altitude ($r = -0.44$), both parameters were maintained for correspondence analysis. For the analysis, Fields 2 and 12 were excluded. Fields 9 and 10 were excluded as doubts existed on the correctness of the data on their use-history. Data from the remaining 24 fields were weighted according to their sampled area, resulting in weighting factors 0.25 for Fields 5, 8 and 15, 1.50 for Field 17, and 1.00 for the remaining fields. Species which occurred less than 4 times (see Section 5.3) were given 0-weight in the analysis, and do not influence ordination. This is justified, as the issue of study is secondary vegetation and not the presence of rare species, however important they may be in forest regeneration. Detrended correspondence analysis showed that it was justified to suppose a unimodal response model of species to environmental and management variables. Hence constrained correspondence analysis could be applied to the data on crown projection, using the same restrictions and weighting as in detrended correspondence analysis.

Variables of environment and management were selected in order of their contribution to variation in the species composition. Contributions were tested for statistical significance. Age, altitude, village, lithology and order of regrowth all significantly contributed to explaining variation in species composition between fields, whereas slope-aspect did not. The parameters mentioned explained 33% of the observed variation.

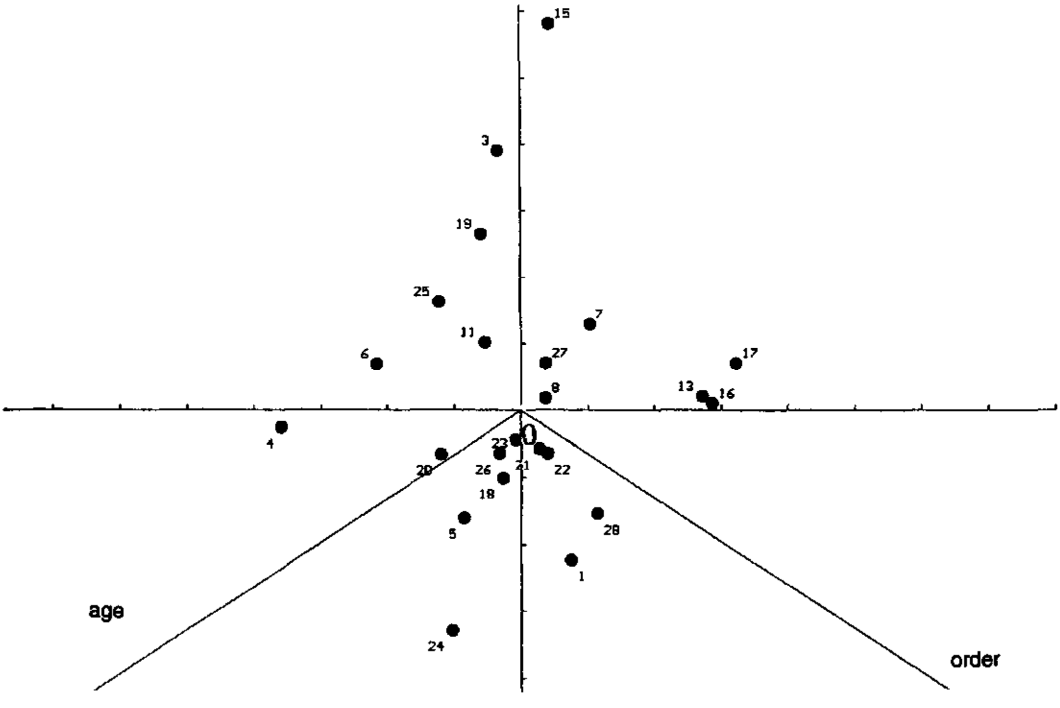

Figure5-5. Field ordination constrained to age and order of regrowth. First-order regrowths in the upper-left quadrant. Frequently used fields are in the lower part of the upper-right quadrant.

An ordination of fields and species was made, constrained to the variables "age" and "order of regrowth", while lithology, altitude and village were assigned as covariables. Fields 2, 9, 10, 12 and 14 were excluded from the ordination. The motive for the exclusion of Field 14 was its excessive influence on the ordination. In the field and species ordinations (Figure 5-5 and 5-6) age decreases along the age-axis from the lower left to the upper right; order of regrowth increases from the upper left to the lower right along the order-axis. The ordination of fields (Figure 5-5) shows consistency with the data on use-history provided by the farmers. The ordination of species (Figure 5-6) reflects the sequences of species that may be expected in function of age and order of regrowth. Together, age and order of regrowth explained 16% of the variation in species composition.

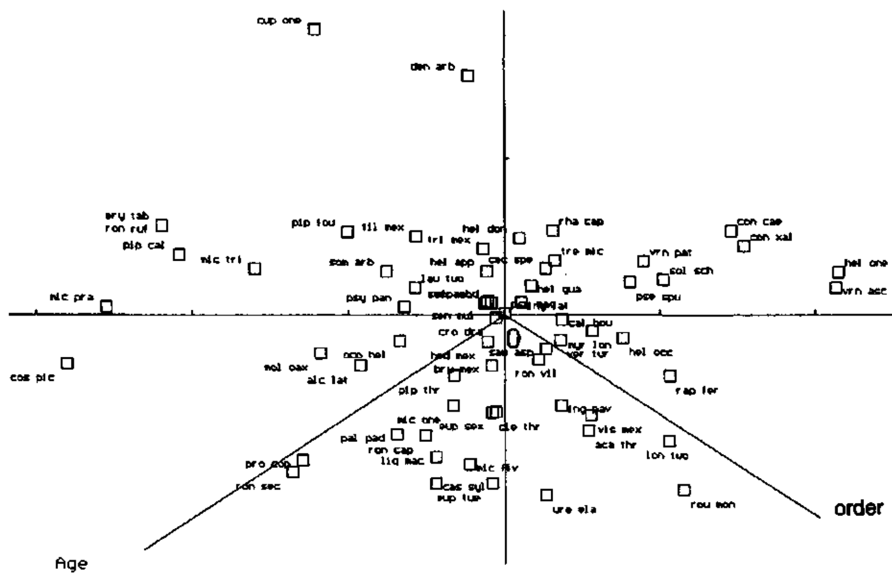

Figure 5-6. Species ordination constrained to age and order of regrowth. Species at the lower-right are those of frequently used fields. Species codes are explained in ANNEX 3.

5.4.3 Altitudinal ranges of frequent species

The altitudinal range of the 30 most frequent species was determined (Figure 5-7). The majority of the 30 most frequent species covered the altitudinal range of the sampled fields to a great extent, i.e. from 360 to 1450 m altitude. However, *Liquidambar macrophylla, Brunellia mexicana, Hedyosmum mexicanum* and *Rapanea ferruginea* were only found above 800 m, in accordance with information provided by the farmers. Some species, for example *Miconia* sp., covered a small altitudinal range in the present survey.

5.4.4 Discussion

Many of the species found in Santa Cruz Tepetotutla and Santiago Tlatepusco also occur at low altitudes (*cf.* Sarukhán 1964, Sousa 1964). However, many do not, confirming that the species composition of secondary communities varies with altitude (see also Section 2.2).

Cluster and correspondence analysis showed that the variation in species composition of secondary vegetation cannot be explained by the order of regrowth and age of secondary vegetation alone, which together explained 16% of the variation in species composition. The parameters village, altitude and lithology also significantly influenced the species composition of secondary vegetation. The observed variation between villages may be due to several factors, such as climate, edaphical factors and geographical factors (see: Figure 2-5 and Section 2.2) and confirms the site-specificity of the development of secondary vegetation. As a result of the simultaneous action of different environmental factors and management, the mosaic of fields with secondary vegetation is quite diverse as to species composition.

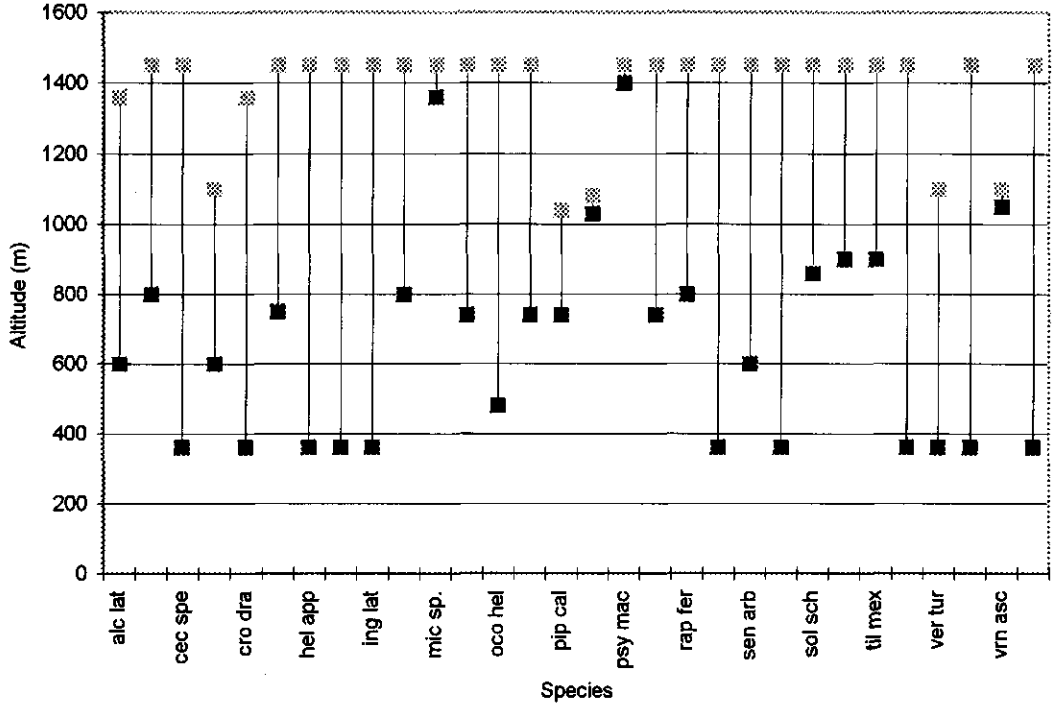

Figure 5-7. Altitudinal ranges of most frequent secondary species. Species codes in ANNEX 3. Most of the frequent species covered a wide altitudinal range. *B. mexicana*, *H. mexicanum* and *L. macrophylla* were confined to the upper part of the considered range.

Vegetation after repeated cultivation at higher altitudes was similar to vegetation on less frequently cultivated fields at lower altitudes. This indicates that repeated stress at these altitudes leads to the immigration of species from stressed environments to lower altitudes. Young first-order regrowths showed strong dominance of few species; in higher order regrowths the tree canopy was shared by several species. Species composition in the 50-year-old regrowth was more similar to chablis in primary vegetation than it resembled 5 to 7 and 12 to 20 year-old regrowths.

The altitudinal range of the most frequent species spanned to a large extent the altitudinal range of the sampled fields. However, some species such as *Brunellia mexicana* and *Hedysosmum mexicanum* showed a preference for higher altitudes, others such as *Croton draco* for lower altitudes.

5.5 Farmers' information on species composition

5.5.1 Introduction

Information on the localization of fields and on the species composition of secondary vegetation on these fields was provided by the farmers in Santa Cruz Tepetotutla (Section 5.3). The number of interviewed farmers (129) permitted a quantitative analysis of data on the spatial distribution of fields, their use-history and species composition. This analysis was undertaken to answer the following questions:

- Are there differences in use-history between geographically grouped fields (sites)?
- Is there a shift in the taxa judged to be the most abundant with increasing number of burns?
- Are there differences between different sites as to the most abundant secondary taxa?
- Are these differences related to differences in landuse-history?

5.5.2 Results

Farmers' information on the localization (*cf.* Section 4.3.1) and use-history of fields and the vernacular names of the most abundant taxa on these fields were recorded (ANNEX 6).

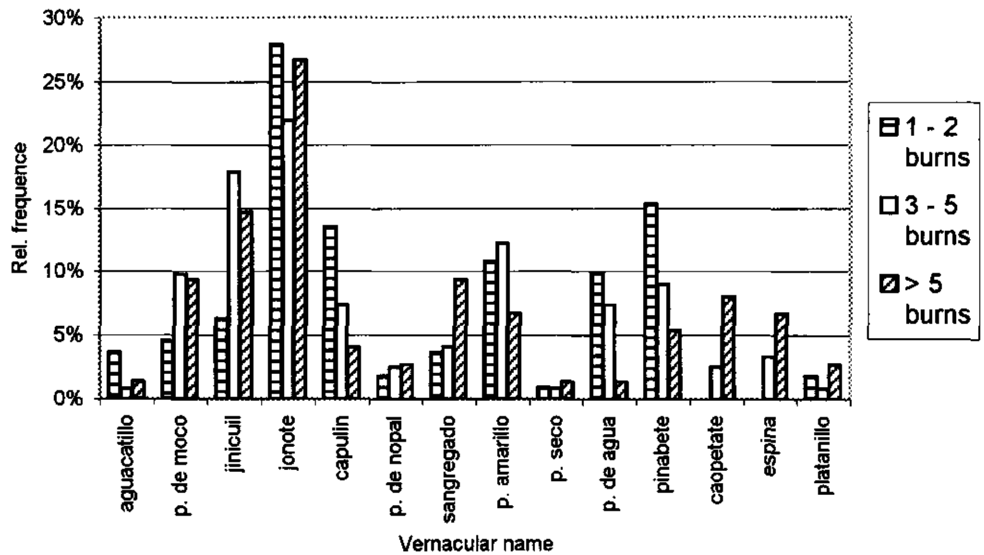

Figure 5-8. Farmers' evaluation of species abundance according to order of regrowth in Santa Cruz Tepetotutla. Figure based on interviews with farmers on 195 fields. Legend: aguacatillo = *Ocotea* sp.; p. = palo; p. de moco = *Saurauia* sp.; jinicuil = *Inga* sp.; jonote = *Heliocarpus* sp.; capulin = *Trema micrantha*; p. de nopal = *Brunellia mexicana*; sangregado = *Croton draco*; p. amarillo = *Vismia mexicana*; p. seco = *Vernonia patens*; p. de agua = *Hedyosmum mexicanum*; pinabete = *Liquidambar macrophylla*; caopetate = *Sticherus* sp. ; espina = *Mimosa* sp.; platanillo = *Heliconia* sp.

Abundance of species varied according to the number of burns (Figure 5-8). 'Palo de moco' (*Saurauia* sp.) and 'jinicuil' (*Inga* sp.) were more frequently named for fields that had been burnt 3 or more times. 'Sangregado' (*Croton draco*), 'caopetate' (*Sticherus* sp.) and 'espina' (*Mimosa* sp.) were most frequently mentioned by farmers with fields that had been burnt more than 5 times. 'Jonote' (principally *Heliocarpus* sp.) was the most frequently named taxon, independently of the number of burns. 'Capulin' (*Trema micrantha*) , 'palo de agua' (*Hedyosmum mexicanum*) and 'pinabete' (*Liquidambar macrophylla*) were mentioned less frequently by the farmers who cultivated more frequently burnt fields.

Five taxa were considered abundant in fields in all site-groups (Figure 5-9; *cf.* Section 4.3.1). Of these, *Croton draco* had a preference for the lower sites in the North-West, where fields have been frequently used. *Hedyosmum mexicanum* was only mentioned by farmers with fields in West and East, generally located at higher elevations as compared to the fields in North-West and Village. *Liquidambar macrophylla* was not mentioned by farmers with fields in North-West, probably due to altitude. *Vismia mexicana* was only considered abundant by farmers with fields in West.

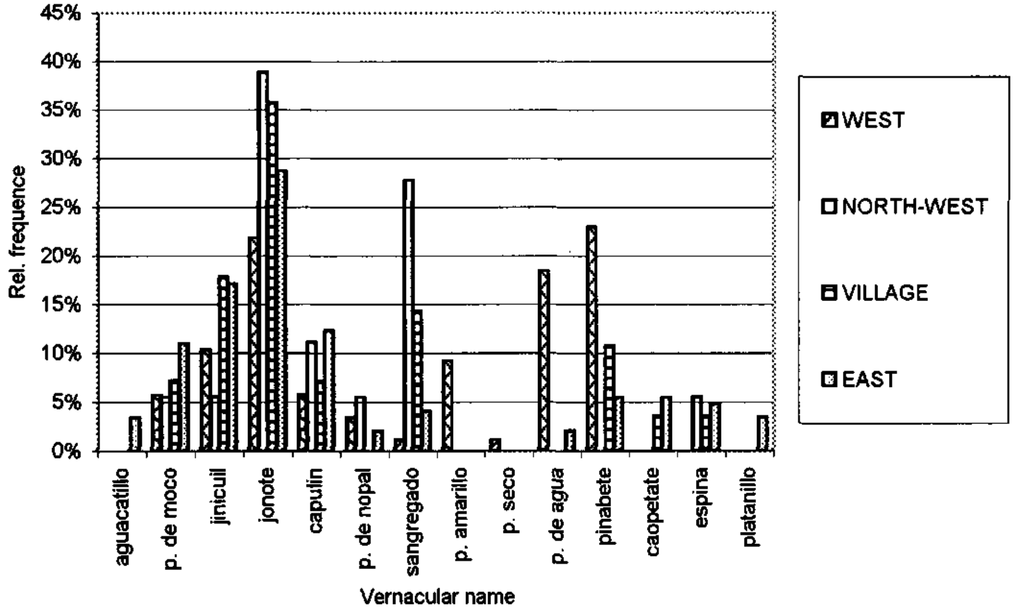

Figure 5-9. Farmers' evaluation of species abundance in four groups of sites in Santa Cruz Tepetotutla. Figure based on interviews with farmers on 195 fields. Five taxa were found in all zones. Legend: aguacatillo = *Ocotea* sp.; p. = palo; p. de moco = *Saurauia* sp.; jinicuil = *Inga* sp.; jonote = *Heliocarpus* sp.; capulin = *Trema micrantha*; p. de nopal = *Brunellia mexicana*; sangregado = *Croton draco*; p. amarillo = *Vismia mexicana*; p. seco = *Vernonia patens*; p. de agua = *Hedyosmum mexicanum*; pinabete = *Liquidambar macrophylla*; caopetate = *Sticherus* sp. ; espina = *Mimosa* sp.; platanillo = *Heliconia* sp.

5.5.3 Discussion

Most species were judged abundant in fields in both West and East, as expected because of the wide geographical distribution of early secondary species (Budowski 1965). However, *Liquidambar macrophylla*, *Hedyosmum mexicanum* and to a lesser extent *Vismia mexicana* were more frequently considered abundant in West than in East. These differences parallel and may be due to the higher numbers of burns on fields in East. Also the herbaceous species *Sticherus* sp. and *Mimosa* sp. were mentioned more for fields in East than in West.

In general the results of the analysis of farmers' information validated the results based on sampling and mathematical models. The correct knowledge that farmers have of their environment offers a good possibility to asses the impact of landuse on vegetation.

5.6 Structural parameters and use-history

5.6.1 Introduction

Structural parameters of a forest provide a very general information on its organization. They are arrived at by determining average values of measurements on many individual trees. These measurements give an indication of the development of trees.

5.6.2 Basal area, number of trees and crown projection

Structural parameters in young secondary vegetation varied as a function of the order of regrowth (Tables 5-3 and 5-4). Smallest values were found in the highest-order regrowths.

Table 5-3. Use-history of fields with 5 to 7 year-old secondary regrowths. Name = first name of the farmer who last cropped the field; Field number corresponds to number in ANNEX 1; Order of regrowth = number of times that the development of secondary vegetation has started since the cutting of primary vegetation; Age = number of years since vegetation was last slashed; primary = time in years since primary or old secondary vegetation was cut.

Name	Field number	Order of regrowth	Age	Primary
Leopoldo	3	1	5	5
Lorenzo	19	1	7	7
Maximino	15	1	5	5
Maximino	8	2	6	12
Joel	21	2	5	15
Aniceto	25	2	6	12
Pedro	22	3	7	14
Benito	17	3	5	17
Justiniano	16	4	5	20

Basal area, average height and number of trees, as well as the crown area index were as similar as one may expect when comparing transects within fields. The largest variation coefficients, indicating architectural heterogeneity of the vegetation, were found in Benito's and Justiniano's fields, with third- and fourth-order regrowths; the smallest variation coefficients were found in Leopoldo's and Lorenzo's fields, with first-order regrowths (Table 5-4).

Table 5-4. Structural parameters in 5 to 7 year-old secondary vegetation. Basal area expressed in $m^2 \cdot ha^{-1}$, correcting for slope; Height = average height of trees; Crown Area Index = sum of horizontal crown-projections of all trees divided by the horizontal surface area of the transects; Number of trees refers to a hectare, correcting for slope; C. of V. = coefficient of variation.

Field	Transect	Basal area	Height	Crown area index.	Number of trees
First order					
Leopoldo	8	29.8	6.3	2.0	12586
	9	29.4	5.2	2.5	17090
	10	26.5	6.0	1.9	16274
	11	35.4	6.9	1.9	12027
	C. of V.	*12%*	*11%*	*13%*	*17%*
Maximino	50	41.0	6.1	5.5	17884
Lorenzo	65	19.0	6.1	3.1	8429
	66	22.7	6.5	4.1	8614
	67	26.3	5.6	4.1	9660
	68	20.0	6.5	3.5	8685
	C. of V.	*14%*	*7%*	*13%*	*6%*
Second order					
Maximino	25	29.9	5.4	1.9	17623
Joel	73	18.5	6.2	2.9	9471
	74	30.9	8.2	3.3	7279
	75	35.5	8.2	4.1	8493
	76	15.1	6.6	2.4	4732
	C. of V.	*39%*	*14%*	*22%*	*27%*
Aniceto	90	23.3	6.27	5.2	10116
	91	43.6	8.58	6.9	10012
	92	27.7	8.43	6.8	11483
	93	34.2	8.46	6.8	9009
	C. of V.	*27%*	*14%*	*12%*	*10%*
Third order					
Pedro	77	13.2	4.6	1.9	8616
	78	18.8	5.4	3.2	8890
	79	19.7	6.1	3.3	9853
	80	20.5	6.6	3.1	7553
	C. of V.	*18%*	*15%*	*22%*	*10%*
Benito	55	11.3	5.0	2.3	10961
	56	31.3	4.5	1.5	9457
	57	10.4	4.8	1.7	9343
	58	11.8	5.4	2.5	11540
	59	3.6	4.3	0.6	3784
	60	7.7	5.0	1.9	7107
	C. of V.	*75%*	*8%*	*39%*	*32%*
Fourth order					
Justiniano	51	3.6	3.7	0.3	2089
	52	2.8	4.7	0.7	2358
	53	5.5	3.6	0.3	2967
	54	17.3	3.2	0.3	3398
	C. of V.	*92%*	*17%*	*49%*	*21%*

Basal area diminished with increasing order of regrowth (Figure 5-10). In first-order regrowths two species were most important: *Heliocarpus appendiculatus* and *Trema micrantha*. The contribution of other species to total basal area was small. However, in one of the transects the contribution of two profusely resprouting trees of *Guarea glabra* was important. In second-order regrowths five species made a major contribution to the basal area: *Brunellia mexicana,* *Hedyosmum mexicanum, Heliocarpus appendiculatus, Saurauia aspera* and, to a lesser degree, *Trema micrantha.* In third- and fourth-order regrowths no single species attained high basal area; dead shrubs and trees made a large contribution, many of which had succumbed under a burden of herbaceous climbers. The relative importance of the category "other species" was highest in second order regrowths.

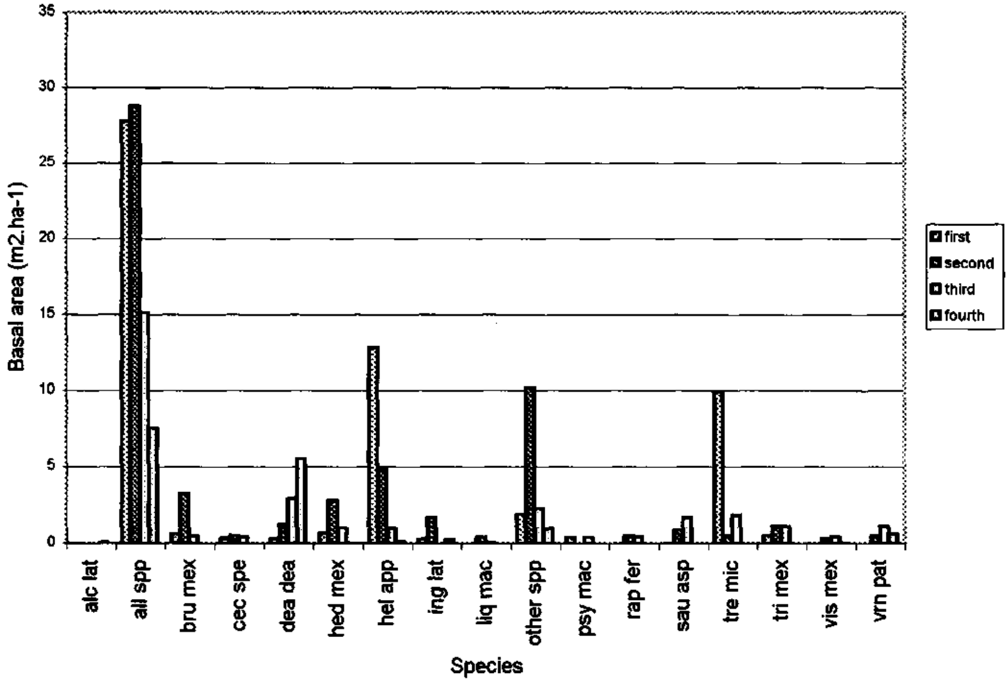

Figure 5-10. Basal area in 5 to 7 year-old regrowths of different order. Basal area is high in first and second order regrowths. Legend: alc lat = *Alchornea latifolia*; all spp = all species; bru mex = *Brunellia mexicana*; cec spe = *Cecropia* sp.; dea dea = dead trees; hed mex = *Hedyosmum mexicanum*; hel app = *Heliocarpus appendiculatus*; ing lat = *Inga latibracteata*; liq mac = *Liquidambar macrophylla*; other spp. = other species; psy mac = *Psychotria macrophylla*; rap fer = *Rapanea ferruginea*; sau asp = *Saurauia aspera*; tre mic = *Trema micrantha*; tri mex = *Trichospermum mexicanum*; vis mex = *Vismia mexicana*; vrn pat = *Vernonia patens*.

Basically the same pattern was observed in the data on crown projection and the number of trees (Figure 5-11 and 5-12). The total number of trees amounts to more than 1 m^{-2} in first-order regrowths. This, and the high coverage, as indicated by a crown area index close to 3, illustrates crowding in these regrowths. Trees need to grow fast to survive and allocate energy and nutrients to this end. This seems to be the case for *Trema micrantha*, the species which combines by far the highest number of individuals with a relatively low basal area in the first-order regrowths.

Also in 12 to 20 year-old regrowths with different use-histories (Table 5-5), a great variation in structural parameters was observed between fields (Table 5-6). Most trees were found in the oldest second-order regrowths (5, 23 and 24), where basal area and crown area index were also highest. The number of trees is high when compared to the first regrowths of similar age on Fields 4 and 6.

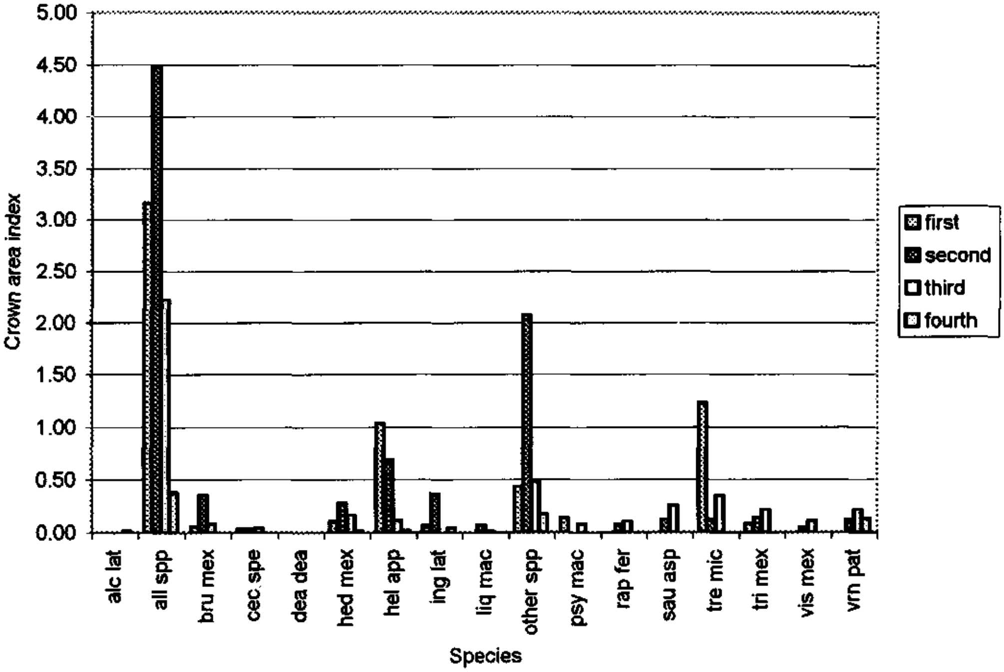

Figure 5-11. Crown area index in regrowths of different order. Legend: see Figure 5-10.

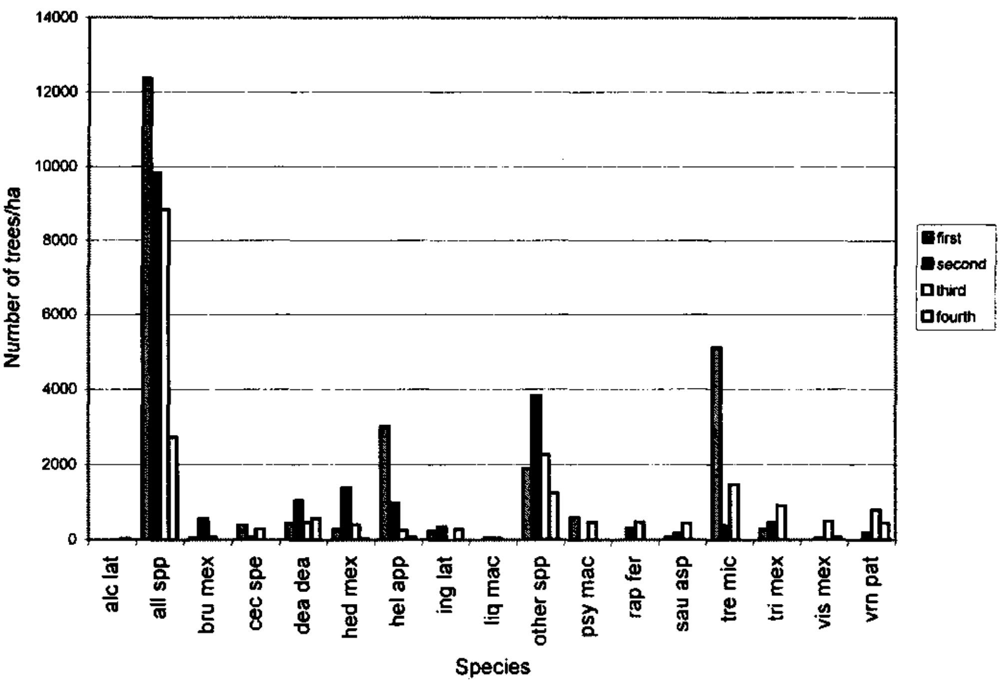

Figure 5-12. Number of trees in regrowths of different order. Legend: see Figure 5-10.

Table 5-5. Use-history of fields with 12 to 20 year-old secondary regrowths. Name = first name of the farmer who last cropped the field; Field number = field number as listed in ANNEX 5; Order of regrowth = number of times that secondary vegetation started developing on the field; Age = number of years since vegetation was last slashed; Primary = time in years since primary or old secondary vegetation was cut.

Name	Field number	Order of regrowth	Age	Primary
Andres	11	1	12	12
Francisco	6	1	16	16
Francisco	4	1	20	20
Jorge	18	2	12	16
Gabino	20	2	12	22
Pedro	23	2	14	21
Romeo	5	2	17	30
Andres	24	2	20	40
Jorge	1	4	12	30

In 12 year-old regrowths the lowest number of trees and basal area were found on Field 18, with a second-order regrowth. Here patches of herbaceous species were found that one would normally expect in higher-order regrowths, indicating the action of an unknown stress factor on this field. Basal area and crown area index were low and similar to those on Field 1, with a fourth-order regrowth. Differences between the first-order regrowth on Field 11 and the second-order regrowth on Field 20 were small (Table 5-6), indicating that Field 20 is more representative of second-order regrowths than Field 18.

Table 5-6. Structural parameters in 12 to 20 year-old secondary regrowths. Data were calculated on a hectare basis, correcting for slope; basal area is expressed in $m^2 \cdot ha^{-1}$; crown area index was calculated as the sum of the horizontal crown projections of all trees divided by the horizontal projection of the surface area of the transects.

Field number	1	4	5	6	11	18	20	23	24
Number of trees	5658	5834	8749	6267	4560	2757	4149	8717	8789
Basal area	17.1	33.5	43.1	26.6	30.1	15.6	33.4	43.2	55.8
Crown area index	1.92	2.47	3.27	1.72	2.78	2.07	3.12	3.17	5.22

In the 50-year-old regrowth, basal area was higher and the number of trees lower than in primary forest, where many small eco-units in different phases of development occur, as a consequence of frequent treefall. Some eco-units in primary forest are made up of many young trees, which explains the higher number of trees. Crown area indices in both situations were similar (Table 5-7); similar values were found in several younger regrowths. Basal area in primary forest was not very different from that in 5 to 7 year-old first-order regrowths.

Table 5-7. Structural parameters in 50-year-old secondary and primary forest. Data were calculated on a hectare basis, correcting for slope; basal area is expressed in $m^2 \cdot ha^{-1}$; crown area index was calculated as the sum of the horizontal crown projections of all trees divided by the horizontal projection of the surface area of the transects.

	Basal area	Number of trees	Crown area index
50 year-old secondary forest	50.17	3045	2.87
primary forest	37.42	4073	2.88

5.6.3 Height-diameter relations in trees of populations of frequent species

The relation between total height and stem diameter is parametric. When tree architecture conforms to a hereditary pattern issued from a seed, the quotient is a constant ($h = 100 \cdot d$ in Guyana, Oldeman 1974). This constant was not checked in Mexico, where it might vary between regions because of variation in environmental circumstances. Therefore, the straight line **h** = 100·d here is used as an arbitrary reference curve, the biological significance of which remains an assumption. If the constant in the Chinantla might differ from 100, the graphs can be easily corrected and their comparison remains the same.

Recently broken trees show $h < 100 \cdot d$ at small diameters. When trees grow strongly in height, either because they regenerate by forming shoots on a broken trunk or because they grow up in a narrow, chimney-like volume as found in very dense plantations, $h > 100 \cdot d$. When tree crowns expand, increases in height are smaller than 100 times the increase in d.

Height-diameter (h-d) relations of trees can be used as a rough indication of the stage of development of trees. In trees of the future, $h > 100 \cdot d$: crowns have not expanded and trunks are slender. Low values indicate trees of the present with expanded crowns, thickened trunks and a stagnating height growth. This is explained by physiological factors linked to the sapstream (Oldeman 1990).

In the following sections, h-d relations of trees of some frequent and important species will be observed in a selection of fields: *Trema micrantha*; *Heliocarpus appendiculatus*; *Hedyosmum mexicanum*; *Alchornea latifolia*; *Trichospermum mexicanum*; and *Liquidambar macrophylla*.

5.6.3.1 H-d relations in trees of populations of *Trema micrantha*

In *T. micrantha* a dense cloud of points is observed to the left of the $h = 100*d$ line, trees being mostly thinner than 10 cm (Figure 5-13). Relatively few trees show signs of crown expansion. Some of these are found in Fields 19 and 11, both first-order regrowths. When young, the trees of this species invest more in height than in crown expansion. In regrowths older than 12 years the species was hardly found, indicating that trees of this species usually die before reaching this age. The foregoing means that trees of *T. micrantha* participate marginally in the architecture of biostatic eco-units. Too few of them remain.

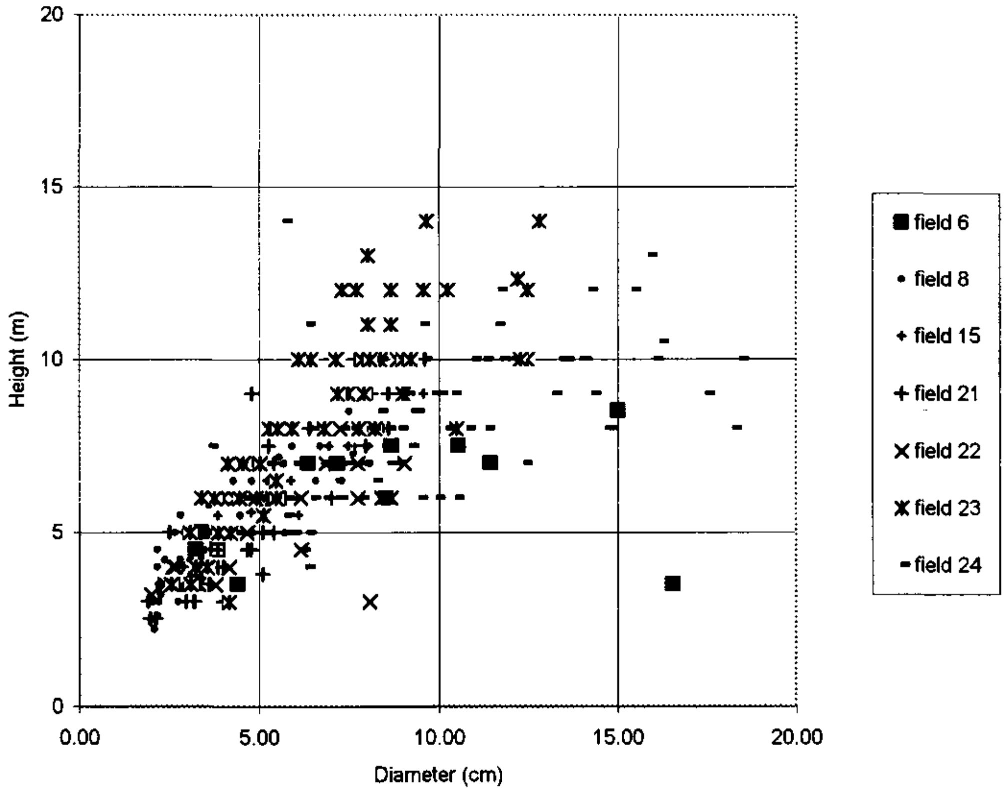

Figure 5-15. H-d relations in trees of populations of *H. mexicanum* in secondary regrowths of varying age and order of regrowth. Trees in the 14-year-old second-order regrowth in Field 23 are slender and have not expanded their crowns; in the second-order regrowth in Field 24 trees are tall and strong.

5.5.3.4 H-d relations in *Trichospermum mexicanum*

Several trees of *T. mexicanum* in the first-order regrowth in Field 11 have a relatively thick trunk, typical of crown-expansion (Figure 5-16). These trees are 12 to 20 m high. Also some individuals on Fields 4 and 6 are at the right of the h = 100*d line. These trees have heights around 8 m. This species thus shows a similar flexibility as *H. appendiculatus*. The difference between both species seems to reside in their altitudinal distribution, *T. mexicanum* being confined to a lower range than *H. appendiculatus* (see Section 5-4).

In the young regrowths in Fields 3, 8, 15 and 17 few trees of T. mexicanum show signs of crown expansion. Apparently the trees in this stage are to young to become trees of the present. Trees of this species can only (co)determine the organization of biostatic eco-units if these are more than 12 years old.

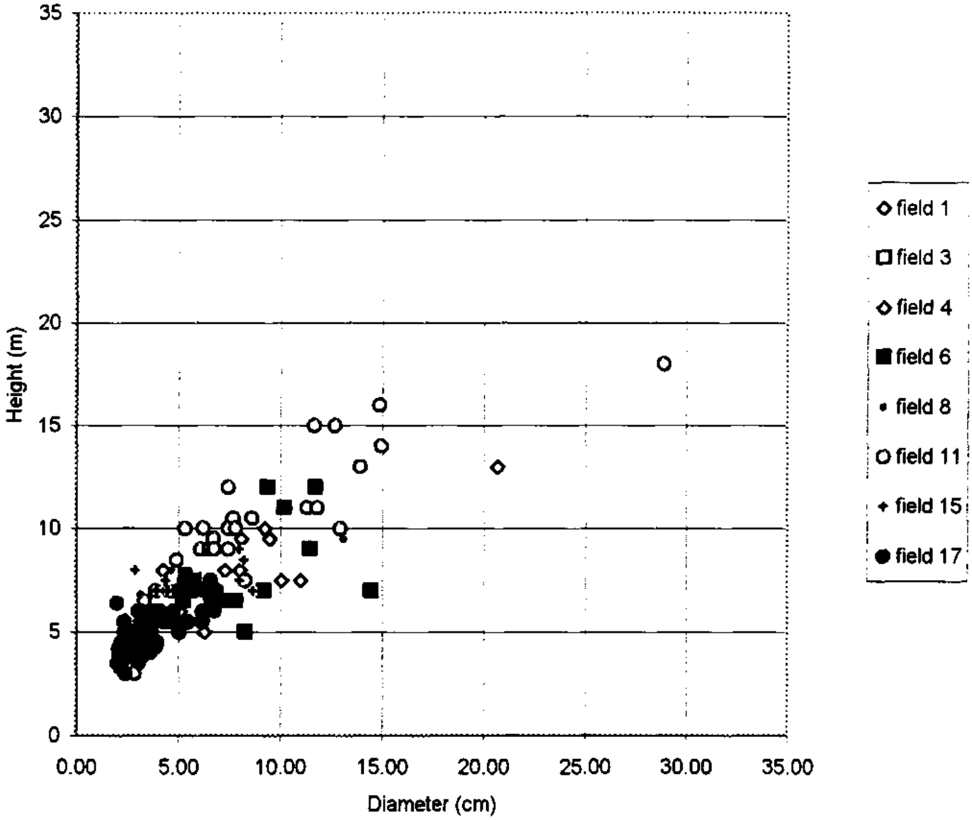

Figure 5-16. H-d relations in trees of populations of *T. mexicanum* in regrowths of different ages and order. Few trees of this species participate in structuring biostatic eco-units. They may do so in eco-units of more than 12 years old.

5.5.3.5 H-d relations in *Alchornea latifolia*

Trees of different populations of *A. latifolia* (Figure5-17) also show the flexibility observed in *H. apendiculatus* and *T. mexicanum*. In the 16- and 20-year-old first order regrowths on Fields 6 and 4, several trees have relatively thick trunks, indicating crown expansion. In the 20-year-old regrowth on Field 4 these trees have heights from 8 to 14 m; in the 16-year-old the regowth in Field 6 their heights vary from 6 to 10 m. Also in the 12-year-old fourth-order regrowth in Field 1 several trees of the present are found. These have heights varying from 4 to 8 m.

The foregoing shows that trees of *A. latifolia* determine in the organization of biostatic eco-units in first order regrowths of 20 years old, as indicated by the large number of trees at the right of the h = 100*d reference line. They start crown expansion at young age and can do this at low heights of the trees, as observed in Field 1.

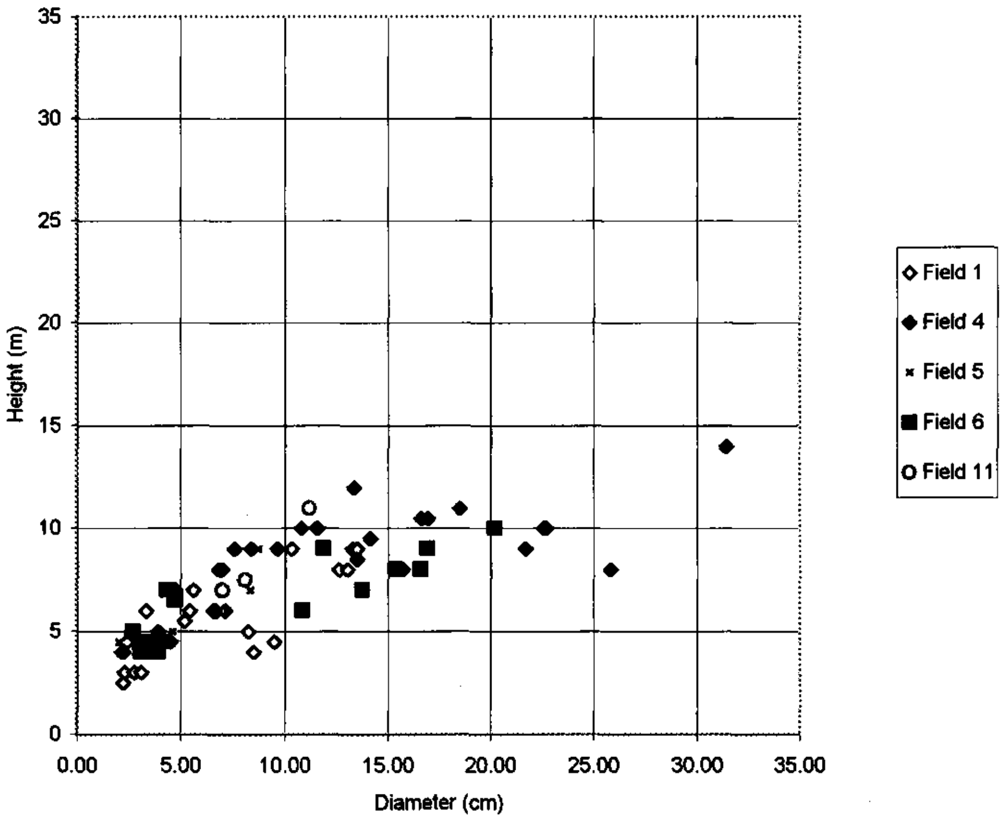

Figure 5-17. H-d relations in trees of populations of *A. latifolia* in regrowths of different ages and order. Trees of *A. latifolia* show great flexibility.

5.5.3.6 H-d relations in trees of populations of *Liquidambar macrophylla*

Trees of *L. macrophylla* quite closely follow the reference line (Figure 5-18). The three trees of 35 m height all stem from a trunk cut 50 years ago at a height of approximately 1.50 m. Two of these trees had already expanded their crowns and formed thick trunks. The other remained suppressed in the stage of potential tree. The height attained by the trees of *L. macrophylla* before starting crown expansion is typical of a long living pioneer species.

5.6.4 Discussion

Basal area, crown projection and the number of trees in both 5 to 7 and 12 to 20 year-old secondary vegetation were related with the order of regrowth of secondary vegetation in accordance with the findings of Cook (1921). In 50-year-old secondary vegetation, basal area was higher and the number of trees lower than in the chablis in primary forest, while crown area indices were similar.

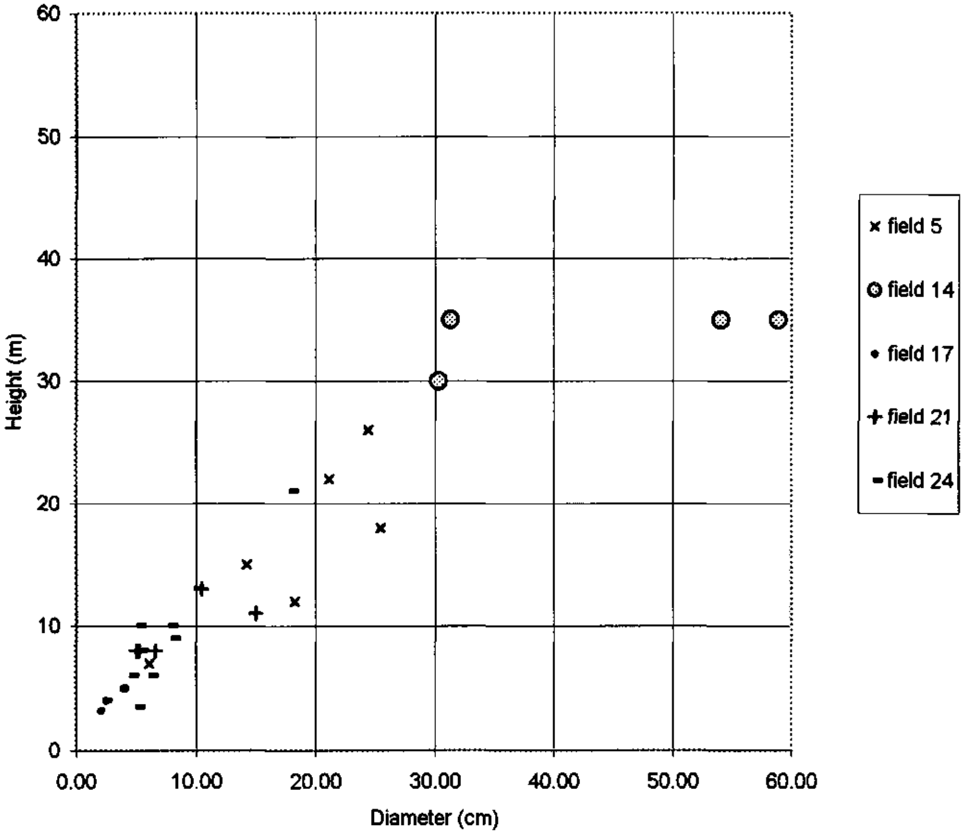

Figure 5-18. H-d relations in trees of populations of *L. macrophylla* in regrowths of different ages and order. *L. macrophylla* is a long-living pioneer species. The trees of 35 m height reiterated from a tree cut 50 years ago.

The form of the cloud of points obtained by plotting 100·d against h is characteristic for the population of trees of one species that grows in an eco-unit. The data indicate a relation between the order of regrowth and the shape of the cloud of points for a certain species (cf. *Heliocarpus appendiculatus*). This shows similarity of eco-units in regrowths of the same order.

On the other hand, the data demonstrate the flexibility of the response of trees to a changing environment, confirming the findings of Vester (1997). In some eco-units the trees of a certain species remain suppressed as trees of the future, whereas they determine the organization of other eco-units in regrowths of similar age as trees of the present.

5.7 Characteristics and sequences of eco-units

5.7.1 Introduction

Drawings to scale were made of representative transects in 5 to 7 and 12 to 20 year-old regrowths, to obtain an integral view of the development of eco-units in the secondary regrowths. The drawings combined in a uniform manner architectural and taxonomic data of individual trees. Simplified, they show the physiognomy of the regrowths as observed in the field. To simplify the drawings of transects in 5 to 7 and 12 to 20 year-old regrowths the program TREEDRAW was used (Leersnijder 1997). Drawings of old secondary vegetation and chablis in primary vegetation were done by hand in a physiognomic style.

5.7.2 Eco-units in 5 to 7 year-old regrowths

In field 3, the first-order regrowth was a mosaic of large eco-units in the aggradation phase, which showed a dense grouping of trees (Figure 5-19). The trees of principally *Trema micrantha* and *Heliocarpus appendiculatus* had a limited volume available for development and had poor access to energy and nutrients. Several trees of *T. micrantha* were dying, whereas the most vigorous trees belonged to *H. appendiculatus*.

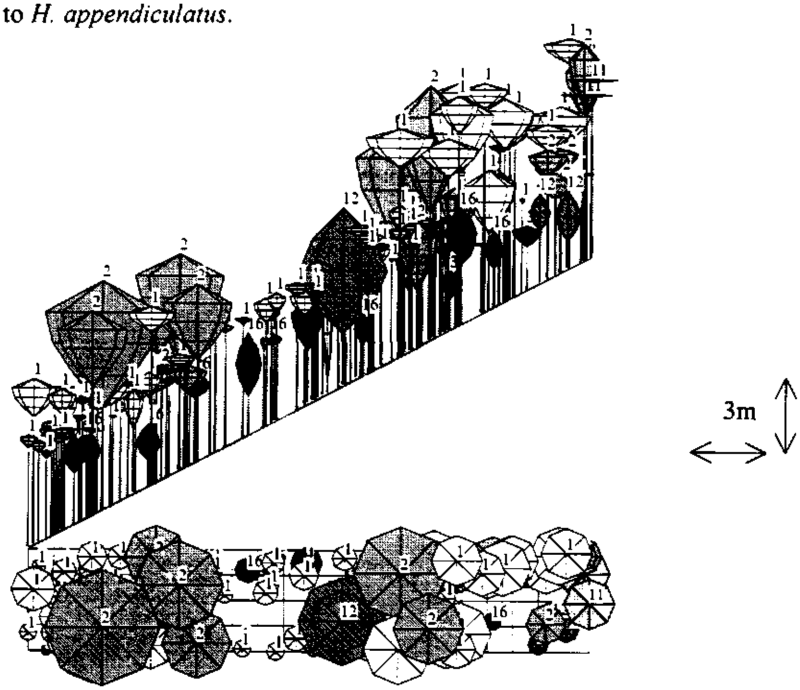

Figure 5-19. Eco-unit in a 5-year-old first-order regrowth at 1050 m altitude. In the transect on field 3, trees of *T. micrantha* are the most frequent; trees of *H. appendiculatus* are higher and have more expanded crowns. See also Figures 5-12 and 5-13. 1. *Trema micrantha* 2. *Heliocarpus appendiculatus* 3. *Hedyosmum mexicanum* 4. *Trichospermum mexicanum* 5. *Psychotria macrophylla* 6. *Vernonia patens* 7. *Vismia mexicana* 8. *Saurauia aspera* 9. *Brunellia mexicana* 10. *Rapanea ferruginea* 11. *Cecropia* sp. 12. *Inga latibracteata* 13. *Alchornea latifolia* 14. *Liquidambar macrophylla* 15. dead trees 16. other species.

Just like the first-order regrowth on Field 3, the second-order regrowth on Field 21 consisted of large eco-units in the aggradation phase (Figure 5-20). However, unlike the situation of nearly single-dominance in the first-order regrowth, trees of several species shared the canopy in the second-order regrowth. Among these species were *Saurauia aspera* and *Brunellia mexicana,* along with *T. micrantha* and *H. appendiculatus*. Common species in the rather prominent undergrowth were *Miconia* sp., *Eupatorium sexangulare, Lonchocarpus* sp., *Heliocarpus donnell-smithii, Palicourea padifolia, Psychotria panamensis* and *Senecio arborescens.*

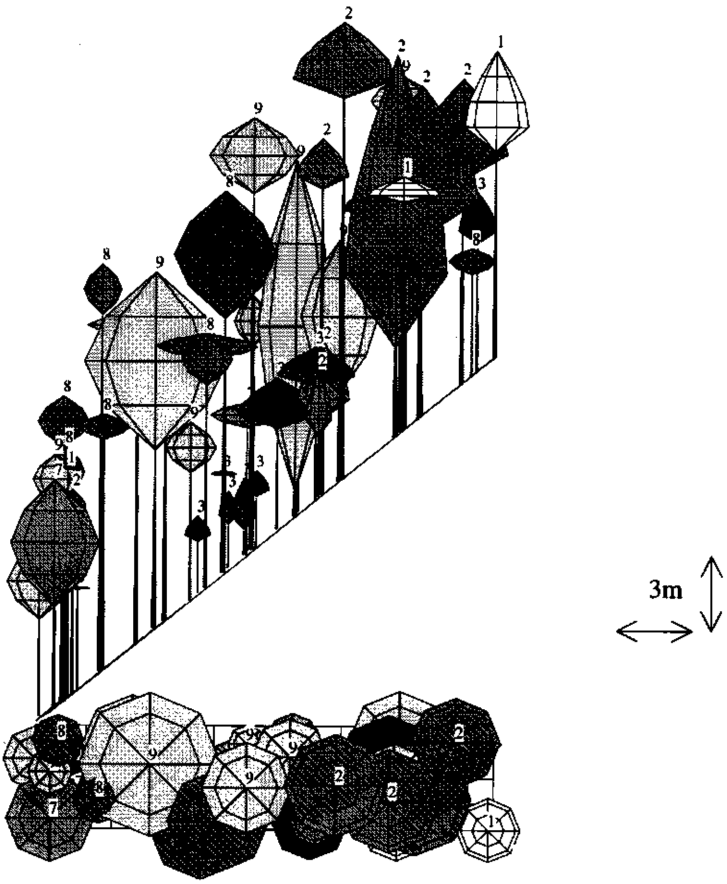

Figure 5-20. Eco-unit in a 5-year-old second-order regrowth at 1450 m altitude. Polydominance of tree-species is observed in the canopy of this transect on Field 21. 1. *Trema micrantha* 2. *Heliocarpus appendiculatus* 3. *Hedyosmum mexicanum* 4.*Trichospermum mexicanum* 5. *Psychotria macrophylla* 6. *Vernonia patens* 7. *Vismia mexicana* 8. *Saurauia aspera* 9. *Brunellia mexicana* 10. *Rapanea ferruginea* 11. *Cecropia* sp. 12. *Inga latibracteata* 13. *Alchornea latifolia* 14. *Liquidambar macrophylla* 15. dead trees 16. other species.

The second-order regrowth in Field 8 also consisted of a mosaic of large eco-units in the aggradation phase. However, in this case there was no polydominance: trees of only a few species shared the canopy. Among these, *Hedyosmum mexicanum* was the most frequent (Figure 5-21). Also several trees of *Trichospermum mexicanum* were present.

Several small eco-units made up the third-order regrowth in Field 17 (Figure 5-22). After early fragmentation in the innovation phase, the eco-units were fusing in the aggradation phase. This can be observed in both the lower and the upper part of the transect. Trees of several species shared the rather even canopy, among them *Vismia mexicana* and *Rapanea ferruginea*. The canopy was situated at a lower height than in first- and second-order regrowths. Low branching was observed in several trees, indicating that shrub-like forms were the optimal organisation form in this environment. Many trees belonged to the category "other species", which here principally contained species of the genus *Conostegia*: *C. caelestis, C. icosandra* and *C. xalapensis*. Trees of *Heliocarpus* sp. and *Vernonia aschenborniana* were also frequently observed.

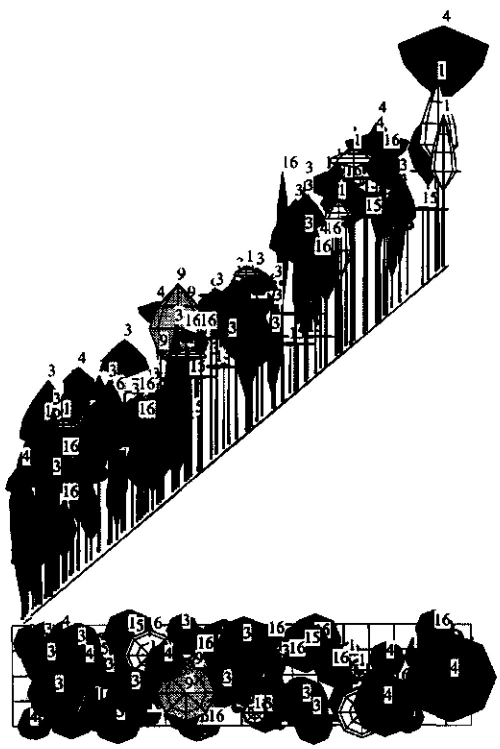

Figure 5-21. Eco-unit in a 6-year-old second-order regrowth at 1120 m altitude. Few species share the canopy in this aggrading eco-unit in Field 8. 1. *Trema micrantha* 2. *Heliocarpus appendiculatus* 3. *Hedyosmum mexicanum* 4.*Trichospermum mexicanum* 5. *Psychotria macrophylla* 6. *Vernonia patens* 7. *Vismia mexicana* 8. *Saurauia aspera* 9. *Brunellia mexicana* 10. *Rapanea ferruginea* 11. *Cecropia* sp. 12. *Inga latibracteata* 13. *Alchornea latifolia* 14. *Liquidambar macrophylla* 15. dead trees 16. other species.

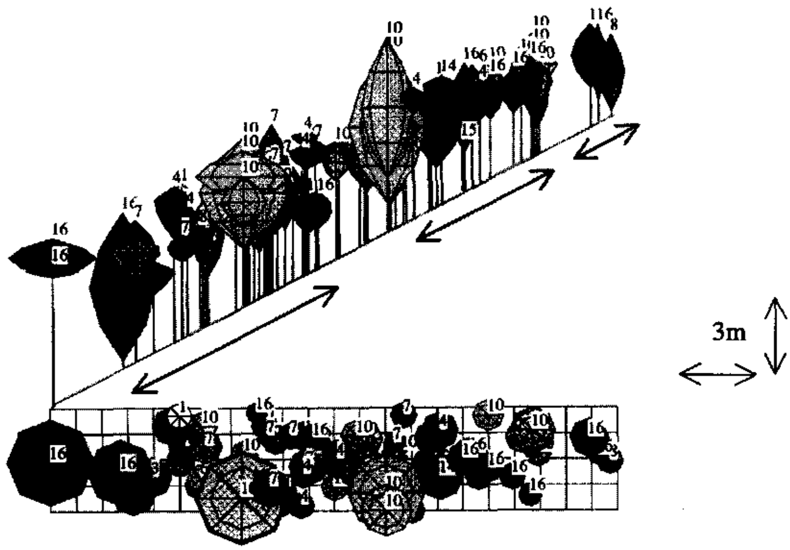

Figure 5-22. Eco-units in a 5-year-old third-order regrowth at 1100 m altitude. Three eco-units in Field 17. Legend: see Figure 5-21.

Many small eco-units in the aggradation phase were found in the fourth-order regrowth (Figure 5-23). The small eco-units were composed of few, small trees, which branched at low height. The eco-units had resulted from early fragmentation of a large eco-unit in the innovation phase, which still surrounded the small eco-units at the time of sampling. Fusion of the small eco-units could therefore not occur as yet. Trees of *Inga latibracteata*, *Alchornea latifolia* and *Vismia mexicana* formed a small eco-unit in the lower part of the transect. The category "other species" included *Croton draco*, *Heliocarpus* sp., *Hibiscus uncinellus*, *Ocotea helicterifolia* and *Licaria peckii.*

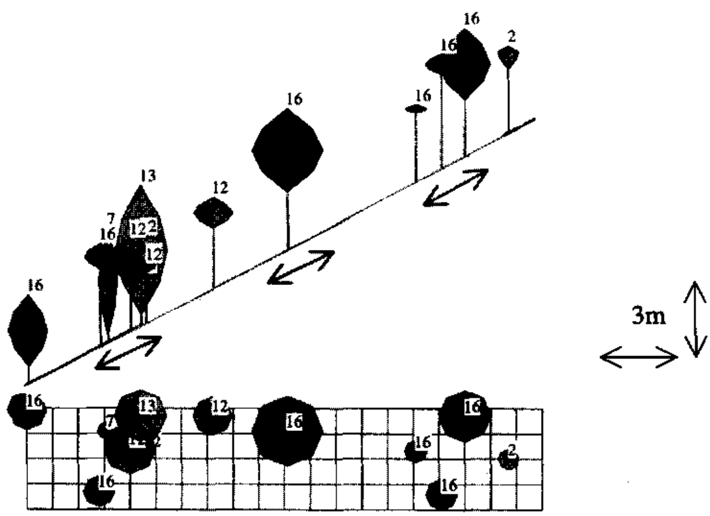

Figure 5-23. Small eco-units in a 5-year-old fourth-order regrowth at 880 m altitude. Several small eco-units of isolated trees and small groups of trees occur in Field 16, which formed by early fragmentation of a large eco-unit in the innovation phase. 2. *H. appendiculatus* 7. *V. mexicana* 12. *I. latibracteata* 13. *A. latifolia* 16. other species.

Heliocarpus appendiculatus and *T. micrantha* (Figure 5-26). This stage, in which an aggrading eco-unit still contains remnants of earlier eco-units is rightly called "reorganisation phase" in the terms of Bormann & Likens (1979), as stated by Oldeman (1990). In the present case, the aggradation phase dominated by trees of *H. mexicanum* succeeds a eco-unit with *T. micrantha* and *H. appendiculatus* which did not reach its biostatic phase.

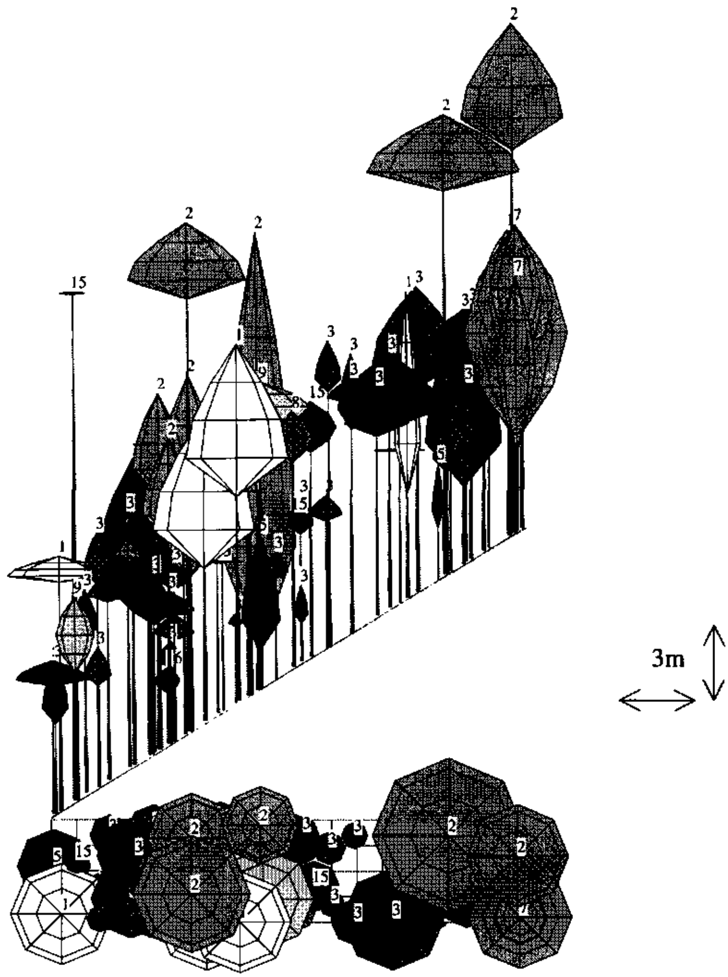

Figure 5-26. Eco-unit in a 14-year-old second-order regrowth at 1450 m altitude. In the regrowth of Field 23, several trees of *H. appendiculatus* and *Trema micrantha* overtop a near-continuous cover of *H. mexicanum*. After the death of the former, *H. mexicanum* will dominate the canopy, together with some trees of *V. mexicana, S. aspera* and *B. mexicana*. 1. *Trema micrantha* 2. *Heliocarpus appendiculatus* 3. *Hedyosmum mexicanum* 4.*Trichospermum mexicanum* 5. *Psychotria macrophylla* 6. *Vernonia patens* 7. *Vismia mexicana* 8. *Saurauia aspera* 9. *Brunellia mexicana* 10. *Rapanea ferruginea* 11. *Cecropia* sp. 12. *Inga latibracteata* 13. *Alchornea latifolia* 14. *Liquidambar macrophylla* 15. dead trees 16. other species.

The transect in the 20-year-old second-order regrowth in Field 24 (Figure 5-27) probably shows a later phase in the development of the eco-unit in the quite distant Field 23, depicted in Figure 5-26.

Two eco-units can be distinguished. The biostatic eco-unit at the left was structured by trees of the present of *Hedyosmum mexicanum*. At the right, there is a multi-species eco-unit in the aggradation phase, probably after the fall of one or several trees of *Hedyosmum mexicanum*. This indicates that a single, large eco-unit built by *Hedyosmum mexicanum* started fragmenting in the biostatic phase at the age of approximately 20 years.

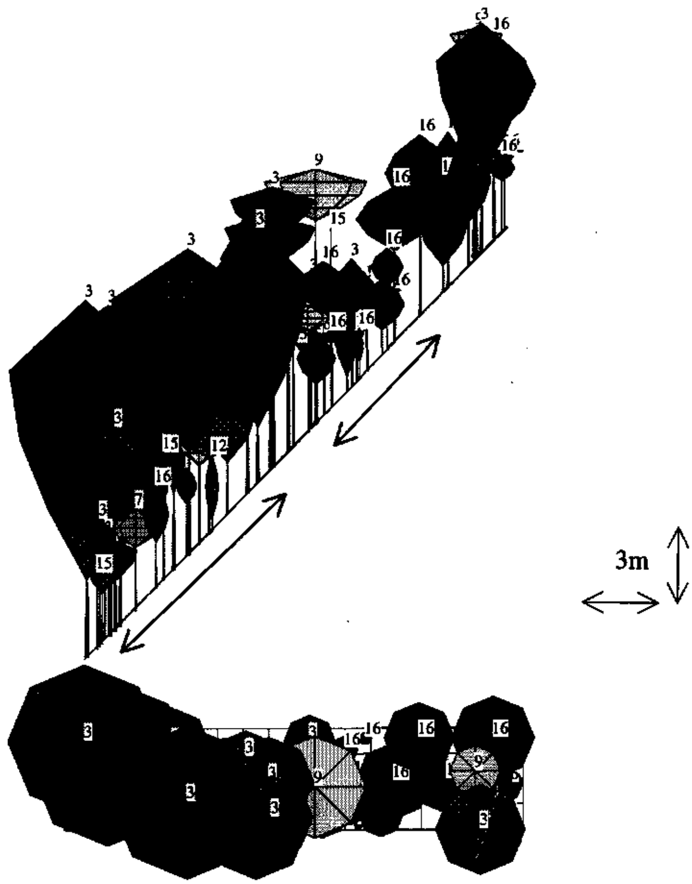

Figure 5-27. Eco-units in a 20-year-old second-order regrowth at 1450 m altitude. At the left of the transect in Field 24, a biostatic eco-unit dominated by trees of *Hedyosmum mexicanum* is observed. At the right an eco-unit in the early aggradation phase with small trees of several species is observed, which develops after fragmentation of the eco-unit dominated by *H. mexicanum*. 1. *Trema micrantha* 2. *Heliocarpus appendiculatus* 3. *Hedyosmum mexicanum* 4.*Trichospermum mexicanum* 5. *Psychotria macrophylla* 6. *Vernonia patens* 7. *Vismia mexicana* 8. *Saurauia aspera* 9. *Brunellia mexicana* 10. *Rapanea ferruginea* 11. *Cecropia* sp. 12. *Inga latibracteata* 13. *Alchornea latifolia* 14. *Liquidambar macrophylla* 15. dead trees 16. other species.

Not all second-order regrowths aged between 12 and 20 years consisted of eco-units structured by *Hedyosmum mexicanum*. This is shown by the transect of Field 18 in Figure 5-28, in which two eco-units are distinguished. The biostatic eco-unit at the right was dominated by trees of *I. latibracteata* reiterated from stumps. The eco-unit at the left was in the aggradation phase. In both eco-units many "other species" were present, but no *Hedyosmum mexicanum*. In the second-order regrowth in Field 20 a similar situation was observed.

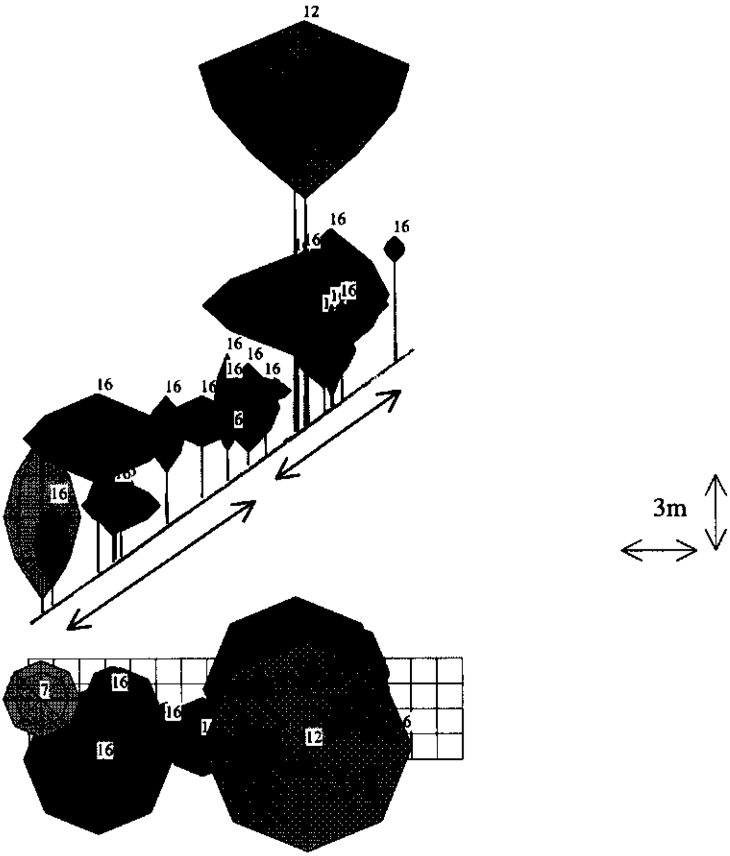

Figure 5-28. Eco-units in a 12-year-old second-order regrowth at 1360 m altitude. Most of the trees in the transect of Field 18 belong to "other species". 1. *T. micrantha* 2. *H. appendiculatus* 3. *H. mexicanum* 4. *T. mexicanum* 5. *P. macrophylla* 6. *V. patens* 7. *Vismia mexicana* 8. *Saurauia aspera* 9. *Brunellia mexicana* 10. *Rapanea ferruginea* 11. *Cecropia* sp. 12. *Inga latibracteata* 13. *Alchornea latifolia* 14. *Liquidambar macrophylla* 15. dead trees 16. other species.

In the transect in the 12-year-old fourth-order regrowth in Field 1, four eco-units are distinguished (Figure 5-29). Fragmentation had occurred in an early phase (*cf.* Figure 5-23). After 12 years, fusion of the eco-units was near. The resulting large eco-unit will probably be structured by trees of *Alchornea latifolia*, the same species that determined the architecture of biostatic eco-units in the first order regrowth of Field 4.

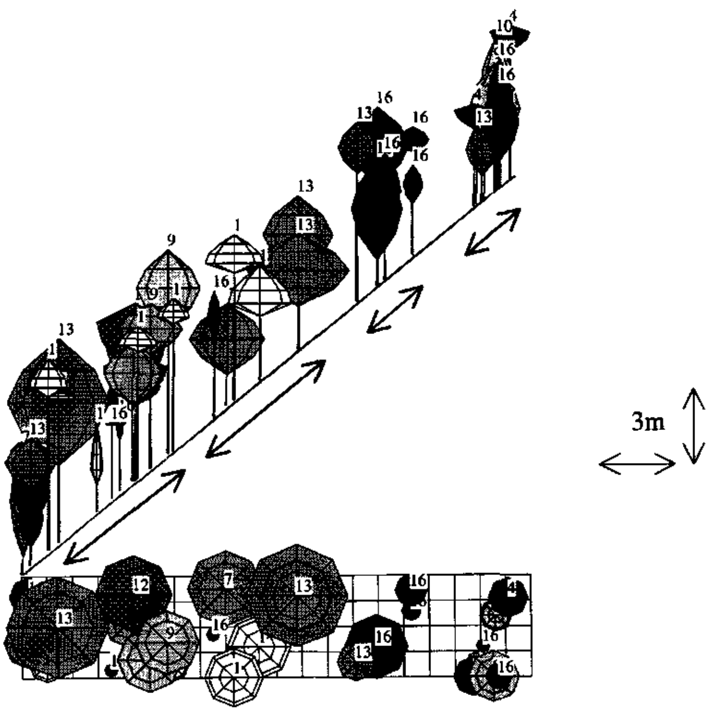

Figure 5-29. Eco-units in a 12-year-old fourth-order regrowth at 850 m altitude. Several eco-units are distinguished in Field 1. *Alchornea latifolia* plays a role in most of them. The eco-units are nearing each other and will soon form a closed cover. Compare with Figure 5-17. Comparison with first- order regrowths in Figure 5-13 and 5-18 shows that the path followed in fourth-order regrowths is quite different. Note also how small the trees are, as compared to the trees in the first-order regrowth of similar age. 1. *Trema micrantha* 2. *Heliocarpus appendiculatus* 3. *Hedyosmum mexicanum* 4.*Trichospermum mexicanum* 5. *Psychotria macrophylla* 6. *Vernonia patens* 7. *Vismia mexicana* 8. *Saurauia aspera* 9. *Brunellia mexicana* 10. *Rapanea ferruginea* 11. *Cecropia* sp. 12. *Inga latibracteata* 13. *Alchornea latifolia* 14. *Liquidambar macrophylla* 15. dead trees 16. other species.

The drawings of the 12 to 20 year-old regrowths are consistent with the drawings of the 5 to 7 year-old regrowths and, like the latter, illustrate the findings of Section 5-6. They confirm that early fragmentation is common in fourth-order regrowths. However, they also show that fusion can occur in these regrowths at the age of approximately 12 years. Trees of *Alchornea latifolia* developed well in both early and late fragmented eco-units. Apparently, this species has a very flexible temperament as to shade in the early phases of development. The drawings of the 12 to 20 year-old regrowths also show that second-order regrowths may or may not show polydominance.

5.7.4 Eco-units in old secondary vegetation

Trees of *Protium copal* and *Ticodendron incognitum* dominated the two eco-units in the transect in old secondary vegetation (Figure 5-30). Trees of *Liquidambar macrophylla*, which had reiterated after cutting ("stump suckers"), dominated another eco-unit not represented here. Reiteration, in addition to rate and persistence of growth, had helped these trees to survive and develop in this environment. *Protium copal*, on the other hand, produced long trunks, which branched high up.

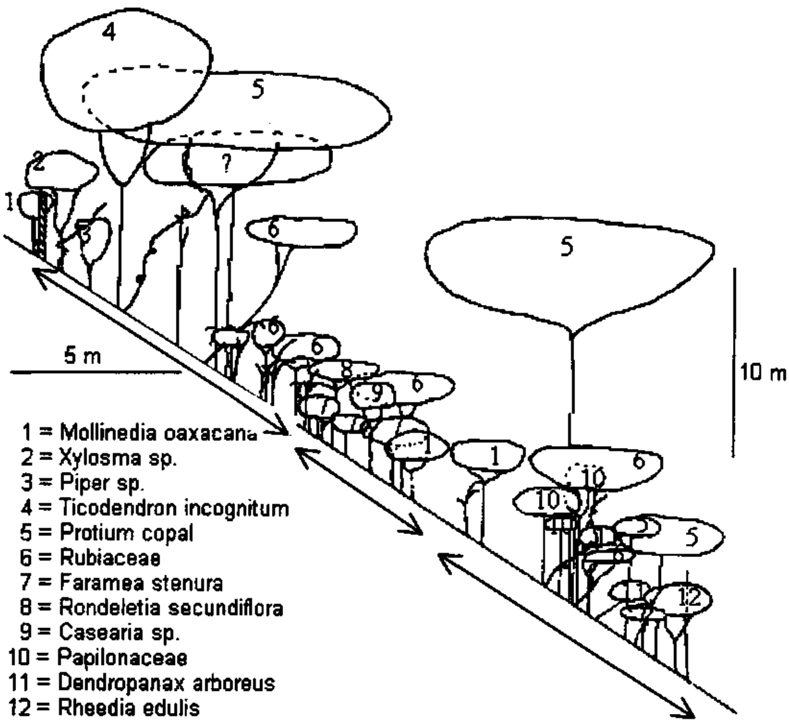

Figure 5-30. Eco-units in 50-year-old secondary vegetation at 1200 m altitude. The profile was drawn using data on crown diameter, height of trees and length of branch-free trunk. It is "schematic", because the crown shape does not exactly correspond to architectural reality, but is approached as a volume like in the computer drawings used earlier. Inclination of trunks estimated in the field. The eco-unit at the left is structured by *Protium copal* and *Ticodendron incognitum*; the eco-unit at the right by *P. copal*. Note the tile-wise imbrication of canopies.

The order of regrowth in the 50-year-old secondary vegetation is not known with certainty. However, it is estimated to be a second-order regrowth, based on a several considerations: i) in a high-order regrowth, the tile-wise imbrication of eco-units would not have been obtained in less than 50 years; the forest would have had a more chaotic appearance; ii) the distance of the site to the village (Figure 5-1) suggests a low order; iii) *L. macrophylla* and *P.copal* were present in several other second-order regrowths (ANNEX 7); iv) the presence of *Ticodendron incognitum* indicates a low order of regrowth (see Section 3.5).

5.7.5 Eco-units in chablis

In contrast with first-order regrowths, regrowths in chablis were not dense (Figure 5-31; compare Figures 5-19, 5-24 and 5-25, representing first-order regrowths).

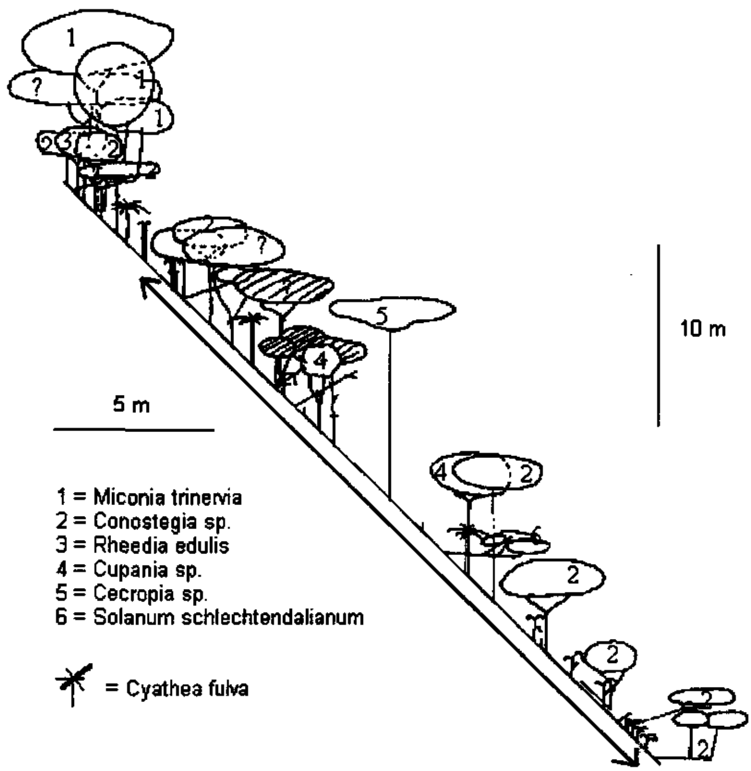

Figure 5-31. Young eco-unit in chablis at 1050 m altitude. *Cecropia* sp. in the center and *Miconia trinervia* bordering the chablis at the left. Many small trees of *Cupania* sp. at the right. Species composition and the number of trees is quite different from that observed in fields.

Trees of *Cecropia* sp. stood in the center of two recent chablis. In one of these, *Cupania* sp., *Vernonia* sp., *Inga acrocephala*, *Urera* sp. and *Piper yzabalanum* were present, amidst an abundant population of the palm *Chamaedorea tepejilote*. In the other chablis, *Conostegia* sp. was dominant; *Miconia trinervia*, *Cupania* sp. and *Solanum schlechtendalianum* were present.

C. tepejilote, *P. yzabalanum*, *Conostegia* sp. and *I. acrocephala* were hardly ever present in 5 to 7 year-old and 10–20 year-old secondary vegetation. Conversely, *Trema micrantha*, *Heliocarpus appendiculatus* and *Hedyosmum mexicanum*, forming dense covers in first- and second-order regrowths, were not found in chablis. A different species composition was also indicated by the TWINSPAN clustering (Figure 5.3).

5.7.6 Paths of eco-unit development

The drawings of the transects show that different paths of eco-unit development are possible. Although the present data set does not allow to trace all possible paths of development, an approximation can be made of common paths in the variant of shifting cultivation related to "selva alta perennifolia de montaña", as dependent on the order of regrowth.

In 5 to 7 year-old first-order regrowths, the large eco-units are in the aggradation phase; the canopy is principally formed by potential trees of *Trema micrantha*. Most of these trees succumb in the aggradation phase. First biostasis is reached at about the age of 12 years, when *Trichospermum mexicanum* starts to dominate the canopy. After its degradation, a second biostatic phase follows when the regrowth is about 20 year-old. The eco-units are then dominated by *Alchornea latifolia* – as observed in Field 4 at 800 m altitude. It is not clear whether this species can dominate regrowths at higher altitudes or if other species take over its role there. Later biostatic eco-units, after degradation of those dominated by *A. latifolia*, are likely to be structured by trees of several species (see Figures 5-19, 5-24 and 5-25, and ANNEX 7 for species found in first-order regrowths).

In second-order regrowths, two different paths of eco-unit development are seen. One path is characterized by polydominance of species; first biostasis is attained at the age of approximately 20 years. The eco-unit is then dominated by *Alchornea latifolia* and/or other species. After degradation and fragmentation, a new biostatic phase is reached, which is dominated by trees of *Protium copal* and/or *Liquidambar macrophylla*. The other path is characterized by single-dominance of *Hedyosmum mexicanum*, from young age onwards, until biostasis is reached at the age of about 20 years. After late fragmentation, new eco-units can be built by trees of several species, among them *Liquidambar macrophylla* (*cf.* Field 24, ANNEX 7).

In third- and fourth-order regrowths, development is determined by early fragmentation of the eco-unit: shortly after the zero-event the eco-unit splits into several small eco-units, when small islands of trees emerge in the midst of a herbaceous cover. When 5 to 7 year-old, the small eco-units in the aggradation phase, which usually contain trees of *A. latifolia*, remain separated. At a later age the small eco-units may reach fusion. The resulting mosaic may be dominated by *A. latifolia*, but probably trees of other species, *Inga latibracteata* among them, play a role too.

In the foregoing cases three successive generations of eco-units will reach biostasis in 50 years in first-order regrowths; in the same time-span two successive generations of eco-units come to biostasis in second-order regrowths; in higher order regrowths chaotic processes of early fragmentation and fusion occur.

5.8 Discussion

Secondary vegetation is not poor in species, but its diversity in the sense of polydominance is low. A total of 229 species of trees and shrubs were found in secondary vegetation. Of these species, 107 were represented by three or fewer individuals. As few as 37 species comprised 90% of the total number of 5691 trees and shrubs surveyed.

Whereas most of the secondary species had vernacular names in Spanish and Chinantec, primary species could frequently not be named by farmers. This indicates that secondary forests are more important in providing products and services for daily life than primary forests. This agrees with the findings of Richards (1991), Grenand (1992) and Toledo & al. (1992). Bonnéhin (in prep.) tells that in Côte d' Ivoire there existed a traditional taboo on cultivation of wild primary forest species.

Cluster analysis of data on presence and absence of species revealed differences in species composition between secondary vegetation in Santiago Tlatepusco and secondary vegetation in Santa Cruz Tepetotutla. This is due to the regional distribution of flora: the fields at low altitudes in Santiago Tlatepusco are near to and have species in common with the widely distributed secondary vegetation in the lowlands; the fields in Santa Cruz Tepetotutla receive secondary species migrating downslope (*cf.* Figure 2-5 and 3-2). Both cases confirm Budowkski's rule (see: glossary).

When using data on presence and absence, fields were not consistently clustered according to age and order of regrowth. Sometimes they were, as in the case of the cluster of Fields 13, 16 and 17 and the cluster of Fields 4, 5 and 6. But, young first-order regrowths were not grouped together, as one would expect if species composition were bound to the order of regrowth. However, this was due to the use of data on presence and absence: equal weight was given to infrequent and frequent species. This was not realistic, as secondary forests are generally structured by few very frequent species.

When species were given an importance value according to their crown projection, a parameter of crown architecture, clustering accorded rather well with age and/or order of regrowth. Higher-order regrowths in Santa Cruz Tepetotutla (Fields 16 and 7) were similar to regrowths in Santiago Tlatepusco. This reflects how stress through repeated landuse makes it possible that species such as *Croton draco* and *Vernonia patens* act as invaders from other sites that are stressed naturally or have become stressed as a result of human activities (see Section 2.2.3). Budowski's rule is confirmed once more by these facts.

Correspondence analysis showed that age, village, altitude, lithology and order of regrowth significantly influenced species composition of secondary regrowths, while slope-aspect did not. A correlation of species composition and age is expected by definition when dealing with secondary succession understood in the classical sense as succeeding groups of species. The significant contribution of village to variation confirms the results of the TWINSPAN clustering, demonstrating an effect of the regional distribution of the flora. An effect of altitude was expected (Section 2.2.3), due to its effect on temperature and rainfall and because of the confluence of species from cold and tropical regions along the mountain slopes. Differences in composition related to lithology had been found earlier in the lower part of the Chinantla (Section 3.4). Equally, differences between orders of regrowth had been indicated in the literature (Section 2.2.5).

Evaluation of farmers' information on the relation between order of regrowth and the most important species showed that the relative frequency of *Trema micrantha, Hedyosmum mexicanum* and *Liquidambar macrophylla* is low in high-order regrowths. Herbs were insistently mentioned for orders of regrowth higher than five. In general, the results confirmed those obtained by sampling. This proves that the method of establishing equivalencies of scientific and vernacular names by means of a local herbarium, has a potential for studying the impact of landuse on species composition, and for the design of locally based monitoring systems of the impact of landuse on natural resources.

6.3.2.1 Change on the short term

To study changes in the upper soil layer in the course of one growing season, soil samples were taken thrice, i.e.:

- after cutting/slashing in the month of May
- after burning in June, and
- at harvest in November.

Each time, 30 subsamples were taken along the same tract in each field and from two soil-layers: from 0 to 5 cms, and from 5 to 15 cms. The 30 subsamples of each layer were mixed to make two composed samples. In the limestone area, 6 fields were sampled; in the area of selva alta perennifolia de montaña, 13 fields. Use-history, altitude and slope of the sampled fields were recorded (ANNEX 10).

6.3.2.2 Change on the long term

Changes on the long term were studied by taking 30 subsamples in a selection of 43 fields in the area with selva alta perennifolia de montaña; and in a selection of 13 fields in the limestone area. In both cases the selection of fields formed a sequence of orders and ages of eco-units. The use-histories, altitude and slope of the sampled fields were recorded (ANNEX 11). Samples were taken at harvest in November and composed as described above. Sampling was confined to strong slopes in all fields. For the purpose of this study, only physico-chemical characteristics of soil samples were determined. Information of this type could readily be obtained from many sites, whereas systematic studies in soil biology would constitute another book.

6.3.2.3 Soil analysis

Soil analysis were done at the Laboratory of the Faculty of Agricultural Sciences of the Universidad Autónoma de Puebla, Mexico, and at Wageningen Agricultural University. The following analysis were done in Mexico: % C (Walkley and Black); pH-H_2O and pH-KCl (in a 1: 2 soil-water mixture); cation exchange capacity at pH=7 in acetate of ammonium; exchangeable Na, K, Mg and Ca in the acetate of ammonium extract. In the Netherlands, Total-N and -P were determined by continuous flow analysis in automated equipment; pH, NO_3, NH_4, total soluble nitrogen, soluble carbon and Na and K were determined in a $CaCl_2$ extract; available phosphorus was determined with Dabin's method; cation exchange capacity and exchangeable Ca, Mg, Na, K, Al, Mn and Fe were determined at the pH of the soil in a 0.01 M $BaCl_2$-extract; results concerning % C and Total-N were checked through element-analysis after combustion at 1200 °C; mineralogy was studied through röntgen-diffraction analysis. In Mexico the samples of the 0–5 cm and 5–15 cm soil layers were analyzed separately; in the Netherlands the samples were mixed in a 1 : 2 relation.

6.3.2.4 Data analysis

Average values of soil parameters were calculated for soils derived from limestone, sandstone and metamorphic rock. Differences between these groups were tested for significance. Within groups of fields, soil parameters were checked as to change along the altitudinal gradient. Relations between soil parameters within groups of fields were reviewed to check the consistency of the data. Finally, relations between soil parameters and landuse history were analyzed.

6.4 Results of soil analysis

6.4.1 General

The results of soil analysis are presented in ANNEX 10 (changes on the short term) and ANNEX 11 (changes on the long term). A considerable variation in values of soil parameters between fields is observed.

6.4.2 Average values of soil parameters

On the average, soils derived from sandstone and schists are acid, poor in bases (calcium, magnesium, potassium and sodium) and rich in aluminum. Contents of carbon, nitrogen and phosphorus are generally high. Soils derived from limestone have a higher pH, are poor in aluminum and have a high content of bases. Contents of carbon, nitrogen and phosphorus are high, although both carbon and nitrogen are lower than they are in soils derived from sandstone and schists. Available phosphorus is also lower (Table 6-1).

Table 6-1. Average values of characteristics of soils derived from limestone, sandstone and schists. C: carbon, determined by the method of Walkley & Black; N-t: total nitrogen, determined according to the macro-Kjeldahl technique; P-t: total phosphorus, determined by continuous flow analysis after acid destruction ; P-D: available phosphorus, according to Dabin's method. CEC: cation exchange capacity, measured at the pH of the soil in a 0.01 N $BaCl_2$-extract; Na, K, Ca and Mg as determined in the $BaCl_2$-extract. AVG = average; STD = standard deviation; n= number of observations.

	Sand (%)	Clay (%)	Loam (%)	Total-P (ppm)	P-Dabin (ppm)	C-W & B (%)	pH-KCl	CEC-$BaCl_2$ (cmol + / kg)	Na (cmol + / kg)	K (cmol + / kg)	Ca (cmol + / kg)	Mg (cmol + / kg)	Al (cmol + / kg)
LIMESTONE													
AVG	48.4	28.4	23.4	589	25.0	4.33	5.15	12.76	0.03	0.32	10.77	1.82	0.28
STD	5.2	4.5	2.6	272	8.4	0.95	0.60	5.08	0.03	0.18	5.75	0.75	0.32
RANGE	17.4	14.6	8.4	975	25.5	3.59	2.37	18.22	0.10	0.53	19.21	2.25	0.93
n	10	10	10	14	14	13	13	9	9	9	9	9	9
SANDSTONE													
AVG	56.8	21.5	21.7	352	37.4	5.90	3.95	9.22	0.03	0.35	5.58	1.33	2.21
STD	7.0	5.1	4.4	162	13.7	1.41	0.41	4.20	0.03	0.10	5.48	1.05	1.56
RANGE	20.8	14.5	13.0	460	42.4	5.30	1.93	13.08	0.08	0.30	17.76	3.22	5.51
n	10	10	10	18	18	19	19	10	10	10	10	10	10
SCHISTS													
AVG	51.9	21.8	26.3	638	40.3	6.56	3.91	9.02	0.02	0.25	4.48	1.15	2.81
STD	11.6	7.4	4.9	228	20.6	1.58	0.37	3.06	0.02	0.12	3.87	0.76	2.13
RANGE	44.0	28.2	17.3	984	99.0	6.54	1.47	9.37	0.06	0.49	11.15	2.57	7.91
n	22	22	22	24	24	24	25	13	13	13	13	13	13

Soils derived from limestone were distinct from those derived from sandstone and schists. Neither the average values of soil parameters (Table 6-1), nor results of röntgen-diffraction showed fundamental differences between sandstone- and schists-derived soils. Overall similarity originates from geological history: the sandstone originated as sediments washed from the higher mountains and deposited in continental circumstances (Section 3.2), whereas schists were formed by pressures on these materials during the lifting up of the mountain range. Only differences in Total-P between samples of sandstone- and schists-derived soils were significant (Wilcoxon's rank test). This difference is probably due to erosion: the lowest values of Total-P were found in fields located on top of an erosion front (Estrada & Urban, 1995). Data from fields in the sandstone area hence will not be taken into account when analyzing Total-P data below.

Given their similarity, soils on fields derived from sandstone and schists will be considered as belonging to one group, which will be called "desaturated" soils. Characteristics of the "desaturated" soils were significantly different from those of soils derived from limestone. The latter will therefore be treated as a distinct group of soils, called limestone soils.

6.4.3 Geographical gradient

Altitudes of fields with desaturated soils ranged from 350 to 1520 m. There was no correlation between soil characteristics and altitude, except for Total-P and the C/N-ratio. On limestone, where altitudes of sampled fields ranged from 400 to 1000 m, the C/N-ratio was not significantly correlated with altitude.

The positive correlation of Total-P with altitude was due to the low values of P on sandstone at low altitudes observed in the previous Section. The positive correlation of the C/N-ratio with altitude – $r = 0.40$, $p < 0.07$ – is probably due to lower biological activity at higher altitudes because of low temperatures and/or excessive rain. Except for the C/N-ratio and Total-P, variation in soil characteristics could not be ascribed to a geographical gradient. The dataset can thus be used to study change.

6.4.4 Sampling error

In order to estimate the coefficient of variation of the measured characteristics, in each of 5 fields 4 sub-samples were composed by mixing 8 sub-sub-samples. The standard deviation (sd) of a characteristic of sub-sub-samples and samples composed of 32 subsubsamples (sample) can then be estimated according to:

$$sd_{(subsample)} = a$$
$$sd_{(subsubsample)} = a * \sqrt{8}$$
$$sd_{(sample)} = a/2$$

Coefficients of variation were lowest for pH-KCl and % C. In general, the low coefficients of variation in Table 6-2 demonstrate that the values of soil parameters obtained by analyzing composed samples have a high degree of certitude. This makes it possible to use the dataset to study the change of soil parameters.

Table 6-2. Coefficients of variation (%) of soil parameters in composed samples. Values of coefficients of variation between parentheses are based on values of two subsamples; the other values are based on four subsamples. Observed variation stems from variation within fields and analytical error.

Name of farmer	pH KCl	C %	N-t %	P-t ppm	P-D ppm	CIC	Ca	Mg	Na	K
						(cmol+/kg)				
Albino	5.1	2.8	13.7	13.9	9.6	(13	32	27	0	3)
Calixto	1.1	1.2	8.0	9.7	9.9	(7	12	4	25	10)
Fausto	1.3	4.6	6.3	10.9	19.3	(6	4	4	0	7)
Gabriel	2.5	3.7	13.0	4.6	10.5	8	12	12	0	14
Raymundo	4.0	11.3	12.3	8.5	10.3	(11	24	21	15	20)

6.4.5 Characteristics and their relations

To evaluate the consistency of the data-set – analyses took place in different laboratories – relations between parameters were analyzed.

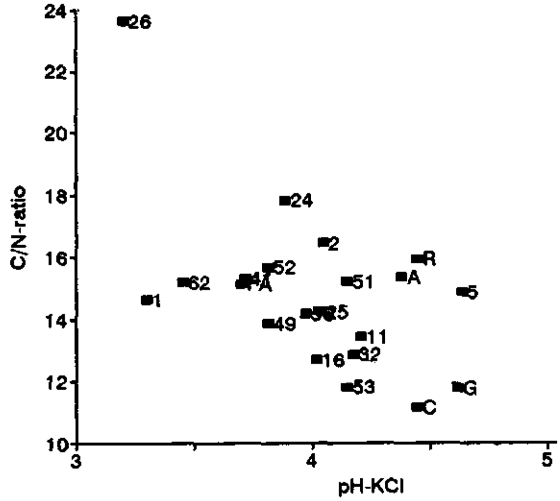

Figure 6-4. C/N-ratio and pH-KCl in desaturated soils. Numbers refer to sample numbers in ANNEX 11.

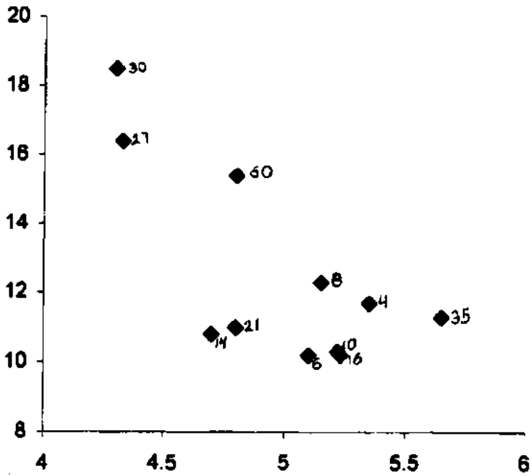

Figure 6-5. C/N-ratio and pH-KCl in limestone soils. Numbers refer to sample numbers in ANNEX 11.

No problems showed up for data from desaturated soils:

- the C/N-ratio decreased significantly with increasing pH in both desaturated soils (Figure 6-4) and limestone soils (Figure 6-5).
- in desaturated soils the ratio of NO_3/Total Soluble Nitrogen (NTS) increased with increasing values of pH ($r = 0.62$), while the ratio NH_4/NTS decreased ($r = -0.66$).
- in desaturated soils, the cation exchange capacity measured at the soil-pH varied in function of the C-content and pH ($r^2 = 0.60$). CEC was not correlated with the clay content, illustrating that clay minerals have insignificant net negative electric charge. The data indicate an average

CEC of carbon of 55 cmol(+)/kg C. In limestone soils, CEC was significantly correlated with pH-KCl, but not with carbon content.

- carbon data, obtained by the method of Walkley and Black, corresponded well with data obtained by means of automated analysis after total combustion at high temperature.
- in both desaturated and limestone soils, exchangeable aluminum decreased with increasing pH (Figure 6-6 and 6-7), while exchangeable Ca (and also Mg) increased strongly (Figure 6-8 and 6-9). As expected the ratio between monovalent and divalent cations was highest at low pH.

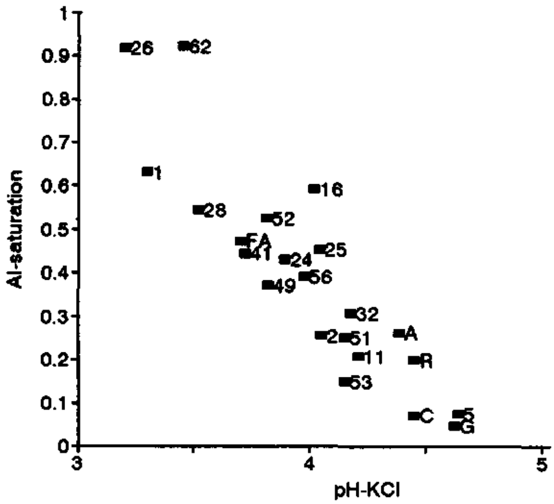

Figure 6-6. pH-KCl and Al-saturation in desaturated soils
A wide range of the fraction Al-saturation is observed. At high fractions, rooting of plants is severely inhibited.

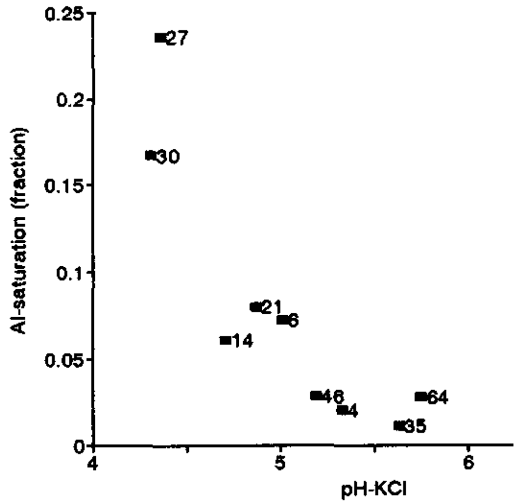

Figure 6-7. pH-KCl and Al-saturation in limestone soils
The observed range is not nearly as wide as in the case of desaturated soils. Root growth is not hampered.

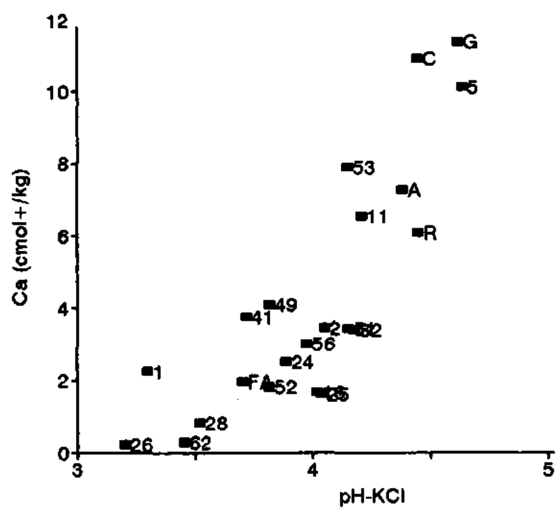

Fig. 6-8. Ca and pH-KCl on desaturated soils

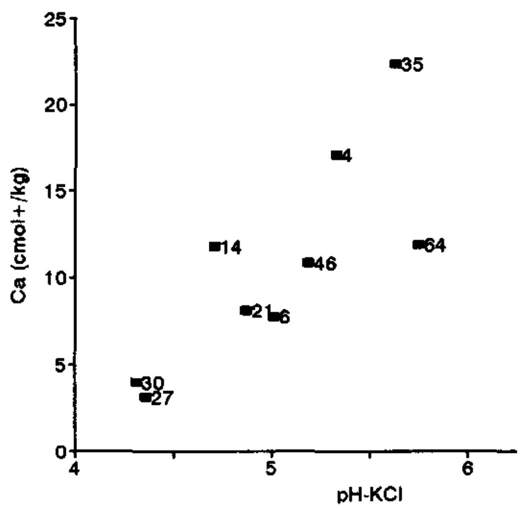

Fig. 6-9. Ca and pH-KCl on limestone soils

6.4.6 Discussion

Data were quite consistent, also when comparing data obtained by laboratories in Mexico and The Netherlands. The dataset can thus be used to study soil change and to relate changes with use-history.

6.5 Changes on the short term

6.5.1 Limestone soils

In limestone soils, pH-KCl increased slightly from burning to harvest (Wilcoxon's sign test, z = 0.04; Figure 6-10 and Table 6-3). Total-N (Kjeldahl) was generally higher after burning than immediately after slashing, although the difference was not significant (z = 0.11; Table 6-3).

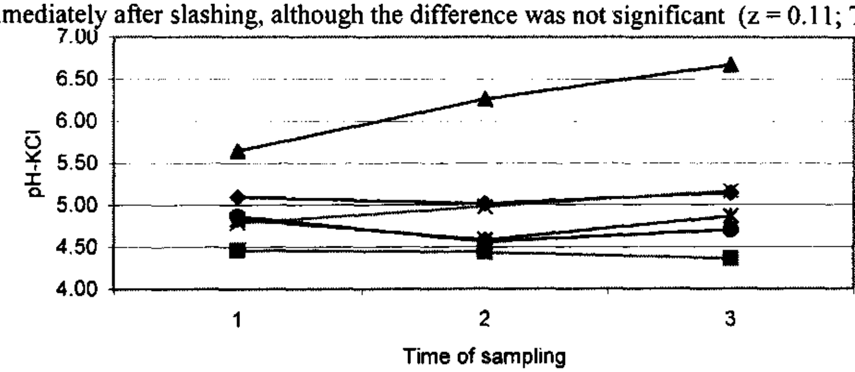

Figure 6-10. Change in pH-KCl from slashing to harvest in limestone soils. 1 = after slashing; 2 = after burning; 3 = at harvest

Table 6-3. Soil parameters after cutting (1) and burning (2) and at harvest (3).

	pH-KCl			C (%)			N (%)			Bases (cmol +/kg)		
LIMESTONE	1	2	3	1	2	3	1	2	3	1	2	3
Jose Ramos Leonardo	5.10	5.02	5.15				0.18	0.23	0.15	3.90	4.25	3.91
Francisco Manuel Sixto	4.46	4.44	4.36				0.17	0.31	0.16	2.47	2.90	2.40
Francisco Toribio Perez	5.65	6.26	6.68	7.20		6.65	0.44	0.40	0.56	7.19	8.38	7.97
Genaro Graciano Sixto	4.79	4.98	5.17	5.04		5.29	0.33	0.30	0.28	4.36	4.65	4.82
Juan Marcos Agapito	4.83	4.59	4.87		3.75		0.18	0.23	0.17	4.19	4.07	4.06
Valentino Manuel Sixto	4.87	4.56	4.71	5.16	4.48	4.86	0.22	0.34	0.23	5.24	3.88	4.04
Average	4.95	4.97	5.15	5.80	4.11	5.60	0.25	0.30	0.26	4.56	4.69	4.53
SCHISTS-SANDSTONE												
Albino Osorio Garcia	3.96	4.04					0.29	0.25		2.19	2.24	
Andres Jose Antonio	4.02	3.91	3.98	6.30	5.99	6.18	0.23	0.22	0.24	2.50	2.42	2.24
Apolinar Hernandez Osorio	3.62	3.91	3.89	3.72	3.80		0.15	0.14	0.14	2.19	3.62	2.79
Casimiro Garcia Cuevas	3.80	3.82	3.80				0.24	0.26	0.24	2.36	2.42	2.45
Felipe Osorio Martinez	3.25	3.18					0.11	0.13		1.72	1.97	
Francisco Hernandez Cecilio	3.15	3.45	3.52				0.15	0.12	0.10	2.10	2.42	2.24
Hipolito Lopez Garcia	3.81	3.81	3.89				0.23	0.24	0.26	2.14	2.67	2.55
Laurentino Hernandez Osorio	4.01		4.02				0.32		0.32	2.13		2.41
Simon Osorio Cuevas	3.78	3.92	3.88	7.03	6.83	7.07	0.29	0.29	0.30	2.06	2.09	2.67
Ciriaco Juan Toribio	3.93	4.06	4.04				0.16	0.29	0.16	2.58	3.86	2.82
Francisco Toribio Perez	3.77	3.85	3.81	6.83	6.39	6.71	0.19	0.29	0.18	2.25	2.80	2.67
Juan Marcos Agapito	3.68	3.82	3.80				0.30	0.26	0.19	2.44	2.73	2.65
Marcelino Toribio Perez	3.93	4.01		5.53			0.21	0.17		2.55	2.63	
Average	3.74	3.81	3.86	5.88	5.75	6.65	0.22	0.22	0.21	2.25	2.65	2.55

In limestone soils, only n and CEC_{pH7} showed a significant correlation. However, the information regarding limestone soils is not considered conclusive, due to the reduced number of samples on fields with low n and the large variation of soil parameters in fields with high n. More fields should be sampled to determine how soil parameters are related to use-history.

6.6.2 Use-history, pH-KCl and bases in desaturated soils

In desaturated soils, pH-KCl increased with n ($r = 0.59$, $p < 0.0001$; Figure 6-12). The number of burns was also significantly correlated with the sum of exchangeable bases ($r = 0.57$, $p < 0.006$), exchangeable Ca ($r = 0.57$, $p < 0.006$; Figure 6-13) and Mg ($r = 0.54$, $p < 0.01$). For most n, variation between fields of pH-KCl and other parameters was considerable. When data were averaged for each n, the following significant correlation coefficients were obtained: $r = 0.87$ for pH-KCl; $r = 0.74$ for exchangeable bases; $r = 0.74$ for Ca; $r = -0.86$ for Al; and $r = 0.56$ for CEC.

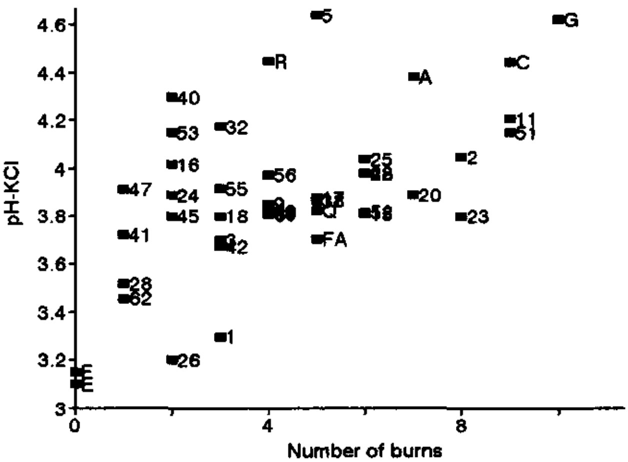

Figure 6-12. The number of burns and pH-KCl. Numbers correspond to field numbers in ANNEX 11. Values from several fields coincide: at n=0: Field E and F; at n=3: Field 42 and 3; at n=4: Field 9, 49, 69, 61; at n=5: Field 17, 38 and Q; and at n=6: Field 22 and 48; 15 and 52.

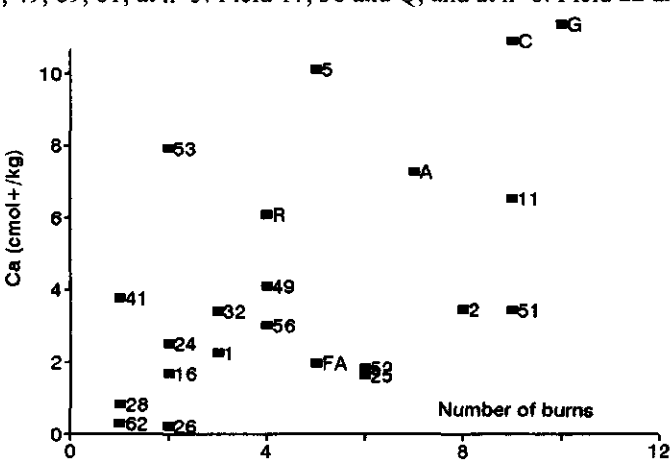

Figure 6-13. Exchangeable calcium and number of burns. For numbers: see ANNEX 11.

Exchangeable divalent cations, principally Ca, increased with *n*, while both the percentage Al-saturation and the absolute quantity of exchangeable aluminum decreased with increasing *n* (Figure 6-14).

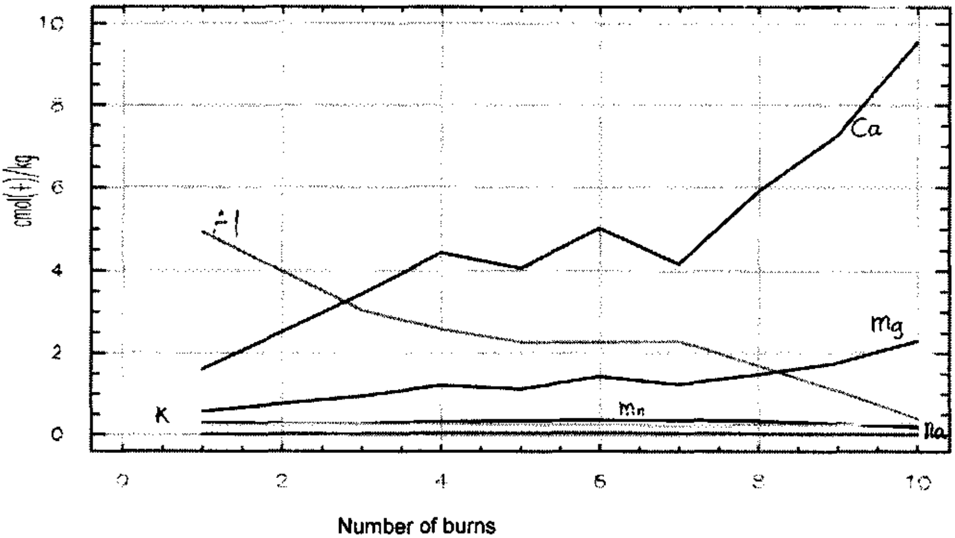

Figure 6-14. Exchangeable cations and the number of burns. Data were smoothed, averaging data for 3 consecutive values of *n*. Aluminum decreased, whereas Mn, K and Na showed little change. Ca and Mg increased.

The amounts of bases stored in primary vegetation were estimated by determining the difference between storage of exchangeable bases in the topsoil at low resp. high *n* (Table 6-5). The obtained amounts probably underestimate storage in primary vegetation, as bases may have been lost from the topsoil by lixiviation, fixation, uptake by crops or runoff.

Table 6-5. Soil content of bases (kg/hectare) at high and low number of burns.

	Ca	Mg	K
n = 1 or 2	600	90	150
n = 9 or 10	2700	380	150
estimated storage in primary vegetation	2100	290	0

6.6.3 Use-history and organic matter: carbon, nitrogen and phosphorus

Large differences in carbon and nitrogen content were found between fields that had been burnt an equal number of times (Figure 6-15). This may explain why no significant correlation between C or N and *n* was found (Table 6-4). However, if carbon contents within pairs of neighboring fields were compared, consistent increases were found with increasing *n* (Figure 6-15). The geographical position of the compared fields is indicated in Figure 6-3. When tested statistically, the hypothesis that no systematic differences arise by variation in *n* is rejected (Wilcoxon's sign test for paired observations; $Z=2.47$, $p < 0.02$).

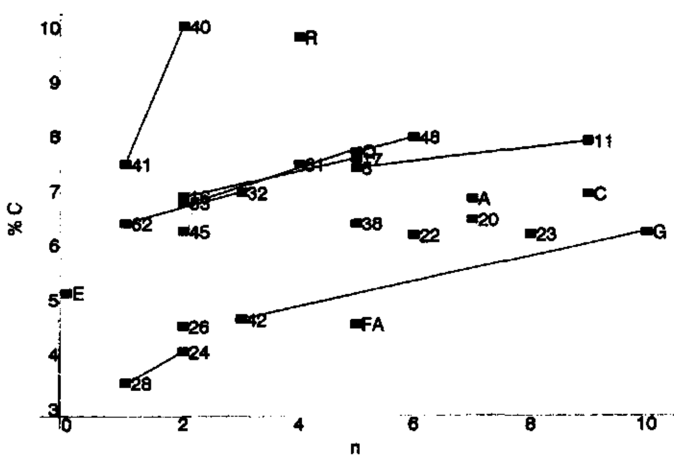

Figure 6-15. C-content of soils in a sample of fields with varying *n*. Pairs of fields connected with a line are separated by short geographical distances.

The C/N-ratio decreased with the age of the slashed vegetation ($r = -0.48$, $p < 0.05$) and pH ($r = -0.58$, $p < 0.005$), but was not significantly correlated with the number of burns (Figure 6-16). For $n = 2$ the highest values of the ratio were found when pH was lowest (compare Figure 6-4). Whereas the C/N-ratio of Fields 41 and 62 ($n = 1$) coincided, there was a large variation of the C/N-ratio at $n = 2$. This suggests that under primary vegetation there is a rather fixed value of C/N, which fits with low biological activity in the soil at low pH. This fixed value was maintained on both the field subjected to a complete burn (Field 41) and the field subjected to a partial burn.(Field 62). Apparently, a cropping period of half a year is too short to arrive at divergent ratios between these fields. However, at approximately 5 years after the cutting of primary vegetation ($n = 2$) a large variation is observed. This variation may result from divergent development, depending on the initial circumstances (after the first burn): partial burn and low pH in Field 26; complete burn and elevated pH in Field 53. Besides the mentioned factors, C/N-ratios can also be influenced by symbiotic N-fixation. In Field C, *Inga* sp. was the most important tree species in the secondary regrowth; in Field G, *Mimosa* sp. was the most abundant "weed" in the maize-crop. Symbiotic fixation may explain the low C/N-ratios observed in Fields C and G.

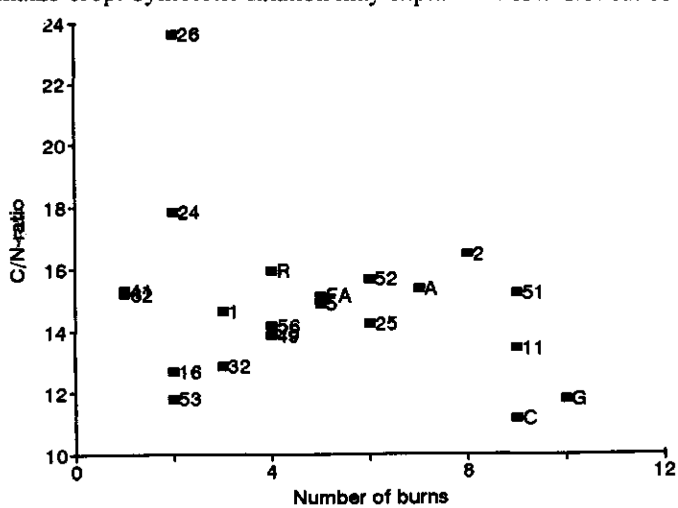

Figure 6-16. C/N-ratio and the number of burns. Data points of Fields 41 and 62 coincide. At $n = 2$, lowest values of the ratio are found at highest pH. Compare Figure 6-4.

Total-P was neither significantly correlated with parameters of landuse history, nor with pH-KCl. Available P (P-Dabin) was not significantly correlated with Total-P ($r = 0.43$, $p<0.11$). Also correlation of P-Dabin with *n* was low and not significant ($r = -0.25$, $p < 0.12$).

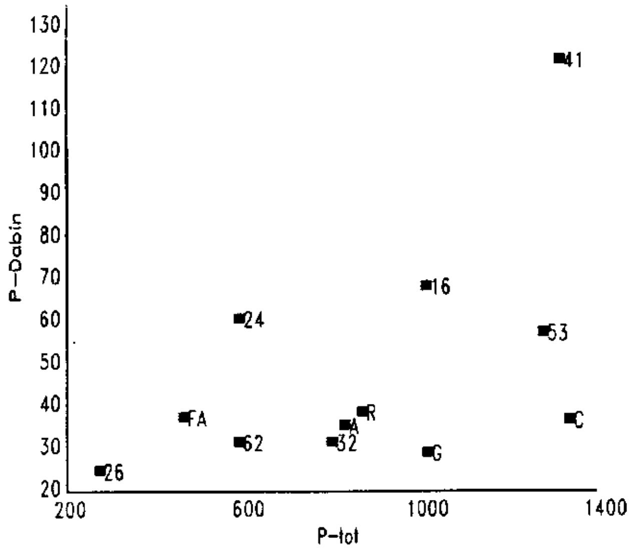

Figure 6-17. Values of P-Dabin and Total-P in desaturated soils. Horizontally, three levels appear: between 20 and 40 ppm, between 55 and 65 ppm; and at 121 ppm. Fields 24, 16 and 63 were burnt twice, field 41 once. On Fields 62 and 26, where burns had largely failed, available P was low, probably similar to values under primary forest. After many burns and many years, nearly all phosphorus previously stored in the primary vegetation on Fields G and C must have been transferred to the soil. In spite of this, available P was low, indicating fixation of phosphorus in unavailable forms.

The quantity of phosphorus contained in primary vegetation can be estimated in two independent ways:

- from data of neighboring Fields 24 and 28. In Field 24 the soil contained 155 ppm phosphorus more than in Field 28. Field 24 started its development 5 years before Field 28; the former had been burnt twice, the latter only once. As little phosphorus was added to the soil in 1993 when rains hampered the burns, the difference is due to the burning of primary vegetation in Field 24 in 1988 and subsequent mineralization of organic matter. This would indicate that primary vegetation contained 232.5 kg P.
- from the data on available P and additional estimate of the quantity of P contained in primary vegetation can be obtained. In Figure 6-17, three levels of available P can be distinguished. In Field 41, where primary vegetation was cut and burnt rather completely, available P was 121 ppm, 85 ppm P more than on frequently burnt Field C. In several fields burnt twice, P-Dabin was approximately 60 ppm. The quantity of P in primary vegetation in field 41 is then estimated at approximately 128 $kg.ha^{-1}$ ($85*1.5*10^6$ mg, bulk density estimated at 1 $kg.l^{-1}$). The quantity of P in a second order regrowth is estimated at approximately 45 kg $P.ha^{-1}$ (30 $*1.5*10^6$ mg). The real quantities are probably underestimated, because not all biomass was burnt and because some amount of P may have been fixed in the six months between burning and sampling.

6.6.4 Concluding remarks

Changes on the long term were most obvious for pH and amount of exchangeable bases, which both were positively correlated with the number of burns. Correlations between the parameters Total N, C and Total-P and use-history were not significant. Apparently, similar use-histories do not lead to similar contents of these elements in soils. As to carbon and nitrogen this is expected, as a variable fraction of these elements is lost to the atmosphere by the burning of organic materials, whereas transformation by micro-organisms conserves important amounts within the ecosystem. Additionally, nitrogen fixation is likely to vary between fields and this may influence both the nitrogen and the carbon content of soils.

The fact that similar use-histories did not lead to similar values of Total N, C and Total-P may have been due also to differences in the initial values of these parameters between fields, possibly related to remote use-history or localized natural impacts. When comparing the C-contents of soils of pairs of neighboring fields, the higher C-contents were found in fields with higher n. This indicates that this parameter increases parallel to the increases observed in pH and exchangeable bases.

6.7 Discussion

On the short term (one growing season), small changes occurred in desaturated soils. No relation of these changes with the use-history of fields was found, possibly due to the small number of sampled fields and burns being partial and heterogenous in the year of sampling (1993). However, the largest change occurred after burning a first order regrowth. On the long term, considerable increases in exchangeable bases and pH occurred, parallel to a considerable decrease in exchangeable aluminum. Carbon and nitrogen contents were positively correlated with pH, though not directly with use-history parameters.

On limestone soils, a small but significiant increase of pH from slashing to harvest was found, whereas N-Kjeldahl and bases showed no significant change. No firm conclusions could be drawn as to long-term changes, because of the number of sampled fields being too small.

From the observed facts, the following conclusions are drawn:

- physico-chemical parameters in soils change as an integral property of the eco-units resulting from landuse in the form of shifting cultivation.
- long-term tendencies are detected more readily with respect to bases and pH than with respect to nitrogen and carbon, due to losses of unknown and varying magnitude of the latter due to burning.
- seen from the viewpoint of soil fertility, shifting cultivation is better understood as an iterative than as a cyclic form of agriculture.
- the differences between desaturated and limestone soils emphasize the site-specificity of shifting cultivation and the need to adapt development projects to local conditions.

The general methodological problem of chronosequences – are differences between fields due to either different initial conditions of fields, or to changes? – cannot be resolved here. Only by long-term monitoring can certitude be obtained concerning changes on the long term. It is certainly recommended to undertake such studies. However, the changes along the chronosequence in the

Chinantla are considered here to be part of such long-term changes. This is supported by their congruence with results obtained elsewhere:

- in hurricane tracts in primary forest in Puerto Rico, soils had higher pH and exchangeable bases in tracts younger than 60 years as compared to 60 to 90 and 90 to 120 year-old tracts (Scatena & Lugo 1995; see Table 2.2). Increases during the decades following upon the zero-event, due to biological transformation of the abundant dead organic matter, are gradually nullified in later decades by the regenerating vegetation;
- in Pará, Brazil, pH and exchangeable bases (principally Ca) were higher after intense and continuous landuse during more than a decade than in soils under primary vegetation (Buschbacher & al. 1987);
- in Amazonian rain forest, pH was higher in chablis than in eco-units in biostasis (Akker & Groeneveld 1984);
- in the French Alps, the cutting of a spruce forest triggered of a change of moder-humus to mull-humus (Bernier 1995) over a period of several decades;
- in studies on CO_2 storage, increases in soil organic matter after cutting primary vegetation have been found on several sites, although decreases are more commonly reported (Post & Mann 1990);
- the nutrient content of primary rain forest as reported in literature coincides well with estimates calculated on the basis of changes in soil nutrient contents in the present study (e.g. Nye & Greenland 1960).

The following mechanism of change, resting upon the combined action of physical and (micro)-biological processes, is proposed as an explanation of the observed long-term changes of soil parameters:

- After cutting and partial burning of primary or old secondary vegetation, pH-KCl rises as a direct consequence of the addition of ashes to the soil.
- This causes the precipitation of aluminum in insoluble forms, possibly with phosphorus.
- As aluminum precipitates, room is made for cations on the adsorption complex, which is principally occupied by the divalent cations Ca and Mg.
- The addition of bases and the increase of pH-KCl make the soil more hospitable and trigger an increased activity of heterotrophic organisms, which transform and translocate organic materials.
- As a consequence, pH-KCl and exchangeable bases increase further.
- As organic matter integrates with the mineral soil, the cation exchange capacity increases.
- Cations added to the soil can be adsorbed and are thus protected from lixiviation.

In the observed time-span of approximately 50 years, desaturated soils in the Chinantla become more hospitable for roots. This is confirmed by the fact that developing secondary vegetation does not form a root mat as found in biostatic eco-units in primary forest (Oldeman 1990). In the process of "hospitabilization", participating organisms and also the cycled nutrients penetrate into the mineral soil, whereas in biostatic eco-units in primary vegetation processes take place to an important extent above the mineral soil, including the absorption of nutrients (Kahn 1982). Species with stolons, from inhospitable environments such as savannas and intensively used lowlands or cold páramos can take particular advantage of the newly generated soil-hospitability and progressively exclude tree species with increasing orders of regrowth, thus contributing to the early fragmentation of eco-units in high-order regrowths observed earlier.

The data show that changes on the long term are not of the same magnitude for all fields. For example, it makes a difference for the amount of nutrients and the development of populations of organisms in the ecosystem whether primary vegetation is completely or only slightly burnt. It

vegetation. In the area of selva alta perennifolia de montaña, all selected fields were cropped with the local variety "white hard" maize; in the limestone area with the local variety "yellow" maize.

In each of the four sites in each field, plant density was determined by counting the number of plant holes and the number of plants per plant hole on 100 m^2 of sloping surface. This area was marked by describing a circle with a radius of 5.64 m around a fixed point with a rope. The slope angle was determined on all sites. The following parameters were determined in each of the four sites in each field:

- the number of well-formed ears, not showing deformation or damage
- the number of deformed ears, showing deformation or damage
- the fresh weight of well-formed ears
- the fresh weight of deformed ears.

Intra-field variation of these four parameters was determined, by measuring the fresh weight and counting the number of well-formed and deformed ears obtained from each of 40 individual plant holes, 10 in each of the four sites in each field.

In a sample of 40 ears, the following parameters were determined:

- the number of rows of grains on ears
- the number of grains in rows
- length of the part of the ear with full grains
- fraction of fresh grain weight to total fresh ear weight.

Grain yields and aerial biomass were determined stepwise (ANNEX 13). To determine aerial biomass, the fresh leaves and stalks obtained from eight plant holes (approximately 40 plants), two from each of the four sites of sampling, were weighed. The fresh weight of the ears, obtained from 4 plots of approximately 40 plant holes, was multiplied by the fraction of grain weight to total ear weight. Percentage humidity of grains, cobs, leaves and stalks was determined by weighing samples of approximately 1 kg fresh weight before and after sun-drying.

Yields per plant hole, expressed in grammes per plant hole, were calculated by dividing the summed dry grain yield of the four plots by the total number of harvested plant holes. Yields referring to the sloping area, expressed in grammes per square meter sloping area, were calculated by dividing the average dry grain yield per plant hole by the average area available per plant hole. Standardized grain yields, expressed in kilogrammes per hectare, were calculated by multiplying the average dry grain yield per plant hole with the number of plant holes per hectare of sloping surface and dividing the result by the cosinus of the slope-angle. Standardized biomass was calculated by multiplying dry plant weight with the number of plants per hectare of sloping surface and dividing the result by the cosinus of the slope angle.

Correlations between properties of the soil compartment of the eco-units (Chapter 6) and yields and yield parameters referring to the sloping area were calculated. The effect of the addition of fertilizer nitrogen and phosphorus on yields and yield components referring to sloping area was studied in four factorial field experiments, with a randomized block design with four replicates and four treatments: (1) zero application; (2) application of 45 kg nitrogen$\cdot ha^{-1}$; (3) application of 45 kg $P_2O_5 \cdot ha^{-1}$ and (4) the combined application of 45 kg nitrogen and of 45 kg $P_2O_5 \cdot ha^{-1}$. In each of the experiments, fertilizers were applied at 1 month after sowing. Plots were 40 plant holes large. Yields and related parameters were determined as described above.

7.4 Results

7.4.1 Shifting cultivation in the limestone area

7.4.1.1 Crop performance

Standardized grain yields varied from 2.1 to 3.2 ton·ha^{-1} (Table 7-1) and differed significantly between fields (one-way ANOVA; $F = 6.51$, $p < 0.005$). In Genaro's field, lowest yield variation coincided with the highest yield. Crop biomass varied from 7 to 12 tonnes and was lowest in the fields where lowest yields were obtained.

The number of grains per row and the length of rows was positively correlated with standardized yields ($r = 0.92$, $p < 0.03$), whereas the thickness of grains was negatively correlated ($r = -0.85$, $p < 0.07$). Correlations with the number of well-formed and deformed ears were not siginificant. Yields referring to sloping surface showed similar correlations.

Table 7-1. Standardized grain yields and biomass in 5 fields with different use-histories in the limestone area. Std. dev. = standard deviation; C. of V. (%) = coefficient of variation; H.I. = harvest index, *i.e.* mass of grain as a fraction of biomass. Average yields marked with a same letter are not significantly different.

Name of farmer	Yield (kg·ha^{-1}) site 1	site 2	site 3	site 4	Avg. yield (kg·ha^{-1})	Std. dev.	C. of V. (%)	Biomass (kg·ha^{-1})	H.I.
Eleuterio	1864	2050	2073	2555	2136^{a}	295	13.8	6897	0.31
Ciriaco	2469	2926	2313	2578	2572^{ab}	260	10.1	7627	0.34
Nicolas	3271	2459	2616	3252	2900^{bc}	423	14.6	10487	0.28
Genaro	3560	3197	3238	2941	3234^{c}	254	7.8	11710	0.28
Timoteo	3604	3049	2528	3428	3152^{c}	476	15.1	9229	0.34

Yield per plant hole was lowest and varied most (C. of V. = 43.8%) in Ciriaco's field (Table 7-2). At the same time, the number of ears and plants per plant hole was lowest in this field. Yield per plant hole in Eleuterio's field, with the lowest standardized yield (Table 7-1), was slightly higher than that obtained in Ciriaco's field. This coincided with a wider spacing of plant holes and a larger number of plants per plant hole in Eleuterio's field (see data ANNEX 13). Yield per plant hole was not significantly correlated with the numbers of well-formed and deformed ears.

The number of deformed ears per plant hole was significantly correlated with the number of plants per plant hole ($r = 0.87$, $p < 0.06$), whereas there was no such correlation regarding the number of well formed ears. This indicates that at a high number of plants per plant hole the development of some of the plants becomes stressed (*cf.* Eleuterio's and Timoteo's fields).

Table 7-2. Yield parameters referring to plant hole and sloping area and characteristics of ears in 5 fields with different use-histories in the limestone area. n plt / pl. h. = number of plants per plant hole; C. of V. fr.w./pl.h. = coefficient of variation of the fresh weight of ears per plant hole; n mz b / pl. h. = number of perfectly formed ears per plant hole; n mz m/ pl. h. = number of badly formed or damaged ears per plant hole; dwg / pl. h. = dry weight of grains per plant hole (g); m2 / pl. h. = surface available per plant hole; dwg / m^2 = dry grain weight per square meter sloping surface; nu gr = number of grains in row on corn ear; lwg = length of row of grains on corn ear; gg = thickness of grains (cm).

	n plt / pl.h.	n mz b / pl.h.	n mz m / pl.h.	dgw / pl.h.	C.of V. fr.w./pl.h.	m^2 / pl.h	dgw / m^2	nu gr	Lwg	gg
Eleuterio	5.13	3.18	1.53	305.5		1.58	193.2	24.6	11.4	0.48
Ciriaco	4.10	2.97	1.12	291.9	43.8	1.33	218.9	26.1	11.0	0.48
Nicolas	4.45	3.31	1.08	354.0	28.9	1.37	258.4	25.8	11.9	0.47
Genaro	4.44	3.10	1.14	394.5	36.8	1.41	278.9	28.6	12.5	0.45
Timoteo	4.91	3.21	1.26	345.6	33.9	1.40	247.1	28.2	12.2	0.44

7.4.1.2 Crop performance and use-history

Yield per square meter sloping surface and the number of burns were significantly and negatively correlated ($r = -0.83$, $p < 0.09$). The number of well-formed ears per square meter sloping surface was negatively correlated with the number of burns ($r = -0.96$, $p < 0.02$), whereas the number of deformed or damaged ears was positively correlated ($r = 0.87$, $p < 0.06$). Also the number of burns and the number of grains in rows on corn ears were negatively correlated. The decrease of yield for increasing n in the interval from $n = 2$ to $n = 10$ is estimated by the linear regression coefficient of yield on n, and amounts to 9.3 grammes $\cdot m^{-2}$.

7.4.1.3 Crop performance and soil characteristics

Yield per square meter of sloping surface was not significantly correlated with any of the determined soil parameters. The number of badly formed ears was positively correlated with exchangeable aluminum ($r = 0.95$, $p < 0.06$) and negatively with pH ($r = -0.82$, $p < 0.10$). However, it is thought that no causal relation exists between these parameters and yield at the prevailing level of pH (ANNEX 11), but rather that high numbers of badly formed ears coincided with high numbers of plants per plant hole at low pH (*cf.* Eleuterio's and Timoteo's fields).

7.4.2 Shifting cultivation in selva alta perennifolia de montaña

7.4.2.1 Crop performance

Standardized grain yields varied from to 915 to 4685 kg$\cdot$ha^{-1} (Table 7-3). Lowest yield coincided with the highest yield variation in Albino's field; generally a low coefficient of variation was found when high yields were obtained. Biomass varied from 3873 to 13739 kg$\cdot$ha^{-1}. Harvest indexes varied strongly, even between crops with similar yields (*cf.* Alfonso and Leopoldo). The lowest index by far was found in Albino's crop, indicating some physiological difficulty of unknown origin. For statistical analysis this crop hence is discarded.

Standardized yields were significantly correlated with the number of grains in the rows on corn ears ($r = 0.69$, $p < 0.005$), the number of well formed ears ($r = 0.82$, $p < 0.001$) and the number of deformed ears ($r = -0.46$, $p < 0.09$).

Table 7-3. Standardized maize yields and their variation in fields with different use-histories in the area of selva alta perennifolia de montaña. Std. dev. = standard deviation; C. of V. (%) = coefficient of variation; H.I. = harvest index. A wide variation is observed in yield, yield variation, biomass and harvest index.

Name of farmer	Yield ($kg \cdot ha^{-1}$)				Avg. yield ($kg \cdot ha^{-1}$)	Std dev	C. of V. (%)	Biomass ($kg \cdot ha^{-1}$)	H.I.
	plot 1	plot 2	plot 3	plot 4					
Albino	520	1208	990	944	915	288	31	3873	0.24
Alfonso	4321	4234	3604		4053	392	10	8996	0.45
Alfredo	3575	3709	4362		3882	421	11	9915	0.39
Andres	3514	3930	3406	3889	3685	264	7	8129	0.45
Armando	2279	2332	3645	2535	2698	641	24	7674	0.35
Calixto	4813	5196	4058	4674	4685	473	10	13321	0.35
Fausto	2872	2905	3062	2567	2852	207	7	7565	0.38
Fulgencio	2235	2959	2057	2470	2430	391	16	5473	0.44
Gabriel	3958	3603	3851	4367	3945	318	8	9598	0.41
Gildardo	4429	2964	3743	2699	3459	784	23	8735	0.40
Jorge	1998	2205	3350		2518	728	29	7108	0.35
Laurentino	2516	3383	3685	2745	3082	544	18	8503	0.36
Leopoldo	4223	4502	5679	3237	4410	1005	23	13739	0.32
Lorenzo	3362	1953	2837	2010	2541	680	27	7042	0.36
Quirino	2845	3072	3803	3348	3267	412	13	7856	0.42
Raymundo	2153	1930	2060	1198	1835	434	24	5611	0.32

Yield per square meter of sloping surface was also significantly correlated with the number of well-formed ears per square meter sloping surface ($r = 0.85$, $p < 0.0001$), with the number of grains in the rows on corn ears ($r = 0.70$, $p < 0.004$) and the length of the rows of grains on these ears ($r = 0.70$, $p < 0.004$).

The average number of plants per plant hole varied between fields from 4.35 to 5.43 (Table 7-4). This parameter was not correlated with yield per plant hole. Yields per plant hole were positively correlated with the number of well formed ears ($r = 0.82$, $p < 0.001$) and the total number of ears per plant hole ($r = 0.72$, $p < 0.003$) and negatively with the number of deformed ears per plant hole ($r = -0.47$, $p < 0.08$). Yields per planthole were also positively correlated with the number of grains on ears ($r = 0.68$, $p < 0.006$). The numbers of well-formed and deformed ears per plant hole were not significantly correlated with the number of plants per plant hole.

Table 7-4. Yield parameters referring to plant hole and sloping area and characteristics of ears in fields in the area of selva alta perennifolia. n plt / pl. h. = number of plants per plant hole; C.of V. fr.w./pl.h. = coefficient of variation of the fresh weight of ears per plant hole; n mz b / pl. h. = number of perfectly formed ears per plant hole; n mz m/ pl. h. = number of badly formed or damaged ears per plant hole; dwg / pl. h. = dry weight of grains per plant hole (g); m2 / pl. h. = surface available per plant hole; dwg / m^2 = dry grain weight per square meter sloping surface; nu gr = number of grains in row on corn ear; lwg = length of row of grains on corn ear; gg = thickness of grains (cm).

	n plt / pl. h.	n mz b / pl. h.	n mz m / pl. h.	dgw / pl.h.	C.of V. fr.w./pl.h.	m^2 /pl.h	dgw /m^2	nu gr	lwg	gg
Albino	5.08	0.78	3.46	176.6	34.3	1.54	114.7	14.3	7.3	0.54
Alfonso	4.83	3.72	0.73	524.6	29.8	1.53	342.3	26.6	12.1	0.47
Alfredo	5.22	3.20	1.76	510.2	33.9	1.76	289.1	24.0	11.2	0.50
Andres	5.16	2.77	2.07	480.9	33.6	1.57	306.5	26.4	12.6	0.51
Armando	5.11	1.64	2.54	313.9	60.8	1.45	215.8	24.8	11.7	0.49
Calixto	5.02	3.63	1.41	523.9		1.44	364.1	27.9	12.7	0.46
Fausto	4.95	1.95	2.78	315.0	25.5	1.42	222.1	22.9	10.5	0.46
Fulgencio	4.53	1.92	2.32	351.8	44.9	1.83	192.6	24.4	10.7	0.46
Gabriel	4.48	3.23	1.28	440.9	33.1	1.42	310.9	26.0	11.8	0.46
Gildardo	4.61	3.04	1.47	464.9	38.2	1.63	285.9	25.9	12.6	0.50
Jorge	5.16	3.06	1.33	345.0	40.4	1.72	201.0	23.6	10.9	0.47
Laurentino	4.18	3.10	1.08	419.0	28.2	1.66	252.5	27.5	12.9	0.48
Leopoldo	5.17	3.26	2.23	551.0	27.3	1.49	369.1	24.3	11.6	0.50
Lencho	5.11	2.03	2.52	344.5	36.2	1.65	209.3	22.8	10.1	0.45
Quirino	5.04	3.16	1.10	355.6	43.7	1.37	259.6	24.8	11.4	0.46
Raymundo	5.17	1.69	2.38	222.7	54.2	1.51	147.2	20.9	10.1	0.50

7.4.2.2 Crop performance and use-history

Neither standardized yield, nor yield per square meter sloping surface, nor yield per planthole were significantly correlated with any of the parameters used to characterize the use-history of fields. The influence of a complex of factors and events on the yield potential and more particularly on realized yield in 1994 could not be summarized in the parameters of use-history.

Two parameters related to yield, however, were significantly correlated with the number of burns. The number of well formed ears as a fraction of the total number of ears per plant hole increased with n ($r = 0.49$, $p < 0.07$), indicating damage by pests and/or diseases and/or some nutritional constraint on *not-frequently* burnt fields. As no pests and diseases are likely to have built up in these fields, nutritional constraints are the most probable cause. The thickness of grains diminished with n ($r = - 0.57$, $p < 0.03$), probably reflecting a larger number of grains, though the correlation of the latter parameter with n was not significant.

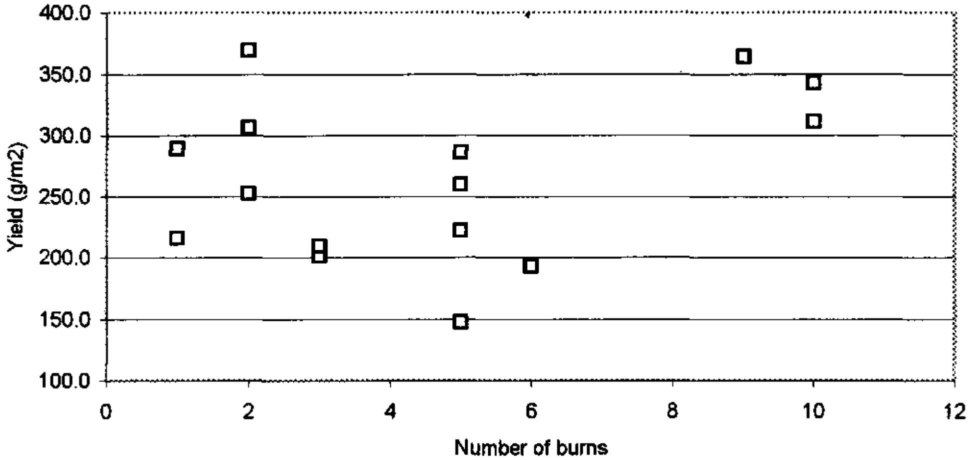

Figure 7-1. Maize yields and number of burns on fields in the area of selva alta perennifolia de montaña. Yields are expressed in grammes per square meter sloping area. No clear relation is observed: high yields can be obtained on recently established fields with a low number of burns as well as on fields established long ago that had already gone through a high number of burns.

7.4.2.3 Crop performance and soil characteristics

Yield per square meter sloping surface was significantly correlated with CEC-$BaCl_2$, exchangeable calcium, Total-P and the C/N-ratio (Table 7-5). The numbers of well-formed ears and deformed ears were significantly correlated with the same parameters and also with aluminum saturation. The number of grains per corn ear was also significantly and negatively correlated with the C/N-ratio and positively with CEC-$BaCl_2$. No significant correlation between yield parameters and Total-N or pH-KCl was found (Table 7-5).

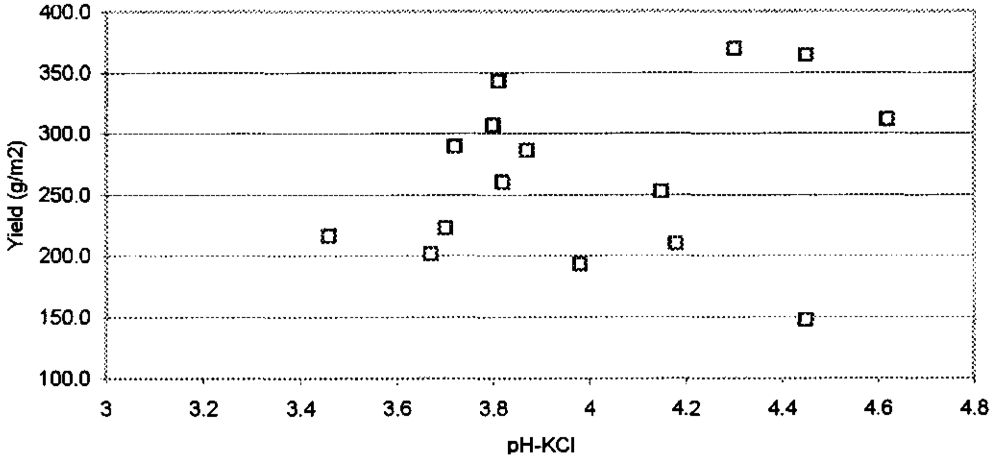

Figure 7-2. Yield and pH-KCl in fields in the area of selva alta perennifolia de montaña. If the pH-traject is divided in two parts, a positive correlation (r = 0.67) is observed at values of pH-KCl below 3.9.

7.5 Discussion

The performance of maize crops was studied at different levels of detail in a sample of fields, in both the limestone area and in the area of selva alta perennifolia de montaña. For each area separately, it was checked whether or not significant correlations existed between parameters of crop performance and parameters of use-history and soil. It was also determined which crop parameters showed significant correlation with yield.

In the limestone area a direct relation between use-history and grain yields was found. Yields per square meter of sloping surface were negatively correlated with the number of burns that preceded the actual crop. In a linear model, yield decrease was equivalent to 9.3 grammes·m^{-2} per burn. The number of grains on rows of corn ears was also negatively correlated with the number of burns. The numbers of deformed and well-formed ears were not correlated with the number of burns and no significant correlations between yield and soil parameters were found. Together, these results indicate that biological eco-unit properties (weeds, pests and diseases) and/or management (weeding and/or use of biocides) depress yields increasingly with increasing number of burns.

In the area of selva alta perennifolia de montaña no direct relation was found between yields and use-history. The crops sampled in 1994 generally performed well, both in unfrequently cropped fields (n = 1 or 2) and in frequently cropped fields (n > 7). These results did not match farmers' empirical rule, according to which yields in the area of selva alta perennifolia are generally low in first crops, best yields are attained in third and fourth crops and good or bad yields can be attained in later crops (Section 2.4.2). That findings did not match farmers' empirical rule is probably due to the atypical distribution of rains in the year of sampling: the month of May was completely dry and rains during the development of the crop were moderate (*cf.* Section 3.3 and ANNEX 14). Burns were complete and additions of bases and phosphorus with ashes were high where primary vegetation and first- and second-order regrowths were burnt (cf. Chapter 5). As a consequence of the complete burns and the favorable distribution and level of rains, pH, exchangeable bases and phosphorus in the soil could rise to similar levels as those attained normally in the course of a longer time-span. In fact, yields in fields with low n shifted upwards (Figure 7-1) as compared to the normal situation the farmers' empirical rule refers to.

In spite of the absence of a direct relation between yield and use-history, some parameters related to yield showed a relation with the number of burns: the number of well-formed ears as a fraction of the total number of ears per plant hole increased with n, whereas the thickness of grains decreased with increasing n. The increase of the fraction of well formed ears with increasing n points at nutritional constraints at low n and the decreasing thickness of grains reflects large ears at high n.

Yield showed a significant correlation with pH at pH levels below 3.9, and was also significantly correlated with Total-P, CEC-$BaCl_2$, exchangeable calcium and the C/N-ratio. Also biomass, the number of grains on corn ears, the number of well-formed ears and the number of deformed ears were correlated with these parameters. The nutritional constraints mentioned above are thus confirmed. It is remarked here that all of the mentioned parameters except Total-P were significantly correlated with n (Chapter 6). This indicates that the relation between yield and the number of burns is influenced by the change of soil parameters with increasing number of burns. As observed in Chapter 6, change of soils is not linearly related with the number of burns.

Nutritional constraints were also confirmed in factorial experiments on N- and P-fertilization. No significant effect of application of nitrogen and phosphorus was found on frequently cropped fields, where without fertilization yields of more than 4 tonnes were obtained. On a field where 1835 $kg \cdot ha^{-1}$ was obtained without fertilization, the combined application of nitrogen and phosphorus increased yield to 2600 $kg \cdot ha^{-1}$. This was still far below the yield obtained on the frequently cropped fields, indicating that nitrogen and phosphorus additions influence only some of the complex eco-unit properties.

The combined application of nitrogen and phosphorus increased average yield per plant hole, but did not increase maximum attained yield per planthole. This demonstrates the patchy availability of nitrogen and phosphorus in non-fertilized fields: the plants of some plant holes have enough of these nutrients, whereas others have not. The patchy availability must be due to constrained biological activity in part of the field, most likely due to low pH.

Together, yield parameters, correlations between yield and soil parameters and responses to nitrogen and phosphorus fertilization show that each eco-unit is the locus of a network of interacting factors, in which several parameters change in accordance with biological activity related to the transformation of organic materials and the effect of burns.

Through management measures, varying from planting trees to determining the length of the periods in which secondary succession is allowed to take its course, one may attempt to guide the sequence along desirable paths. Such paths must lead to a composition of the mosaic of eco-units in which variation is maintained. At the local level the ideal composition of the mosaic should be defined by mobilizing available ecological and botanical knowledge and by evaluating possible uses of the different units of the mosaic.

- *Indigenous farmers have knowledge of paths of development of secondary vegetation, soils and crop performance, and of the factors that influence them. For this reason, the redesign of locally adapted forms of shifting cultivation cannot be conceived without farmers playing a central role.*

Indigenous farmers have knowledge of the possible paths of development of secondary vegetation and of their options to influence the path taken, as illustrated by taxonomic skills and landuse practice of Chinantec farmers. This knowledge is necessary for the redesign of local forms of shifting cultivation. Farmers and their formal and informal organizations should therefore play a central role in redesign, not only because of democratic decency, but also out of absolute necessity.

- *In shifting cultivation related to "selva alta perennifolia de montaña" the landuse pattern leads to a mosaic of eco-units. Conversely, the composition of this mosaic influences the local practice of shifting cultivation.*

The ecological rationale of the traditional landuse pattern resides in the prevailing climatic conditions, soil conditions and available useful organisms. As a result of the sequence of cropping periods and periods of secondary regrowth in the individual fields, each with a certain combination of decomposition through burns and biological decomposition, a mosaic of eco-units is formed. In this mosaic, some eco-units have a high potential for the production of maize. This potential is being generated in low-order regrowths when soils are still inhospitable due to low pH. Elsewhere, the additions of ashes and biological enrichment of the soils has lead to advantages for species with subterranean structures for vegetative reproduction, such as *Sticherus* sp. and *Mimosa* sp. (espina). As these species hinder cropping with annuals, large periods of secondary regrowth were maintained in the landuse pattern. The generated situation can also be taken advantage of by planting plantains, as is indeed widely practiced.

Local experience shows that, in order to maintain the diversity of the mosaic of eco-units on the long term and the potential of its diverse use, fields should not be cultivated with annual crops more often than approximately five times, separated by fallow periods of approximately five years, before going into a long fallow period. Fallow periods during several years permit substantial regrowth of trees; annual and perennial herbs are shaded out and seed production of at least the pioneer trees is guaranteed. Long fallow periods in the landuse pattern ensure the immigration and establishment of long-lived pioneers and other interesting species.

By applying the traditional landuse pattern, multiple paths of eco-unit development can be maintained, along with the diversity of species that play a role in them. It is recommended that a diverse mosaic of secondary vegetation be maintained in each of the clusters of fields in the landscape to ensure the viability of paths in each of them.

- *Like shifting cultivation related to "selva alta perennifolia de montaña", shifting cultivation in the limestone area and in the oaklands constitute highly specific responses to the social and ecological environment.*

  In the variant of shifting cultivation practiced in the limestone area, a conflict over land titles with a neighboring community has caused an intensification of landuse. As a result the diversity of the mosaic has been reduced. It is therefore recommended that efforts to resolve the conflict be increased. Once the conflict is resolved, actions should start which focus on the reconstitution of a diverse mosaic.

  So far, little is known about the variant of shifting cultivation practiced in the oaklands. The *Quercus* forests in the Chinantla indicate a stressed environment. Their transition to secondary forests proper of a rain forest environment may contain valuable elements for the reconstitution of mosaics of secondary vegetation in situations of repeated stress through cultivation. In these situations secondary vegetation also consists of species from different types of vegetation. It is therefore recommended that shifting cultivation in the oaklands be studied in more detail.

- *The iterative and interactive character of indigenous shifting cultivation gives this form of landuse the potential to become a form of mosaic management which optimally combines conservation and diverse production goals.*

  Indigenous shifting cultivation is a complex form of agriculture. Though frequently it has evolved to degradation of natural resources, this may not necessarily be the case if a fair price were paid for the products that can derive from mosaic management; if the benefits in the area of landscape management and conservation were paid for; and if institutional arrangements were made that start from the specificity of local forms of agriculture and the local capacity to creatively combine multiple goals in multiple production.

  Many challenges are ahead!

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Panotla (= "place to wade the river" in Nahuatl), Tlaxcala, México
July 28, 1999

Annex 1. Data on transects sampled for secondary vegetation.

field	1	1	1	1	2	2	2	3
name	jorge	jorge	jorge	jorge	virgin	virgin	virgin	leopoldo
plot	1	2	3	4	5	6	7	8
lithology	1	1	1	1	1	1	1	1
community	1	1	1	1	1	1	1	1
altitude	860	860	800	830	1050	1030	1080	1080
aspect	60	1	330	330	75	45	90	240
slope	45	35	39	35	37	38	40	30
age	12	12	12	12				5
order	4	4	4	4				1
virgin	30	30	30	30	0	0	0	5
hor. length	17.68	20.48	19.43	20.48	19.97	19.70	19.15	21.65

field	3	3	3	4	4	4	4	5
name	leopoldo	leopoldo	leopoldo	francisco	francisco	francisco	francisco	romeo
plot	9	10	11	12	13	14	15	16
lithology	1	1	1	1	1	1	1	1
community	1	1	1	1	1	1	1	1
altitude	1080	1080	1080	740	740	800	780	800
aspect	255	120	135	30	30	30	45	330
slope	30	27	25	42	45	35	45	43
age	5	5	5	20	20	20	20	17
order	1	1	1	1	1	1	1	2
virgin	5	5	5	20	20	20	20	30
hor. length	21.65	22.28	22.66	18.58	17.68	20.48	17.68	18.28

field	6	6	6	6	7	7	7	7
name	francisco	francisco	francisco	francisco	jaime	jaime	jaime	jaime
plot	17	18	19	20	21	22	23	24
lithology	1	1	1	1	1	1	1	1
community	1	1	1	1	1	1	1	1
altitude	820	800	800	750	1080	1070	1070	1050
aspect	45	60	90	90	1	345	345	330
slope	35	42	45	46	29	29	33	36
age	16	16	16	16	6	6	6	6
order	1	1	1	1	2	2	2	2
virgin	16	16	16	16	12	12	12	12
hor. length	20.48	18.58	17.68	17.37	21.87	21.87	20.97	20.23

field	8	9	9	9	9	10	10	10
name	maximino	sotero	sotero	sotero	sotero	luis	luis	luis
plot	25	26	27	28	29	30	31	32
lithology	1	1	1	1	1	1	1	1
community	1	1	1	1	1	1	1	1
altitude	1120	800	800	800	800	880	960	940
aspect	345	45	60	75	105	1	15	15
slope	40	30	30	45	40	32	40	45
age	6	5	5	5	5	5	5	5
order	2	5	5	5	5	2	2	2
virgin	12	50	50	50	50	20	20	20
hor. length	19.15	21.65	21.65	17.68	19.15	21.20	19.15	17.68

field	10	11	11	11	11	12	12	12
name	luis	andres	andres	andres	andres	virgin	virgin	virgin
plot	33	34	35	36	37	38	39	40
lithology	1	1	1	1	1	1	1	1
community	1	1	1	1	1	1	1	1
altitude	900	1040	1020	1000	980	1030	1030	1030
aspect	15	180	235	165	195	45	15	45
slope	39	34	40	43	30	36	44	41
age	5	12	12	12	12			
order	2	1	1	1	1			
virgin	20	12	12	12	12	0	0	0
hor. length	19.43	20.73	19.15	18.28	21.65	20.23	17.98	18.87

field	12	13	13	13	13	14	14	14
name	virgin	leandro	leandro	leandro	leandro	unknown	unknown	unknown
plot	41	42	43	44	45	46	47	48
lithology	1	1	1	1	1	1	1	1
community	1	1	1	1	1	1	1	1
altitude	1030	1050	1050	1050	1050	1200	1200	1200
aspect	45	240	210	100	240	150	165	180
slope	39	43	40	35	42	43	40	35
age		5	5	5	5	50	50	50
order		4	4	4	4	2	2	2
virgin	0	40	40	40	40	70	70	70
hor. length	19.43	18.28	19.15	20.48	18.58	18.28	19.15	20.48

field	14	15	16	16	16	16	17	17
name	unknown	maximino	justiniano	justiniano	justiniano	justiniano	benito	benito
plot	49	50	51	52	53	54	55	56
lithology	1	1	1	1	1	1	1	1
community	1	1	1	1	1	1	1	1
altitude	1200	1200	880	880	880	880	1100	1100
aspect	150	30	5	10	15	30	45	20
slope	42	40	40	32	36	28	20	26
age	50	5	5	5	5	5	5	5
order	2	1	4	4	4	4	3	3
virgin	70	5	20	20	20	20	17	17
hor. length	18.58	19.15	19.15	21.20	20.23	22.07	23.49	22.47

field	17	17	17	17	18	18	18	18
name	benito	benito	benito	benito	jorge	jorge	jorge	jorge
plot	57	58	59	60	61	62	63	64
lithology	1	1	1	1	1	1	1	1
community	1	1	1	1	1	1	1	1
altitude	1100	1100	1100	1100	1360	1360	1360	1360
aspect	45	45	150	135	135	135	135	90
slope	23	22	35	38	35	45	30	35
age	5	5	5	5	12	12	12	12
order	3	3	3	3	2	2	2	2
virgin	17	17	17	17	16	16	16	16
hor. length	23.01	23.18	20.48	19.70	20.48	17.68	21.65	20.48

field	19	19	19	19	20	20	20	20
name	lorenzo	lorenzo	lorenzo	lorenzo	gabino	gabino	gabino	gabino
plot	65	66	67	68	69	70	71	72
lithology	1	1	1	1	1	1	1	1
community	1	1	1	1	1	1	1	1
altitude	1400	1400	1400	1400	1450	1450	1450	1450
aspect	50	20	38	72	120	115	92	105
slope	30	43	40	34	39	43	38	42
age	7	7	7	7	12	12	12	12
order	1	1	1	1	2	2	2	2
virgin	7	7	7	7	22	22	22	22
hor. length	21.65	18.28	19.15	20.73	19.43	18.28	19.70	18.58

field	21	21	21	21	22	22	22	22
name	joel	joel	joel	joel	pedro	pedro	pedro	pedro
plot	73	74	75	76	77	78	79	80
lithology	1	1	1	1	1	1	1	1
community	1	1	1	1	1	1	1	1
altitude	1450	1450	1450	1450	1450	1450	1450	1450
aspect	204	195	156	185	53	30	36	46
slope	20	23	39	18	40	37	28	24
age	5	5	5	5	7	7	7	7
order	2	2	2	2	3	3	3	3
virgin	15	15	15	15	21	21	21	21
hor. length	23.49	23.01	19.43	23.78	19.15	19.97	22.07	22.84

field	23	23	23	23	24	24	24	24
name	pedro	pedro	pedro	pedro	andres	andres	andres	andres
plot	81	82	83	84	85	86	87	88
lithology	1	1	1	1	1	1	1	1
community	1	1	1	1	1	1	1	1
altitude	1450	1450	1450	1450	1450	1450	1450	1450
aspect	50	50	57	56	87	120	185	171
slope	34	31	32	29	43	46	48	46
age	14	14	14	14	20	20	20	20
order	2	2	2	2	2	2	2	2
virgin	21	21	21	21	40	40	40	40
hor. length	20.73	21.43	21.20	21.87	18.28	17.37	16.73	17.37

field	25	25	25	25	26	26	26	26
name	aniceto	aniceto	aniceto	aniceto	anselmo	anselmo	anselmo	anselmo
plot	89	90	91	92	93	94	95	96
lithology	2	2	2	2	1	1	1	1
community	2	2	2	2	2	2	2	2
altitude	900	900	900	900	360	360	360	360
aspect	233	210	220	205	20	155	49	195
slope	43	35	43	39	35	39	41	45
age	6	6	6	6	12	12	12	12
order	2	2	2	2	4	4	4	4
virgin	12	12	12	12	60	60	60	60
hor. length	18.28	20.48	18.28	19.43	20.48	19.43	18.87	17.68

field	27	27	27	27	28	28	28	28
name	pedro	pedro	pedro	pedro	anacleto	anacleto	anacleto	anacleto
plot	97	98	99	100	101	102	103	104
lithology	1	1	1	1	2	2	2	2
community	2	2	2	2	2	2	2	2
altitude	600	600	600	600	480	480	480	480
aspect	5	5	355	15	255	240	218	213
slope	35	34	36	35	43	33	43	49
age	7	7	7	7	5	5	5	5
order	4	4	4	4	4	4	4	4
virgin	30	30	30	30	30	30	30	30
hor. length	20.48	20.73	20.23	20.48	18.28	20.97	18.28	16.40

Legend: field = field number; name = name of the farmer who last cropped the field; plot = transect number; community: 1 = Santa Cruz Tepetotutla, 2 = Santiago Tlatepusco; aspect: direction in degrees with respect to the North, faced when standing in the field; slope: in degrees; age = age in years of secondary regrowth; order: order of regrowth; virgin: time in years since cutting of primary or old secondary vegetation; hor. length = length of the horizontal projection of the transect.

Annex 2. List of species.

No.	FAMILY	GENUS	SPECIES
1	Acanthaceae	Odontonema	Odontonema callistachyum
2	Actinidiaceae	Saurauia	Saurauia aspera
3	Actinidiaceae	Saurauia	Saurauia conzattii
4	Actinidiaceae	Saurauia	Saurauia pringlei
5	Actinidiaceae	Saurauia	Saurauia scabrida
6	Actinidiaceae	Saurauia	Saurauia sp. 1
7	Actinidiaceae	Saurauia	Saurauia sp. 2
8	Actinidiaceae	Saurauia	Saurauia sp. 3
9	Actinidiaceae	Saurauia	Saurauia sp. 4
10	Actinidiaceae	Saurauia	Saurauia sp. 5
11	Actinidiaceae	Saurauia	Saurauia sp. 6
12	Anacardiaceae	Spondias	Spondias radlkoferi
13	Annonaceae	Annona	Annona globiflora
14	Annonaceae	Desmopsis	Desmopsis trunciflora
15	Annonaceae	Guatteria	Guatteria galeottiana
16	Apocynaceae	Tabernaemontana	Tabernaemontana alba
17	Araliaceae	Dendropanax	Dendropanax arboreus
18	Asteraceae	Asteraceae	Asteraceae 1
19	Asteraceae	Asteraceae	Asteraceae 2
20	Asteraceae	Calea	Calea ternifolia
21	Asteraceae	Eupatorium	Eupatorium araliaefolium
22	Asteraceae	Eupatorium	Eupatorium macrophylum
23	Asteraceae	Eupatorium	Eupatorium sexangulare
24	Asteraceae	Eupatorium	Eupatorium sp. 1
25	Asteraceae	Eupatorium	Eupatorium tuerzkeinii
26	Asteraceae	Eupatorium	Eupatorium morifolium
27	Asteraceae	Eupatorium	Eupatorium albicaule
28	Asteraceae	Eupatorium	Eupatorium ligustrinum
29	Asteraceae	Eupatorium	Eupatorium sp. 2
30	Asteraceae	Schistocarpha	Schistocarpha platyphylla
31	Asteraceae	Senecio	Senecio arborescens
32	Asteraceae	Verbesina	Verbesina turbacensis
33	Asteraceae	Verbesina	Verbesina sp. 1
34	Asteraceae	Verbesina	Verbesina sp. 2
35	Asteraceae	Vernonia	Vernonia aschenborniana
36	Asteraceae	Vernonia	Vernonia patens
37	Asteraceae	Vernonia	Vernonia sp. 1
38	Asteraceae	Vernonia	Vernonia sp. 2
39	Bignoniaceae	Amphitecna	Amphitecna macrophylla
40	Bixaceae	Cochlospermum	Cochlospermum vitifolium
41	Bombacaceae	Ochroma	Ochroma pyramidale
42	Boraginaceae	Boraginaceae	Boraginaceae 1
43	Boraginaceae	Boraginaceae	Boraginaceae 2
44	Boraginaceae	Cordia	Cordia sp. 1
45	Boraginaceae	Cordia	Cordia spinescens
46	Boraginaceae	Cordia	Cordia stellifera
47	Boraginaceae	Cordia	Cordia alliadora
48	Brunelliaceae	Brunellia	Brunellia mexicana
49	Burseraceae	Protium	Protium copal
50	Cecropiaceae	Cecropia	Cecropia sp.
51	Celastraceae	Perrotetia	Perrottetia longistylis
52	Chloranthaceae	Hedyosmum	Hedyosmum mexicanum
53	Clethraceae	Clethra	Clethra mexicana
54	Clethraceae	Clethra	Clethra sp. 1
55	Clethraceae	Clethra	Clethra sp. 2
56	Clethraceae	Clethra	Clethra sp. 3
57	Combretaceae	Terminalia	Terminalia amazonia
58	Costaceae	Costus	Costus pictus
59	Cyatheaceae	Cyathea	Cyathea fulva
60	Erythroxylaceae	Erythroxylum	Erythroxylum tabascense
61	Euphorbiaceae	Acalypha	Acalypha macrostachya
62	Euphorbiaceae	Acalypha	Acalypha sp. 1
63	Euphorbiaceae	Acalypha	Acalypha sp. 2
64	Euphorbiaceae	Acalypha	Acalypha sp. 3
65	Euphorbiaceae	Acalypha	Acalypha sp. 3
66	Euphorbiaceae	Alchornea	Alchornea latifolia
67	Euphorbiaceae	Cnidoscolus	Cnidoscolus multilobus
68	Euphorbiaceae	Croton	Croton draco
69	Euphorbiaceae	Croton	Croton sp. 1
70	Euphorbiaceae	Euphorbiaceae	Euphorbiaceae 1
71	Euphorbiaceae	Sapium	Sapium nitidum
72	Flacourtiaceae	Casearia	Casearia corymbosa
73	Flacourtiaceae	Casearia	Casearia sp. 1
74	Flacourtiaceae	Casearia	Casearia sylvestris
75	Flacourtiaceae	Zuelania	Zuelania guidonia
76	Flacourtiaceae	Xylosma	Xylosma sp. 1
77	Guttiferae	Rheedia	Rheedia edulis
78	Guttiferae	Vismia	Vismia mexicana
79	Hammamelidaceae	Liquidambar	Liquidambar macrophylla
80	Lauraceae	Lauraceae	Lauraceae 1
81	Lauraceae	Lauraceae	Lauraceae 2
82	Lauraceae	Lauraceae	Lauraceae 3
83	Lauraceae	Lauraceae	Lauraceae 4
84	Lauraceae	Lauraceae	Lauraceae 5
85	Lauraceae	Licaria	Licaria caudata
86	Lauraceae	Licaria	Licaria excelsa
87	Lauraceae	Licaria	Licaria guatemalensis
88	Lauraceae	Licaria	Licaria misantlae
89	Lauraceae	Licaria	Licaria peckii
90	Lauraceae	Licaria	Licaria sp. 1
91	Lauraceae	Nectandra	Nectandra longicaudata
92	Lauraceae	Nectandra	Nectandra salicifolia
93	Lauraceae	Ocotea	Ocotea helicterifolia
94	Lauraceae	Ocotea	Ocotea henkewerffi
95	Lauraceae	Persea	Persea americana
96	Leguminosae	Calliandra	Calliandra grandiflora
97	Leguminosae	Calliandra	Calliandra houstoniana
98	Leguminoseae	Acacia	Acacia cornigera
99	Leguminosae	Dalbergia	Dalbergia sp.
100	Leguminosae	Inga	Inga acrocephala
101	Leguminosae	Inga	Inga latibracteata
102	Leguminosae	Inga	Inga pavoniana
103	Leguminosae	Inga	Inga aestuariorum
104	Leguminosae	Inga	Inga sp. 1
105	Leguminosae	Leguminosae	Leguminosae 1
106	Leguminosae	Leguminosae	Leguminosae 2
107	Leguminosae	Leguminosae	Leguminosae 3
108	Leguminosae	Leguminosae	Leguminosae 4
109	Leguminosae	Lonchocarpus	Lonchocarpus sp. 1
110	Leguminosae	Lonchocarpus	Lonchocarpus sp. 2
111	Leguminosae	Lonchocarpus	Lonchocarpus sp. 3
112	Leguminosae	Mimosa	Mimosa albida
113	Leguminosae	Ormosia	Ormosia sp. 1
114	Leguminosae	Papilonaceae	Papilonaceae 1
115	Leguminosae	Pterocarpus	Pterocarpus sp. 1

No.	FAMILY	GENUS	SPECIES
116	Leguminosae	Senna	Senna multijuga
117	Leguminosae	Swartzia	Swartzia sp. 1
118	Leguminosae	Swartzia	Swartzia sp. 2
119	Magnoliaceae	Magnoliaceae	Magnoliaceae 1
120	Malpighiaceae	Bunchosia	Bunchosia lindeniana
121	Malpighiaceae	Byrsonima	Byrsonima crassifolia
122	Malvaceae	Hibiscus	Hibiscus uncinellus
123	Melastomataceae	Conostegia	Conostegia caelestis
124	Melastomataceae	Conostegia	Conostegia icosandra
125	Melastomataceae	Conostegia	Conostegia sp. 1
126	Melastomataceae	Conostegia	Conostegia xalapensis
127	Melastomataceae	Conostegia	Conostegia sp. 2
128	Melastomataceae	Miconia	Miconia serrulata
129	Melastomataceae	Miconia	Miconia argentea
130	Melastomataceae	Miconia	Miconia ibaguensis
131	Melastomataceae	Miconia	Miconia laevigata
132	Melastomataceae	Miconia	Miconia prasina
133	Melastomataceae	Miconia	Miconia sp. 1
134	Melastomataceae	Miconia	Miconia sp. 2
135	Melastomataceae	Miconia	Miconia sp. 3
136	Melastomataceae	Miconia	Miconia sp. 4
137	Melastomataceae	Miconia	Miconia trinervia
138	Melastomataceae	Miconia	Miconia barbinervis
139	Melastomataceae	Miconia	Miconia sp. 5
140	Melastomataceae	Miconia	Miconia sp. 6
141	Melastomataceae	Miconia	Miconia sp. 7
142	Melastomataceae	Miconia	Miconia sp. 8
143	Melastomataceae	Miconia	Miconia sp. 9
144	Meliaceae	Guarea	Guarea grandifolia
145	Meliaceae	Guarea	Guarea glabra
146	Meliaceae	Guarea	Guarea sp. 1
147	Monimiaceae	Mollinedia	Mollinedia oaxacana
148	Monimiaceae	Mollinedia	Mollinedia viridiflora
149	Monimiaceae	Siparuna	Siparuna andina
150	Monimiaceae	Siparuna	Siparuna austromexicana
151	Moraceae	Ficus	Ficus insipida
152	Moraceae	Pseudolmedia	Pseudolmedia oxyphyllaria
153	Moraceae	Pseudolmedia	Pseudolmedia spuria
154	Myricaceae	Myrica	Myrica cerifera
155	Myrsinaceae	Ardisia	Ardisia paschalis
156	Myrsinaceae	Ardisia	Ardisia revoluta
157	Myrsinaceae	Rapanea	Rapanea ferruginea
158	Myrtaceae	Calyptranthes	Calyptranthes chytraculia
159	Myrtaceae	Calyptranthes	Calyptranthes sp. 1
160	Myrtaceae	Eugenia	Eugenia acapulcensis
161	Myrtaceae	Eugenia	Eugenia sp. 1
162	Myrtaceae	Myrcia	Myrcia splendens
163	Myrtaceae	Myrcia	Myrcia sp. 1
164	Papaveraceae	Bocconia	Bocconia frutescens
165	Phytolaccaceae	Phytolacca	Phytolacca icosandra
166	Piperaceae	Piper	Piper aequale
167	Piperaceae	Piper	Piper calophyllum
168	Piperaceae	Piper	Piper luxii
169	Piperaceae	Piper	Piper marginatum
170	Piperaceae	Piper	Piper sp. 4
171	Piperaceae	Piper	Piper sp. 3
172	Piperaceae	Piper	Piper auritum
173	Piperaceae	Piper	Piper sp. 1
174	Piperaceae	Piper	Piper sp. 2
175	Piperaceae	Piper	Piper yzabalanum
176	Polygonaceae	Coccoloba	Coccoloba matuciae
177	Proteaceae	Roupala	Roupala montana
178	Rhamnaceae	Rhamnus	Rhamnus capreifolia
179	Rosaceae	Prunus	Prunus tetradenia
180	Rubiaceae	Cephaelis	Cephaelis elata
181	Rubiaceae	Faramea	Faramea schultesii
182	Rubiaceae	Faramea	Faramea stenura
183	Rubiaceae	Hoffmania	Hoffmania culminicola
184	Rubiaceae	Hoffmannia	Hoffmannia aff. tonduzii
185	Rubiaceae	Hoffmannia	Hoffmannia ixtlanensis
186	Rubiaceae	Palicourea	Palicourea padifolia
187	Rubiaceae	Psychotria	Psychotria macrophylla
188	Rubiaceae	Psychotria	Psychotria panamensis
189	Rubiaceae	Rondeletia	Rondeletia capitellata
190	Rubiaceae	Rondeletia	Rondeletia villosa
191	Rubiaceae	Rondeletia	Rondeletia secundiflora
192	Rubiaceae	Rondeletia	Rondeletia rufescens
193	Rubiaceae	Rubiaceae	Rubiaceae 1
194	Rubiaceae	Rubiaceae	Rubiaceae 2
195	Rubiaceae	Rubiaceae	Rubiaceae 3
196	Rubiaceae	Rubiaceae	Rubiaceae 4
197	Rubiaceae	Sommera	Sommera arborescens
198	Sapindaceae	Cupania	Cupania one
199	Sapindaceae	Cupania	Cupania glabra
200	Sapindaceae	Matayba	Matayba oppositifolia
201	Scrophulariaceae	Uroskinnera	Uroskinnera hirtiflora
202	Simaroubaceae	Picramnia	Picramnia teapensis
203	Solanaceae	Cestrum	Cestrum racemosum
204	Solanaceae	Solanum	Solanum hispidum
205	Solanaceae	Solanum	Solanum schlechtendalianum
206	Solanaceae	Solanum	Solanum sp. 1
207	Solanaceae	Solanum	Solanum sp. 2
208	Solanaceae	Solanum	Solanum sp. 3
209	Solanaceae	Solanum	Solanum sp. 4
210	Solanaceae	Solanum	Solanum sp. 5
211	Slanaceae	Solanaceae	Solanaceae 1
212	Staphyleaceae	Turpinia	Turpinia occidentalis
213	Sterculiaceae	Helicteres	Helicteres guazumaefolia
214	Ticodendraceae	Ticodendron	Ticodendron incognitum
215	Tiliaceae	Heliocarpus	Heliocarpus appendiculatus
216	Tiliaceae	Heliocarpus	Heliocarpus donnell-smithii
217	Tiliaceae	Heliocarpus	Heliocarpus occidentalis
218	Tiliaceae	Heliocarpus	Heliocarpus sp. 1
219	Tiliaceae	Heliocarpus	Heliocarpus sp. 2
220	Tiliaceae	Luehea	Luehea speciosa
221	Tiliaceae	Tilia	Tilia mexicanum
222	Tiliaceae	Trichospermum	Trichospermum mexicanum
223	Tiliaceae	Triumfetta	Triumfetta grandiflora
224	Ulmaceae	Trema	Trema micrantha
225	Ulmaceae	Ulmus	Ulmus sp. 1
226	Urticaceae	Myriocarpa	Myriocarpa longipes
227	Urticaceae	Urera	Urera elata
228	Urticaceae	Urera	Urera sp. 1
229	Urticaceae	Urera	Urera sp. 2

Annex 3. Species codes.

aca cor	Acacia cornigera
aca fou	Acalypha sp. 3
aca mac	Acalypha macrostachya
aca one	Acalypha sp. 1
aca thr	Acalypha sp. 3
aca two	Acalypha sp. 2
alc lat	Alchornea latifolia
amp mac	Amphitecna macrophylla
ann glo	Annona globiflora
ard pas	Ardisia paschalis
ard rev	Ardisia revoluta
ast one	Asteraceae 1
ast two	Asteraceae 2
boc fru	Bocconia frutescens
bor one	Boraginaceae 1
bor two	Boraginaceae 2
bru mex	Brunellia mexicana
bun lin	Bunchosia lindeniana
byr cra	Byrsonima crassifolia
cal chy	Calyptranthes chytraculia
cal gra	Calliandra grandiflora
cal hou	Calliandra houstoniana
cal one	Calyptranthes sp. 1
cal ter	Calea ternifolia
cas cor	Casearia corymbosa
cas one	Casearia sp. 1
cas syl	Casearia sylvestris
cec spe	Cecropia sp.
cep ela	Cephaelis elata
ces rac	Cestrum racemosum
cle mex	Clethra mexicana
cle one	Clethra sp. 1
cle thr	Clethra sp. 3
cle two	Clethra sp. 2
cni mul	Cnidoscolus multilobus
coc mat	Coccoloba matuclae
coc vit	Cochlospermum vitifolium
con cae	Conostegia caelestis
con ico	Conostegia icosandra
con one	Conostegia sp. 1
con two	Conostegia sp. 2
con xal	Conostegia xalapensis
cor all	Cordia alliadora
cor one	Cordia sp. 1
cor spi	Cordia spinescens
cor ste	Cordia stellifera
cos pic	Costus pictus
cro dra	Croton draco
cro one	Croton sp. 1
cup gla	Cupania glabra
cup one	Cupania one
cya ful	Cyathea fulva
dal one	Dalbergia sp.
den arb	Dendropanax arboreus
des tru	Desmopsis trunciflora
ery tab	Erythroxylum tabascense
eug aca	Eugenia acapulcensis
eug one	Eugenia sp. 1
eup alb	Eupatorium albicaule
eup ara	Eupatorium araliaefolium
eup hor	Euphorbiaceae 1
eup lig	Eupatorium ligustrinum
eup mac	Eupatorium macrophylum
eup mor	Eupatorium morifolium
eup one	Eupatorium sp. 1
eup sex	Eupatorium sexangulare
eup tue	Eupatorium tuerzkeinii
eup two	Eupatorium sp. 2
far sch	Faramea schultesii
far ste	Faramea stenura
fic ins	Ficus insipida
gua gal	Guatteria galeottiana
gua gla	Guarea glabra
gua gra	Guarea grandifolia
gua one	Guarea sp. 1
hed mex	Hedyosmum mexicanum
hel app	Heliocarpus appendiculatus
hel don	Heliocarpus donnell-smithii
hel gua	Helicteres guazumaefolia
hel occ	Heliocarpus occidentalis
hel one	Heliocarpus sp. 1
hel two	Heliocarpus sp. 2
hib unc	Hibiscus uncinellus
hof cul	Hoffmania culminicola
hof ixt	Hoffmannia ixtlanensis
hof ton	Hoffmannia aff. tonduzii
ing acr	Inga acrocephala
ing aes	Inga aestuariorum
ing lat	Inga latibracteata
ing one	Inga sp. 1
ing pav	Inga pavoniana
lau fiv	Lauraceae 5
lau fou	Lauraceae 4
lau one	Lauraceae 1
lau thr	Lauraceae 3
lau two	Lauraceae 2
leg fou	Leguminosae 1
leg one	Leguminosae 1
leg thr	Leguminosae 1
leg two	Leguminosae 1
lic cau	Licaria caudata
lic exc	Licaria excelsa
lic gua	Licaria guatemalensis
lic mis	Licaria misantlae
lic one	Licaria sp. 1
lic pec	Licaria peckii
liq mac	Liquidambar macrophylla
lon one	Lonchocarpus sp. 1
lon thr	Lonchocarpus sp. 3
lon two	Lonchocarpus sp. 2
lue spe	Luehea speciosa
mag one	Magnoliaceae 1
mat opp	Matayba oppositifolia
mic arg	Miconia argentea

mic bar	Miconia barbinervis
mic eig	Miconia sp. 8
mic fiv	Miconia sp. 5
mic fou	Miconia sp. 4
mic iba	Miconia ibaguensis
mic lae	Miconia laevigata
mic nin	Miconia sp. 9
mic one	Miconia sp. 1
mic pra	Miconia prasina
mic ser	Miconia serrulata
mic sev	Miconia sp. 7
mic six	Miconia sp. 6
mic thr	Miconia sp. 3
mic tri	Miconia trinervia
mic two	Miconia sp. 2
mim alb	Mimosa albida
mol oax	Mollinedia oaxacana
mol vir	Mollinedia viridiflora
myr cer	Myrica cerifera
myr lon	Myriocarpa longipes
myr one	Myrcia sp. 1
myr spl	Myrcia splendens
nec lon	Nectandra longicaudata
nec sal	Nectandra salicifolia
och pyr	Ochroma pyramidale
oco hel	Ocotea helicterifolia
oco hen	Ocotea henkewerffi
odo cal	Odontonema callistachyum
orm one	Ormosia sp. 1
pal pad	Palicourea padifolia
pap one	Papilonaceae 1
per ame	Persea americana
per lon	Perrottetia longistylis
phy ico	Phytolacca icosandra
pic tea	Picramnia teapensis
pip aeq	Piper aequale
pip aur	Piper auritum
pip cal	Piper calophyllum
pip fou	Piper sp. 4
pip lux	Piper luxii
pip mar	Piper marginatum
pip one	Piper sp. 1
pip thr	Piper sp. 3
pip two	Piper sp. 2
pip yza	Piper yzabalanum
pro cop	Protium copal
pru tet	Prunus tetradenia
pse oxy	Pseudolmedia oxyphyllaria
pse spu	Pseudolmedia spuria
psy mac	Psychotria macrophylla
psy pan	Psychotria panamensis
pte one	Pterocarpus sp. 1
rap fer	Rapanea ferruginea
rha cap	Rhamnus capreifolia
rhe edu	Rheedia edulis
ron cap	Rondeletia capitellata
ron ruf	Rondeletia rufescens
ron sec	Rondeletia secundiflora
ron vil	Rondeletia villosa
rou mon	Roupala montana
rub fou	Rubiaceae 4
rub one	Rubiaceae 1
rub thr	Rubiaceae 3
rub two	Rubiaceae 2
sap nit	Sapium nitidum
sau asp	Saurauia aspera
sau con	Saurauia conzattii
sau fiv	Saurauia sp. 5
sau fou	Saurauia sp. 4
sau one	Saurauia sp. 1
sau pri	Saurauia pringlei
sau sca	Saurauia scabrida
sau six	Saurauia sp. 6
sau thr	Saurauia sp. 3
sau two	Saurauia sp. 2
sch pla	Schistocarpha platyphylla
sen arb	Senecio arborescens
sen mul	Senna multijuga
sip and	Siparuna andina
sip aus	Siparuna austromexicana
sol ana	Solanaceae 1
sol fiv	Solanum sp. 5
sol fou	Solanum sp. 4
sol his	Solanum hispidum
sol one	Solanum sp. 1
sol sch	Solanum schlechtendalianum
sol thr	Solanum sp. 3
sol two	Solanum sp. 2
som arb	Sommera arborescens
spo rad	Spondias radlkoferi
swa one	Swartzia sp. 1
swa two	Swartzia sp. 2
tab alb	Tabernaemontana alba
ter ama	Terminalia amazonia
tic inc	Ticodendron incognitum
til mex	Tilia mexicanum
tre mic	Trema micrantha
tri gra	Triumfetta grandiflora
tri mex	Trichospermum mexicanum
tur occ	Turpinia occidentalis
ulm one	Ulmus sp. 1
ure ela	Urera elata
ure one	Urera sp. 1
ure two	Urera sp. 2
uro hir	Uroskinnera hirtiflora
ver one	Verbesina sp. 1
ver tur	Verbesina turbacensis
ver two	Verbesina sp. 2
vis mex	Vismia mexicana
vrn asc	Vernonia aschenborniana
vrn one	Vernonia sp. 1
vrn pat	Vernonia patens
vrn two	Vernonia sp. 2
xyl one	Xylosma sp. 1
zue gui	Zuelania guidonia

Annex 4. List of genera.

GENUS	number of species	number of individuals	summed basal area (cm2)	summed crown proyection (m2)	GENUS	number of species	number of individuals	summed basal area (cm^2)	summed crown proyection (m^2)
Acacia	1	8	107	21	Miconia	16	168	3786	789
Acalypha	5	29	242	47	Mimosa	1	2	8	3
Alchornea	1	89	8092	660	Mollinedia	2	33	423	82
Amphitecna	1	2	9	1	Myrcia	3	10	661	55
Annona	1	3	66	2	Myriocarpa	1	17	146	29
Ardisia	2	5	56	7	Nectandra	2	3	127	20
Asteraceae	2	12	2538	52	Ochroma	1	2	30	10
Bocconia	1	1	5	0	Ocotea	2	40	1593	311
Boraginaceae	2	2	33	2	Odontonema	1	1	5	0
Brunellia	1	96	7628	769	Ormosia	1	2	15	4
Bunchosia	1	3	17	3	Palicourea	1	57	482	105
Byrsonima	1	1	10	3	Papilonaceae	1	3	30	4
Calea	1	1	4	2	Perrotetia	1	8	3193	107
Calliandra	2	18	147	41	Persea	1	1	27	3
Calyptranthes	2	4	269	37	Phytolacca	1	2	12	1
Casearia	3	16	115	36	Picramnia	1	2	13	4
Cecropia	1	118	4758	351	Piper	10	147	1438	306
Cephaelis	1	8	57	12	Protium	1	11	2022	268
Cestrum	1	4	30	15	Prunus	1	3	106	34
Clethra	4	46	896	108	Pseudolmedia	2	24	663	133
Cnidoscolus	1	1	15	4	Psychotria	2	164	1386	317
Coccoloba	1	1	6	0	Pterocarpus	1	1	3	1
Cochlospermu	1	5	125	18	Rapanea	1	109	1432	261
Conostegia	5	84	807	271	Rhamnus	1	21	633	106
Cordia	4	18	186	51	Rheedia	1	15	738	63
Costus	1	17	707	86	Rondeletia	4	68	1125	170
Croton	2	94	3159	714	Roupala	1	11	69	17
Cupania	2	23	227	31	Rubiaceae	4	28	419	63
Cyathea	1	8	439	47	Sapium	1	2	22	4
Dalbergia	1	1	6	1	Saurauia	10	162	9276	1010
Dendropanax	1	21	746	45	Schistocarpha	1	1	10	2
Desmopsis	1	2	8	2	Senecio	1	58	1032	162
Erythroxylum	1	39	556	90	Senna	1	27	1701	362
Eugenia	2	7	91	43	Siparuna	2	115	1548	228
Eupatorium	9	50	1651	214	Solanaceae	8	61	442	75
Euphorbiacea	1	1	7	2	Sommera	1	34	1369	132
Faramea	2	15	82	29	Spondias	1	9	424	91
Ficus	1	3	122	17	Swartzia	2	3	33	6
Guarea	3	25	1089	77	Tabernaemontan	1	4	26	4
Guatteria	1	2	12	5	Terminalia	1	1	4	1
Hedyosmum	1	349	16413	1625	Ticodendron	1	9	756	64
Helicteres	1	16	117	25	Tilia	1	37	885	194
Heliocarpus	5	626	33999	2954	Trema	1	693	19577	2260
Hibiscus	1	8	35	8	Trichospermum	1	411	16514	1550
Hoffmannia	3	6	24	4	Triumfetta	1	8	50	11
Inga	5	143	4883	971	Turpinia	1	2	68	10
Lauraceae	5	19	426	81	Ulmus	1	2	723	39
Leguminosae	4	10	832	177	Urera	3	25	852	83
Licaria	6	22	1361	156	Uroskinnera	1	1	8	0
Liquidambar	1	33	10200	391	Verbesina	3	44	644	77
Lonchocarpus	3	46	542	142	Vernonia	4	199	3194	559
Luehea	1	1	8	10	Vismia	1	184	3519	669
Magnoliaceae	1	1	17	2	Xylosma	1	1	4	3
Matayba	1	3	25	2	Zuelania	1	5	77	16

Annex 5. List of families.

FAMILY	number of genera	number of species	number of individuals	summed basal area (cm^2)	summed crown proyection (m^2)
Acanthaceae	1	1	1	5	0
Actinidiaceae	1	10	162	9276	1010
Anacardiaceae	1	1	9	424	91
Annonaceae	3	3	7	86	9
Apocynaceae	1	1	4	26	4
Araliaceae	1	1	21	746	45
Asteraceae	8	21	364	9065	1065
Bignoniaceae	1	1	2	9	1
Bixaceae	1	1	5	125	18
Bombacaceae	1	1	2	30	10
Boraginaceae	2	6	20	219	53
Brunelliaceae	1	1	96	7628	769
Burseraceae	1	1	11	2022	268
Cecropiaceae	1	1	118	4758	351
Celastraceae	1	1	8	3193	107
Chloranthaceae	1	1	349	16413	1625
Clethraceae	1	4	46	896	108
Combretaceae	1	1	1	4	1
Costaceae	1	1	17	707	86
Cyatheaceae	1	1	8	439	47
Erythroxylaceae	1	1	39	556	90
Euphorbiaceae	5	11	216	11537	1430
Flacourtiaceae	3	5	22	196	56
Guttiferae	2	2	199	4257	732
Hammamelidaceae	1	1	33	10200	391
Lauraceae	5	16	85	3533	572
Leguminosae	12	23	264	8307	1732
Magnoliaceae	1	1	1	17	2
Malpighiaceae	2	2	4	27	6
Malvaceae	1	1	8	35	8
Melastomataceae	2	21	252	4593	1060
Meliaceae	1	3	25	1089	77
Monimiaceae	2	4	148	1971	310
Moraceae	2	3	27	785	150
Myricaceae	1	1	4	18	3
Myrsinaceae	2	3	114	1487	268
Myrtaceae	3	6	17	1003	131
Papaveraceae	1	1	1	5	0
Phytolaccaceae	1	1	2	12	1
Piperaceae	1	10	147	1438	306
Polygonaceae	1	1	1	6	0
Proteaceae	1	1	11	69	17
Rhamnaceae	1	1	21	633	106
Rosaceae	1	1	3	106	34
Rubiaceae	8	18	380	4944	832
Sapindaceae	2	3	26	252	33
Scrophulariaceae	1	1	1	8	0
Simaroubaceae	1	1	2	13	4
Solanaceae	2	9	65	472	91
Staphyleaceae	1	1	2	68	10
Sterculiaceae	1	1	16	117	25
Ticodendraceae	1	1	9	756	64
Tiliaceae	5	9	1083	51456	4719
Ulmaceae	2	2	695	20300	2299
Urticaceae	2	4	42	998	112

Annex 6. Vernacular plant names.

Cientific name	Chinantec name	Spanish name	Cientific name	Chinantec name	Spanish name
Acalypha sp.	mah la		Miconia serrulata	mah ni ca mo	p. de pescado
Alchornea latifolia	mah hu	p. de rosario	Miconia trinervia	mah ni	p. de pescado
Annona globiflora		anona de monte	Mollinedia oaxacana	ma ih nao	
Asteraceae	mah lliu nom	encino de monte	Myrica cerifera		p. pajarito
Bocconia frutescens		copalera	Nectandra longicaudata	mah gui ti	aguacatillo
Brunellia mexicana	mah lau	p. de nopal	Ocotea helicterifolia	mah ghoh	aguacatillo peludo
Calyptranthes chytraculia		te de monte	Palicourea padifolia	mah li guie	p. de flor de viejo
Cecropia sp.		chancarro	Persea americana		aguacatillo
Cephaelis elata		p. de flor	Phytolacca icosandra		huele de noche
Cestrum racemosum		huele de noche	Piper aequale	mah au hi	hierba del viento
Clethra mexicana	mah gua	p. de tierra	Piper calophyllum	mah ha dje	flor de mazorquita
Clethra sp.	mah gua	p. de tierra	Piper marginatum	mah ha	
Conostegia caelestis	mah ni	p. de pescado	Piper sp. 3		p. de guajolote
Conostegia sp.	mah ni	p. de pescado	Protium copal		p. de petroleo
Conostegia xalapensis	mah ni	p. de pescado	Pseudolmedia spuria		durazno de monte
Costus pictus	mah ni	p. de pescado	Psychotria macrophylla	ma laig	
Croton draco	mah mun	sangregado	Psychotria panamensis	mah lui	p. de muerto
Croton sp.	mah mun	sangregado	Rapanea ferruginea	mah leg	p. pajarito
Cyathea fulva		helecho arboreo	Rhamnus capreifolia	mah hu te i moh	aguacate de hoja delgada
Dendropanax arboreus		p. suave	Rondeletia capitellata	ma ki	
Erythroxylum tabascense	mah li	p. de flor	Rondeletia rufescens	mah au	p. de jabon
Eupatorium tuerzkeinii	mah yi		Rondeletia secundiflora	mah ki	p. de basura
Hedyosmum mexicanum	mah nam	p. de agua	Saurauia aspera		p. de moco
Heliocarpus appendiculatus	mah ghe	jonote (rojo, blanco)	Saurauia comitis-rossei		p. de moco
Heliocarpus appendiculatus	mah gi	jonote rojo	Saurauia conzattii		p. de moco
Heliocarpus appendiculatus	ma ghe tiu	jonote blanco	Saurauia scabrida		p. de moco
Heliocarpus donnell-smithii	mah ghe	jonote	Senecio arborescens	mah chi iha	p. de tigre
Inga acrocephala		guajinicuil verde	Senna multijuga	mah nei	p. de frijol
Inga latibracteata	mah ya nin	jinicuil	Siparuna andina	mah mui rea	serbatana
Inga pavoniana	mah ya ki	jinicuil de tejon	Siparuna austromexicana	mah mui rea	serbatana
Lauraceae sp. 4	mah kui	aguacatillo	Solanum schlechtendalianum	mah nin	huele de noche
Lauraceae sp. 3	mah leo	p. pegajoso	Sommera arborescens	ma laig ma	p. de muerto de monte
Lauraceae sp. 2	ma jua	p. de trucha	Terminalia amazonia	mah you	arbol de sol
Licaria guatemalensis	mah co je net	aguacatillo del monte	Ticodendron incognitum	mah jah	p. de durazno
Liquidambar macrophylla	mah la	pinabete	Trema micrantha	mah chi nang	capulin
Miconia argentea	mah ni	p. de pescado	Triumfetta grandiflora	ma i lo	
Miconia sp 5	ma ni tei	p. de pescado	Trichospermum mexicanum	mah choh	
Miconia ibaguensis	mah ni	p. de pescado	Ulmus sp. 1	mah chi te	p. de huarache
Miconia laevigata	mah ni	p. de pescado	Urera elata		mala mujer
Miconia prasina	mah ni	p. de pescado	Verbesina turbacensis	mah li toh kyo dza o	
			Vismia mexicana	mah mi nau	p. amarillo
			Vernonia patens	mah mi king	p. de gusano, seco

Annex 7. TWINSPAN table (presence/absence)

```
Fieldnumber:      222 11178121222212 114563 211
                  678 367  559012384  1      24
   197 myr lon    -11 ------1------- ------ ---   000000
    92 hel gua    11- -------------- ------ ---   000001
   143 cal hou    111 --1----------- ------ ---   000001
   190 cas syl    111 -------------1 ------ ---   000001
   198 sau fiv    1-- -------------- ------ ---   000001
   199 tab alb    1-1 -------------- ------ ---   000001
   200 coc vit    1-- -------------- ------ ---   000001
   201 dal one    1-- -------------- ------ ---   000001
   202 ing ses    1-1 -------------- ------ ---   000001
   203 leg thr    11- -------------- ------ ---   000001
   204 byr cra    1-- -------------- ------ ---   000001
   205 ron vil    111 -------------- ------ ---   000001
   206 hel two    1-- -------------- ------ ---   000001
   207 spo rad    -11 -------------- ------ ---   000001
   208 ver two    -1- -------------- ------ ---   000001
   209 aca fou    -1- -------------- ------ ---   000001
   210 con two    -1- -------------- ------ ---   000001
   211 pip aur    -1- -------------- ------ ---   000001
   212 cup gla    -11 -------------- ------ ---   000001
   213 hel occ    -11 -------------- ------ ---   000001
   214 des tru    --1 -------------- ------ ---   000001
   215 eup mor    --1 -------------- ------ ---   000001
   216 eup alb    --1 -------------- ------ ---   000001
   217 och pyr    --1 -------------- ------ ---   000001
   218 aca one    --1 -------------- ------ ---   000001
   219 eup hor    --1 -------------- ------ ---   000001
   220 lau fiv    --1 -------------- ------ ---   000001
   221 aca cor    --1 -------------- ------ ---   000001
   222 leg one    --1 -------------- ------ ---   000001
   223 leg two    --1 -------------- ------ ---   000001
   224 leg fou    --1 -------------- ------ ---   000001
   225 lon two    --1 -------------- ------ ---   000001
   226 eug aca    --1 -------------- ------ ---   000001
   227 coc mat    --1 -------------- ------ ---   000001
   228 pic tas    --1 -------------- ------ ---   000001
   229 lue spe    --1 -------------- ------ ---   000001
    49 sau pri    1-- -----------1-- -----1 ---   000010
    86 sen mul    --1 ------1------- ------ ---   000010
   153 aca thr    --1 ------------1- ------ ---   000010
   159 pip thr    11- --------1---1- ------ ---   000010
   165 cas rac    11- -------11----- ------ ---   000010
   193 cor all    --1 ------1------- ------ ---   000010
   194 aca two    --1 ------1------- ------ ---   000010
     4 ver tur    111 -111--1------- 1-1--- ---   000011
    14 ing pav    -11 1-1----------- 1-1--- ---   000011
    23 rou mon    --1 -------------- 1----- ---   000011
    57 cle two    -1- -------------- --1--- ---   000011
    70 cro dra    111 -1----1-----1- ---11- ---   000011
    87 con cae    -1- --1----------- ------ ---   000011
    97 con xal    -1- -11----------- ------ ---   000011
   123 cor ste    -11 1-1----------- ------ ---   000011
   142 cas cor    -1- --1----------- ------ ---   000011
   145 con ico    -1- --1----------- ------ ---   000011
    82 vrn pat    11- 1111--1-111-1- ------ ---   0001
    83 hel don    1-1 -1-1111---1--- ------ ---   0001
   180 cle thr    1-- ----------11-- ------ ---   0001
    27 sol sch    -1- 111------1---- 11---- -1-   0010
    31 tre mic    111 1-11111111111- 11---1 ---   00110
    13 ing lat    11- 11-1-11111--11 1---11 ---   001110
                  000 00000000000000 000000 111
                  000 11111111111111 111111
                      00000000000000 111111
                      00011111111111 000001
                         00001111111 00111
                             0000011
```

```
                  222 11178121222212 114563 211
                  678 367  559012384  1      24
    21 sip and    11- 11-1--1111--11 1-111- ---   001110
    29 hel app    11- 111--111111111 111-11 ---   001110
    52 sen arb    -1- --1-1---1111-1 -111-1 ---   001110
     6 cec spa    1-1 1-11-111-1111- 111-11 -1-   001111
   133 cni mul    --- -----1-------- ------ ---   010000
   135 mic thr    --- -----1-------- ------ ---   010000
   136 gua gla    --- -----1-------- ------ ---   010000
   137 rub thr    --- -----1-------- ------ ---   010000
   152 cya ful    --- --------11--11 ------ ---   010000
   154 lau thr    --- ------------1- ------ ---   010000
   155 lau fou    --- ------------11 ------ ---   010000
   156 mic fiv    --- --------111111 ------ ---   010000
   157 mic six    --- ------------1- ------ ---   010000
   158 mic sev    --- ------------1- ------ ---   010000
   160 ron cap    --- --------1---1- ------ ---   010000
   161 rue gui    --- -------11----- ------ ---   010000
   162 lau two    --- -------11--1-- ------ ---   010000
   163 hof cul    --- -------1---1-- ------ ---   010000
   164 psy mac    --- -------1--11-- ------ ---   010000
   166 ure two    --- ------111--1-- ------ ---   010000
   167 eup two    --- --------111--1 ------ ---   010000
   168 mic eig    --- --------1----- ------ ---   010000
   169 eug one    --- ------1-1----- ------ ---   010000
   170 myr one    --- --------1----- ------ ---   010000
   171 pip fou    --- ------1-1----- ------ ---   010000
   172 sol ana    --- --------1----- ------ ---   010000
   173 ulm one    --- --------11---- ------ ---   010000
   174 eup lig    --- ---------1---1 ------ ---   010000
   175 per ame    --- ---------1---- ------ ---   010000
   176 ing one    --- ---------1---- ------ ---   010000
   177 lon thr    --- ---------1---- ------ ---   010000
   178 mic nin    --- ---------1---1 ------ ---   010000
   179 sau fou    --- ----------1--- ------ ---   010000
   181 rub fou    --- ----------1--- ------ ---   010000
   182 sol fiv    --- ----------1--- ------ ---   010000
   183 til max    --- ------1---1--- ------ ---   010000
   184 gua one    --- -----------1-- ------ ---   010000
   185 pru tet    --- -----------1-- ------ ---   010000
   186 sau two    --- -------------1 ------ ---   010000
   187 sau thr    --- -------------1 ------ ---   010000
   188 sau six    --- -------------1 ------ ---   010000
   189 ver one    --- -------------1 ------ ---   010000
   191 mic bar    --- -------------1 ------ ---   010000
   192 mat opp    --- -------------1 ------ ---   010000
   195 sap nit    --- ------1------- ------ ---   010000
   196 fic ins    --- ------1------- ------ ---   010000
    99 hel one    --- -11----------- ------ ---   010001
   120 vrn asc    --- 1-1----------- ------ ---   010001
   121 bor one    --- 1------------- ------ ---   010001
   122 cor one    --- 1------------- ------ ---   010001
   124 aca mac    --- 11------------ ------ ---   010001
   134 cal gra    --- -1---1-------- ------ ---   010001
   138 lic pec    --- -1------------ ------ ---   010001
   139 hib unc    --- -1------------ ------ ---   010001
   140 cal ter    --- --1----------- ------ ---   010001
   141 eup one    --- --1----------- ------ ---   010001
   144 mim alb    --- --1----------- ------ ---   010001
   146 mic two    --- --1----------- ------ ---   010001
   147 mic fou    --- --1----------- ------ ---   010001
   148 myr cer    --- --1----------- ------ ---   010001
   149 boc fru    --- --1----------- ------ ---   010001
                  000 00000000000000 000000 111
                  000 11111111111111 111111
                      00000000000000 111111
                      00011111111111 000001
                         00001111111 00111
                             0000011
```

```
                 222 11178121222212 114563 211
                 678 367  559012384  1      24
150 sol two      --- --1----------- ------ ---   010001
151 sol fou      --- --1----------- ------ ---   010001
  2 eup sex      --- ---------1---1 1----- ---   010010
  5 bru mex      --- --1-11-11111-1 11---- ---   010010
  8 bed max      --- -11111-11111-1 1--111 ---   010010
 22 rap fer      --- --1-----111--1 1---1- ---   010010
 81 rha cap      --- 1----1-------- ----1- ---   010010
 11 vis max      1-- 111-----111111 1--1-- ---   010011
 75 sau asp      11- 1-1111-11111-1 ----1- ---   010011
 15 lon one      --- -----1-------- 1----- ---   010100
 16 mic ser      --- ------------1- 1----- ---   010100
 24 pal pad      --- --------11--11 1111-- ---   010100
 51 gua gal      --- --------1----- -----1 ---   010100
 55 tri gra      --- -------1------ -----1 ---   010100
 73 phy ico      --- ---1---------- ---1-- ---   010100
102 orm one      --- 1------------- -1---- ---   010100
104 sip aus      --- --1----------- -1---- ---   010100
 30 tri mex      --1 --11111-----1- 111-11 ---   010101
  1 eup mac      --- -------------- 11---1 ---   010110
  3 eup tue      --- ------------1- 1--11- ---   010110
 10 cro one      --- -------------- 1-1-11 ---   010110
 12 lic gua      --- -------------- 11--1- ---   010110
 17 mic lae      --- 1------------- 1---1- ---   010110
 18 mic one      --- -------------- 11-1-- ---   010110
 28 sol one      --- -------------- 1----- ---   010110
 50 sau sca      --- -------------- ---1-1 ---   010110
 53 sol his      --- ---1---------- ---1-1 ---   010110
 56 ast one      --- ---1---------- --1-1- ---   010110
 58 cos pic      --- -------------- --1--- ---   010110
 59 ery tab      --- -------------- --1-1- ---   010110
 60 nec lon      --- -------------- --1--- ---   010110
 61 mic pra      --- -------------- --1-1- ---   010110
 62 pip cal      --- -------------- -1111- ---   010110
 63 pip mar      --- -------------- --1--- ---   010110
 64 pip two      --- -------------- --1--- ---   010110
 65 hof ton      --- -------------- --1--- ---   010110
 66 hof ixt      --- 1------------- -11--- ---   010110
 67 ron ruf      --- -------------- --1-1- ---   010110
 68 cor spi      --- -------------- ---1-- ---   010110
 72 mol vir      --- -------------- ---1-- ---   010110
 74 odo cal      --- -------------- ----1- ---   010110
 76 ann glo      --- -------------- ----1- ---   010110
 77 cle one      --- -------------- ----1- ---   010110
 78 ter ama      --- -------------- ----1- ---   010110
 80 ard pas      --- -------------- ----1- ---   010110
100 sch pla      --- -------------- -1---- ---   010110
  9 alc lat      -1- -1----------1- 11111- ---   010111
  7 per lon      --- -------11----- 1----1 1--   0110
 25 psy pan      --- --------11---- 111-1- --1   0110
 38 oco hel      --1 -1------1---11 -1111- 1--   0110
 46 som arb      --- ------111----1 -----1 1-1   0111
 71 liq mac      --- --1-----11---1 ---1-- --1   0111
 19 mic tri      --- --------1----- 111111 -11   100
 32 ure ela      --- ----1--------- 1-1-1- 1--   100
 43 pip aeq      --- -------------- -11--- 1--   100
 20 mol oax      --- -------11----- 1-1-1- 111   1010
101 lic exc      --- 1------------- -1---- -1-   1010
 26 ron sec      --- -------------- 1-1--- 1-1   101100
 40 ing acr      --- -------------- --1--- 1--   101101
 44 pip lux      --- -------------- --1--- 1--   101101
 69 pro cop      --- -------------- ---1-- --1   101101
                 000 00000000000000 000000 111
                 000 11111111111111 111111
                     00000000000000 111111
                     00011111111111 000001
                        00001111111 00111
                            0000011

                 222 11178121222312 114563 211
                 678 367  559012384  1      24
 79 cas one      --- -------------- ----1- --1   101101
 35 vrn two      --- -------------- -----1 1--   10111
 47 cup one      --- -------------- --1-11 111   10111
 54 tur occ      --- -------------- -----1 -1-   10111
103 bun lin      --- -------------1 -1---- --1   1100
 33 den arb      --- ----1--111---- ------ 111   1101
 42 pse spu      --1 -------1-1---- ------ 1--   1101
115 cep ela      --- ---------1---- ------ -1-   1101
125 amp mac      --- -----------1-- ------ --1   1101
119 tic inc      --- ---------1---- ------ -11   11100
 34 eup ara      --- -------------- ------ 1--   11101
 36 rha edu      --- -------------- ------ 111   11101
 37 lic cau      --- -------------- ------ 1--   11101
 39 oco hen      --- -------------- ------ 1--   11101
 41 pse oxy      --- -------------- ------ 1--   11101
 45 pip yza      --- -------------- ------ 11-   11101
 48 ure one      --- -------------- ------ 1--   11101
 88 con one      --- -------------- ------ -1-   11101
105 lau one      --- -------------- ------ -1-   11101
106 lic mis      --- -------------- ------ -11   11101
107 nec sal      --- -------------- ------ -1-   11101
108 pte one      --- -------------- ------ -1-   11101
109 swa one      --- -------------- ------ -11   11101
110 swa two      --- -------------- ------ -1-   11101
111 mag one      --- -------------- ------ -1-   11101
112 gua gra      --- -------------- ------ -11   11101
113 cal chy      --- -------------- ------ -11   11101
114 myr spl      --- -------------- ------ -1-   11101
116 far sch      --- -------------- ------ -1-   11101
117 far ste      --- -------------- ------ -11   11101
118 rub two      --- -------------- ------ -1-   11101
126 xyl one      --- -------------- ------ --1   11101
127 lic one      --- -------------- ------ --1   11101
128 pap one      --- -------------- ------ --1   11101
129 ard rev      --- -------------- ------ --1   11101
130 cal one      --- -------------- ------ --1   11101
131 pip one      --- -------------- ------ --1   11101
132 rub one      --- -------------- ------ --1   11101
 96 cle mex      --- --1----------- ------ --1   1111
                 000 00000000000000 000000 111
                 000 11111111111111 111111
                     00000000000000 111111
                     00011111111111 000001
                        00001111111 00111
                            0000011
Number of species:

                 234 2131 122331122 323132 222
                 730 08439610609838 232920 067
```

Annex 8. TWINSPAN table (crown projection)

```
Field number     721222 5222231111261811 4
                  66578  1234 35890   17
      species
  21 sip and     22244- 23--2-3-55212--- 3   000
   4 ver tur     141224 ------------1--1 1   0010
  14 ing pav     ----54 ------1-----4--1 4   0010
  57 cle two     ----2- ---------------- 2   0010
  23 rou mon     -----4 ------------1--- -   001100
  70 cro dra     -74777 3-------5--5---- -   001100
  86 sen mul     ---8-7 ---------------- -   001100
  92 hel gua     -2--4- ---------------- -   001100
 138 lic pec     --2--- ---------------- -   001100
 139 hib unc     --3--- ---------------- -   001100
 143 cal hou     -4--31 ---------------1 -   001100
 169 eug one     ---5-- ----------2----- -   001100
 171 pip fou     ---4-- ----------1----- -   001100
 183 til mex     ---7-- --2------------- -   001100
 190 cas syl     -4--22 ----3----------- -   001100
 193 cor all     ---4-1 ---------------- -   001100
 194 aca two     ---1-2 ---------------- -   001100
 195 sap nit     ---2-- ---------------- -   001100
 196 fic ins     ---4-- ---------------- -   001100
 197 myr lon     ---134 ---------------- -   001100
 198 sau fiv     -5---- ---------------- -   001100
 199 tab alb     -2---1 ---------------- -   001100
 200 coc vit     -4---- ---------------- -   001100
 201 dal one     -1---- ---------------- -   001100
 202 ing aes     -7---2 ---------------- -   001100
 203 leg thr     -2--7- ---------------- -   001100
 204 byr cra     -2---- ---------------- -   001100
 205 ron vil     -5--33 ---------------- -   001100
 206 hel two     -1---- ---------------- -   001100
 207 spo rad     ----63 ---------------- -   001100
 208 ver two     ----4- ---------------- -   001100
 209 aca fou     ----4- ---------------- -   001100
 210 con two     ----1- ---------------- -   001100
 211 pip aur     ----1- ---------------- -   001100
 212 cup gla     ----31 ---------------- -   001100
 213 hel occ     ----66 ---------------- -   001100
 214 des tru     -----1 ---------------- -   001100
 215 eup mor     -----1 ---------------- -   001100
 216 eup alb     -----1 ---------------- -   001100
 217 och pyr     -----3 ---------------- -   001100
 218 aca one     -----1 ---------------- -   001100
 219 eup hor     -----1 ---------------- -   001100
 220 lau fiv     -----1 ---------------- -   001100
 221 aca cor     -----4 ---------------- -   001100
 222 leg one     -----4 ---------------- -   001100
 223 leg two     -----1 ---------------- -   001100
 224 leg fou     -----1 ---------------- -   001100
 225 lon two     -----7 ---------------- -   001100
 226 eug aca     -----1 ---------------- -   001100
 227 coc mat     -----1 ---------------- -   001100
 228 pic tea     -----2 ---------------- -   001100
 229 lue spe     -----3 ---------------- -   001100
  42 pse spu     -----5 -3-------1------ -   001101
  49 sau pri     -5---- -----2---------- -   001101
  82 vrn pat     64565- -36---1-1-1----6 -   001101
                 000000 0000000000000000 1
                 000000 1111111111111111
                 001111 0000000000001111
                        000001111111
                        011110000001
                             000001
```

```
Field number     721222 5222231111261811 4
                  66578  1234 35890   17

  83 hel don     5618-5 --1----5-----6-- -   001101
  97 con xal     --1-3- ---------------4 -   001101
 152 aca thr     -----4 --------2------- -   001101
 158 pip thr     -7--2- --------4-1----- -   001101
 164 ces rac     -3--1- ---------12----- -   001101
 180 cle thr     -6---- --21------------ -   001101
  27 sol sch     --1-2- -1----4-----1-41 -   001110
  87 con cae     ----3- ---------------5 -   001110
  99 hel one     --3--- ---------------5 -   001110
 123 cor ste     ----12 ------2--------3 -   001110
 124 aca mac     --1--- ------1--------- -   001110
 145 con ico     ----1- ---------------2 -   001110
 165 ure two     ---3-- ---1-----13----- -   001110
  13 ing lat     35487- -4--656564535--- -   001111
  73 phy ico     1----- 1--------------- -   001111
  75 sau asp     77--6- -6747-41-161-4-3 -   001111
  24 pal pad     ------ 54--5---1-5-2-3- 1   010000
   1 eup mac     ------ -----2------1-3- -   010001
   3 eup tue     ------ 4-------4--13--- -   010001
   5 bru mex     ------ -8667--6-44-5551 -   010001
   8 hed mex     3-1--- 577882-8-14518-3 -   010001
  11 vis mex     -81--- 65551-3-5-5-7--5 -   010001
  12 lic gua     ------ ------------3-1- -   010001
  18 mic one     ------ 7-----------2-2- -   010001
  22 rap fer     ------ -63-2-----1-5--5 -   010001
  28 sol one     ------ ------------1--- -   010001
  31 tre mic     15-6-5 -477-877387-6586 -   010001
  96 cle mex     ------ ---------------1 -   010001
 100 sch pla     ------ --------------1- -   010001
 102 orm one     ------ ------2-------1- -   010001
 103 bun lin     ------ ----1---------1- -   010001
 104 sip aus     ------ --------------31 -   010001
 120 vrn asc     ------ ------3--------5 -   010001
 140 cal ter     ------ ---------------1 -   010001
 141 eup one     ------ ---------------1 -   010001
 142 cas cor     ------ ---------------1 -   010001
 144 mim alb     ------ ---------------1 -   010001
 146 mic two     ------ ---------------1 -   010001
 147 mic fou     ------ ---------------1 -   010001
 148 myr cer     ------ ---------------1 -   010001
 149 boc fru     ------ ---------------1 -   010001
 150 sol two     ------ ---------------1 -   010001
 151 sol fou     ------ ---------------1 -   010001
   2 eup sex     ------ -5--3-------1--- -   010010
  50 sau sca     ------ 5----2---------- -   010010
  68 cor spi     ------ 3--------------- -   010010
  69 pro cop     ------ 1--------------- -   010010
  71 liq mac     ------ 85--7-----4----2 -   010010
  72 mol vir     ------ 4--------------- -   010010
 115 cep ela     ------ -2-------------- -   010010
 119 tic inc     ------ -2-------------- -   010010
 125 amp mac     ------ ---1------------ -   010010
 155 mic fiv     ------ -5636---6-1----- -   010010
 162 hof cul     ------ ---1-----1------ -   010010
 163 psy mac     ------ --66-----6------ -   010010
 166 eup two     ------ -12-2-----2----- -   010010
 167 cya ful     ------ -4--4-----4----- -   010010
 174 eup lig     ------ -2--3----------- -   010010
 175 per ame     ------ -1-------------- -   010010
                 000000 0000000000000000 1
                 000000 1111111111111111
                 001111 0000000000001111
                        000001111111
                        011110000001
                             000001
```

```
Field number   721222 5222231111261811 4
                66578  1234 35890   17

 176 ing one   ------ -1-------------- -  010010
 177 lon thr   ------ -5-------------- -  010010
 178 mic nin   ------ -2--2----------- -  010010
 179 sau fou   ------ --1------------- -  010010
 181 rub fou   ------ --1------------- -  010010
 182 sol fiv   ------ --2------------- -  010010
 184 gua one   ------ ---1------------ -  010010
 185 pru tet   ------ ---5------------ -  010010
 186 sau two   ------ ----1----------- -  010010
 187 sau thr   ------ ----2----------- -  010010
 188 sau six   ------ ----1----------- -  010010
 189 ver one   ------ ----3----------- -  010010
 191 mic bar   ------ ----2----------- -  010010
 192 mat opp   ------ ----1----------- -  010010
   7 per lon   ------ -----1---16-1--- -  010011
  15 lon one   ------ -------5----1--- -  010011
  16 mic ser   ------ --------3---1--- -  010011
  17 mic lae   ------ ------3----11--- -  010011
  33 den arb   ------ -1-------41--1-- -  010011
  35 vrn two   ------ -----1---------- -  010011
  46 som arb   ---1-- ----33---35----- -  010011
  51 gua gal   ------ -----1----2----- -  010011
  53 sol his   1----- 1----2---------- -  010011
  54 tur occ   ------ -----1---------- -  010011
  55 tri gra   ------ -----1---3------ -  010011
  74 odo cal   ------ ----------1----- -  010011
  76 ann glo   ------ ----------1----- -  010011
  77 cle one   ------ ----------3----- -  010011
  78 ter ama   ------ ----------1----- -  010011
  79 cas one   ------ ----------1----- -  010011
  80 ard pas   ------ ----------2----- -  010011
  81 rha cap   ------ -----58---5----- -  010011
 101 lic exc   ------ -----6-------1-- -  010011
 121 bor one   ------ -----1---------- -  010011
 122 cor one   ------ -----1---------- -  010011
 133 cni mul   ------ ------4--------- -  010011
 134 cal gra   --1--- ------6--------- -  010011
 135 mic thr   ------ ------6--------- -  010011
 136 gua gla   ------ ------7--------- -  010011
 137 rub thr   ------ ------6--------- -  010011
 153 lau thr   ------ -------1-------- -  010011
 154 lau fou   ------ ---2---4-------- -  010011
 156 mic six   ------ -------4-------- -  010011
 157 mic sev   ------ -------1-------- -  010011
 159 ron cap   ------ -------1-5------ -  010011
 160 sue gui   ------ ---------42----- -  010011
 161 lau two   ------ ---2-----45----- -  010011
 168 mic eig   ------ ----------3----- -  010011
 170 myr one   ------ ----------4----- -  010011
 172 sol ana   ------ ----------1----- -  010011
 173 ulm one   ------ -1--------5----- -  010011
   6 cec spe   26-1-3 -452-47451-41-41 1  0101
  29 hel app   -5282- -668487878752-54 4  0101
  30 tri mex   2--6-5 -----2-86--45687 5  01100
  32 ure ela   ------ -----------143-- 1  01100
  47 cup one   ------ -----2-----1---- 1  011010
  59 ery tab   ------ -----------4---- 1  011010
  67 ron ruf   ------ -----------4---- 1  011010
  19 mic tri   ------ 3----2----241-1- 6  011011
  20 mol oax   ------ ---------1232--- 3  011011
  25 psy pan   ------ -4--------411-1- 3  011011
               000000 0000000000000000 1
               000000 1111111111111111
               001111 0000000000001111
                      000001111111
                      011110000001
                           000001
```

```
Field number   721222 5222231111261811 4
                66578  1234 35890   17

  38 oco hel   --2--4 5---1---1-74--5- 2  0111
  52 sen arb   ----6- 711111----4--511 1  0111
   9 alc lat   --1-1- 7-------5--67-5- 8  100
  62 pip cal   ------ 3----------1--3- 4  100
  66 hof ixt   ------ ------1-------1- 1  100
  10 cro one   ------ -----1-----22--- 5  101
  26 ron sec   ------ ------------1--- 2  101
  43 pip aeq   ------ --------------3- 2  101
  56 ast one   1----- -----------5---- 4  110
  61 mic pra   ------ -----------3---- 6  1110
  40 ing acr   ------ ---------------- 1  1111
  44 pip lux   ------ ---------------- 1  1111
  58 cos pic   ------ ---------------- 6  1111
  60 nec lon   ------ ---------------- 4  1111
  63 pip mar   ------ ---------------- 1  1111
  64 pip two   ------ ---------------- 3  1111
  65 hof ton   ------ ---------------- 1  1111

               000000 0000000000000000 1
               000000 1111111111111111
               001111 0000000000001111
                      000001111111
                      011110000001
                           000001

Number of species:

               121234 1311222122333 23 3
               378110 9097800620602934 2
```

Annex 9. Use-history and most important species of fields on different geographical sites in Santa Cruz Tepetotutla.

site	number of burns	virgin	age	species
Arr. Algodon	0	0	0	mala mujer, mah tan ge
	1	5	5	jonote, capulin
Arr. Del Derrumbe	1	7	7	jonote, pinabete
	1	8	8	jinicuil, jonote, p. de agua
	2	12	6	jonote, jinicuil
	2	12	7	jonote, pinabete
	2	20	8	p. amarillo, jonote, sangregado
	3	30	3	p. de agua, jonote
	4	25	4	jonote, jinicuil, p. de agua
Camino a la Sierra	0	0	0	ciruela de monte, durazno de monte, p. de te
	0	0	0	p. de durazno, ciruela de monte
	1	3	3	p. de agua, p. de rosario
	1	8	8	p. amarillo, p. de agua, pinabete
El Charco	0	0	0	durazno de monte, aguacatillo
La Boca	2	18	8	jonote, capulin, sangregado
	3	50	30	encino, espina
	7	40	7	mah choh, sangregado, p. de moco, jonote
Loma de Sangre	2	17	5	jonote, p. de torro
	2	25	15	p. amarillo, pinabete, capulin
	2	30	10	jonote, jinicuil
	5	25	6	jonote, p. amarillo, p. de moco
	6	35	6	capulin, jonote, mah choh
	7	50	12	p. amarillo, sangregado, jinicuil
	7	55	10	p. de rosario
	9	55	6	jonote, sangregado, espina
	10	50	4	caopetate, p. amarillo
Loma del Gavilan	1	9	9	p. amarillo, pinabete, jonote, sangregado
	2	16	10	mah choh, jonote, capulin
	3	20	12	p. amarillo, jinicuil
	4	30	5	p. de nopal, serbatana, p. amarillo, p. de gusano
	9	55	6	capulin, p. de moco, platanillo
	9	55	10	jonote, capulin, p. de nopal
Loma del Grillo	6	35	10	mah choh, p. amarillo
	8	60	9	p. pajarito, mala mujer, jonote
Loma del Sol	3	25	10	jonote, capulin, sangregado
	9	30	3	sangregado, jonote
Loma Trampa	1	15	15	jonote, p. de nopal, capulin
	4	30	8	p. de agua, jinicuil, pinabete
Mah Kein	6	50	9	mah choh, jonote, jinicuil, p. de nopal, sangregado
Mi Djoh	5	28	5	p. de moco
Monte Calabaza	2	20	6	pinabete, jinicuil, jonote
	2	20	10	p. de agua, p. amarillo
	2	40	6	mah ma, mah yi, jonote, pinabete
	2	40	30	jonote, capulin, mala mujer
	3	40	15	p. de agua, p. de nopal
	4	40	6	capulin, jonote
	4	40	9	p. de nopal, jonote, p. de moco
	5	50	8	pinabete, p. de moco, p. amarillo, p. de agua
Monte Frio	0	0	0	p. de te, nuez de ardilla
	0	0	0	ciruela de monte, durazno de monte
	1	4	4	p. de agua
	1	20	20	pinabete, p. amarillo, p. de agua
	2	12	6	jonote
	2	20	6	p. de agua, p. amarillo, pinabete

site	number of burns	virgin	age	species
	3	45	4	pinabete, jinicuil, p. de agua
	6	40	4	p. de moco, pino, pinabete
Monte Guitarra	0	0	0	pinabete, ciruela de monte
	0	0	0	pinabete, p. de agua
	2	15	7	pinabete, jonote, jinicuil
	4	25	5	jinicuil, p. amarillo, p. de agua
Monte Gusano	1	9	9	jonote, capulin, mah choh
	3	30	17	jinicuil, jonote
	5	35	4	jinicuil, jonote, capulin
Monte Hierba	1	25	25	p. de rosario, jonote, p. de pescado
	3	30	15	jonote, jinicuil, aguacatillo
	5	50	8	jonote, p. de moco
	10	50	4	jinicuil, jonote, p. de moco
Monte Malangar	10	50	4	jonote, espina
Monte Pan	0	0	0	na mah ti, pinabete
	2	15	6	p. de agua
	2	20	5	aguacatillo, p. amarillo, p. de moco
	3	13	5	jonote, p. amarillo, jinicuil
	3	15	6	jinicuil, p. de moco, jonote
	3	25	10	jonote, jinicuil, capulin
	3	28	6	jinicuil, jonote
	4	30	4	capulin, jonote, p. de moco
	5	20	5	p. de moco, p. amarillo, caopetate
	5	20	5	jinicuil, sangregado, p. amarillo
	5	30	4	caopetate, espina, p. amarillo
	5	30	5	p. de moco, p. amarillop. Pajarito
	5	40	6	jonote, platanillo
	6	20	7	jinicuil, p. amarillo, p. de moco, jonote
	7	25	5	p. de moco, jinicuil, caopetate
	7	52	6	jinicuil, caopetate, espina
	10	50	5	'jonote, jinicuil, espina, platanillo
Monte Perfume	0	0	0	ciruela de monte, p. de te
	1	5	5	jonote, capulin, jinicuil
Monte Perro	2	23	8	p. de gusano, platanillo
	2	23	8	jonote, jinicuil, platanillo
	5	30	4	jonote, capulin, jinicuil .
	8	55	8	jonote, pinabete
	10	50	4	caopetate, zacate navajuela, jonote
Monte Peste	1	12	12	capulin
	2	12	7	jonote, capulin, mah choh
	2	14	6	pinabete, p. amarillo, capulin
	2	18	6	p. amarillo, p. de agua
Monte Tejon	1	9	9	jonote, p. de moco, capulin
	3	25	8	p. de agua, p. amarillo, pinabete
	3	30	12	jonote, pinabete
	4	20	5	pinabete, p. de moco, p. pajarito
	4	30	6	pinabete, p. amarillo
	4	30	8	jonote, capulin, pinabete
	5	22	6	pinabete, jonote, p. de agua
	6	54	7	p. de agua, p. seco, pinabete, jinicuil
Monte Tierra	1	7	7	capulin, jonote, p. de nopal
	1	12	5	p. amarillo, pinabete, p. de moco
	2	12	8	jonote, p. de agua, p. de moco
	2	16	10	pinabete, aguacatillo

site	number of burns	virgin	age	species
	2	20	9	jonote, capulin,sangregado
	2	30	5	p. amarillo, pinabete, p. de moco
	2	40	12	aguacatillo, jonote, capulin, mah choh
	3	15	3	capulin, p. de moco
	3	20	8	jonote, jinicuil, capulin
	3	25	10	jinicuil, chancarro, jonote
	5	30	3	jinicuil, jonote, p. de moco
	5	30	4	caopetate, jonote, espina
	5	30	5	jinicuil, espina
	5	35	4	p. amarillo, pinabete, jonote
	5	40	7	p. amarillo, sangregado, jinicuil
	6	30	3	jinicuil, jonote, p. de moco
	6	45	9	sangregado, agiacatillo, p. amarillo
	8	35	4	caopetate, jonote, jinicuil, sangregado
	10	60	3	jonote, jinicuil
	12	60	5	caopetate, espina, camalote
Pueblo	3	20	6	jinicuil, sangregado, pinabete
	3	30	12	sangregado, jonote, jinicuil
	10	55	8	pinabete
Pueblo Viejo	3	25	15	jonote, jinicuil
	4	25	8	p. amarillo

Annex 10. Parameters in soils monitored for change in the course of one cropping period.

Sample number	Lithology	Name	Period	Date	Altitude (m)	Slope (°)	Age (years)	Number of burns	Time since cutting of primary vegetation (years)	Soil layer	pH-H_2O	pH KCl
124	schist	Albino Osorio Garcia	1	6 may	1320	26	4	7	25	1	3.91	3.83
90	schist	Albino Osorio Garcia	1	6 may	1320	26	4	7	25	2	4.34	4.03
89	schist	Albino Osorio Garcia	2	29 may	1320	26	4	7	25	1	4.35	3.82
99	schist	Albino Osorio Garcia	2	29 may	1320	26	4	7	25	2	4.79	4.15
54	schist	Albino Osorio Garcia	3	15 dic	1320	26	4	7	25	1	4.40	3.83
97	schist	Andres Jose Antonio	1	5 may	760	30	5	6	30	1	4.62	3.98
111	schist	Andres Jose Antonio	1	5 may	760	30	5	6	30	2	3.91	4.04
98	schist	Andres Jose Antonio	2	28 may	760	30	5	6	30	1	4.60	3.99
95	schist	Andres Jose Antonio	2	28 may	760	30	5	6	30	2	4.49	3.87
105	schist	Andres Jose Antonio	3	13 nov	760	30	5	6	30	1	4.57	4.06
107	schist	Andres Jose Antonio	3	13 nov	760	30	5	6	30	2	3.73	3.94
104	schist	Apolinar Hernandez Osor	1	7 may	1420	36	6	2	6	1	4.08	3.68
163	schist	Apolinar Hernandez Osor	1	7 may	1420	36	6	2	6	2	3.93	3.59
92	schist	Apolinar Hernandez Osor	2	27 may	1420	36	6	2	6	1	4.59	4.34
87	schist	Apolinar Hernandez Osor	2	27 may	1420	36	6	2	6	2	4.33	3.70
130	schist	Apolinar Hernandez Osor	3	16 nov	1420	36	6	2	6	1	4.56	4.28
121	schist	Apolinar Hernandez Osor	3	16 nov	1420	36	6	2	6	2	3.73	3.70
108	schist	Casimiro Garcia Cuevas	1	6 may	1080	28	4	8	35	1	3.83	3.63
102	schist	Casimiro Garcia Cuevas	1	6 may	1080	28	4	8	35	2	4.59	3.89
126	schist	Casimiro Garcia Cuevas	2	29 may	1080	28	4	8	35	1	3.88	3.65
110	schist	Casimiro Garcia Cuevas	2	29 may	1080	28	4	8	35	2	3.90	3.91
128	schist	Casimiro Garcia Cuevas	3	17 nov	1080	28	4	8	35	1	3.93	3.68
141	schist	Casimiro Garcia Cuevas	3	17 nov	1080	28	4	8	35	2	4.02	3.86
109	schist	Felipe Osorio Martinez	1	7 may	1500	15	4	2	4	1	3.18	3.13
142	schist	Felipe Osorio Martinez	1	7 may	1500	15	4	2	4	2	3.56	3.31
93	schist	Felipe Osorio Martinez	2	27 may	1500	15	4	2	4	1	3.57	2.87
106	schist	Felipe Osorio Martinez	2	27 may	1500	15	4	2	4	2	3.90	3.34
118	schist	Francisco Hernandez Cec	1	7 may	1520	33	80	1	0	1	3.13	3.07
129	schist	Francisco Hernandez Cec	1	7 may	1520	33	80	1	0	2	3.26	3.19
136	schist	Francisco Hernandez Cec	2	27 may	1520	33	80	1	0	1	3.40	3.27
103	schist	Francisco Hernandez Cec	2	27 may	1520	33	80	1	0	2	3.74	3.54
135	schist	Francisco Hernandez Cec	3	16 nov	1520	33	80	1	0	1	3.66	3.59
134	schist	Francisco Hernandez Cec	3	16 nov	1520	33	80	1	0	2	3.67	3.49
96	schist	Hipolito Lopez Garcia	1	5 may	680	38	3	7	38	1	4.32	3.70
138	schist	Hipolito Lopez Garcia	1	5 may	680	38	3	7	38	2	3.91	3.87
94	schist	Hipolito Lopez Garcia	2	28 may	680	38	3	7	38	1	4.30	3.71
139	schist	Hipolito Lopez Garcia	2	28 may	680	38	3	7	38	2	3.98	3.86
125	schist	Hipolito Lopez Garcia	3	13 nov	680	38	3	7	38	1	4.00	3.83
127	schist	Hipolito Lopez Garcia	3	13 nov	680	38	3	7	38	2	3.93	3.92
122	schist	Laurentino Hernandez Os	1	6 may	1000	38	5	2	5	1	3.99	3.91
120	schist	Laurentino Hernandez Os	1	6 may	1000	38	5	2	5	2	4.03	4.06
123	schist	Laurentino Hernandez Os	3	17 nov	1000	38	5	2	5	1	4.29	4.06
133	schist	Laurentino Hernandez Os	3	17 nov	1000	38	5	2	5	2	4.12	4.00
101	schist	Simon Osorio Cuevas	1	6 may	960	35	8	5	34	1	4.27	3.70
137	schist	Simon Osorio Cuevas	1	6 may	960	35	8	5	34	2	3.86	3.82
140	schist	Simon Osorio Cuevas	2	29 may	960	35	8	5	34	1	4.04	3.89
143	schist	Simon Osorio Cuevas	2	29 may	960	35	8	5	34	2	4.11	3.94
132	schist	Simon Osorio Cuevas	3	17 nov	960	35	8	5	34	1	4.16	3.83
131	schist	Simon Osorio Cuevas	3	17 nov	960	35	8	5	34	2	4.08	3.91
85	sandstone	Ciriaco Juan Toribio	1	12 may	280	20	4	6	24	1	4.93	4.00
164	sandstone	Ciriaco Juan Toribio	1	12 may	280	20	4	6	24	2	4.25	3.90
71	sandstone	Ciriaco Juan Toribio	2	19 jun	280	20	4	6	24	1	5.10	4.21
59	sandstone	Ciriaco Juan Toribio	2	19 jun	280	20	4	6	24	2	4.94	3.99
157	sandstone	Ciriaco Juan Toribio	3	5 nov	280	20	4	6	24	1	4.59	4.09
153	sandstone	Ciriaco Juan Toribio	3	5 nov	280	20	4	6	24	2	4.52	4.02
84	sandstone	Francisco Toribio Perez	1	12 may	800	30	10	6	50	1	4.75	3.68
81	sandstone	Francisco Toribio Perez	1	12 may	800	30	10	6	50	2	4.76	3.84
91	sandstone	Francisco Toribio Perez	1	12 may	800	30	10	6	50	2	4.49	3.79
69	sandstone	Francisco Toribio Perez	2	19 jun	800	30	10	6	50	1	4.53	3.69
60	sandstone	Francisco Toribio Perez	2	19 jun	800	30	10	6	50	2	5.17	3.94
160	sandstone	Francisco Toribio Perez	3	7 nov	800	30	10	6	50	1	4.26	3.79
158	sandstone	Francisco Toribio Perez	3	7 nov	800	30	10	6	50	2	4.33	3.82
68	sandstone	Juan Marcos Agapito	1	12 may	800	30	18	3	33	1	4.70	3.64
83	sandstone	Juan Marcos Agapito	1	12 may	800	30	18	3	33	2	4.51	3.70
55	sandstone	Juan Marcos Agapito	2	19 jun	800	30	18	3	33	1	4.74	3.77
74	sandstone	Juan Marcos Agapito	2	19 jun	800	30	18	3	33	2	4.62	3.85
150	sandstone	Juan Marcos Agapito	3	7 nov	800	30	18	3	33	1	4.27	3.71
116	sandstone	Juan Marcos Agapito	3	7 nov	800	30	18	3	33	2	4.12	3.85
147	sandstone	Marcelino Toribio Perez	1	13 may	600	35	4	6	24	1	4.08	3.90
119	sandstone	Marcelino Toribio Perez	1	13 may	600	35	4	6	24	2	3.95	3.90

ample umber	Lithology	Name	Period	Date	Altitude (m)	Slope (°)	Age (years)	Number of burns	Time since cutting of primary vegetation (years)	Soil layer	pH-H_2O	pH-KCl
76	sandstone	Marcelino Toribio Perez	1	13 may	600	35	4	6	24	2	4.92	3.98
78	sandstone	Marcelino Toribio Perez	2	19 jun	600	35	4	6	24	1	5.44	4.16
86	sandstone	Marcelino Toribio Perez	2	19 jun	600	35	4	6	24	2	4.78	3.93
151	sandstone	Marcelino Toribio Perez	3	5 nov	600	35	4	6	24	2	4.41	3.93
73	limestone	Jose Ramos Leonardo	1	11 may	320	36	8	10	70	1	5.60	5.16
72	limestone	Jose Ramos Leonardo	1	11 may	320	36	9	10	70	2	5.39	5.07
62	limestone	Jose Ramos Leonardo	2	19 jun	320	36	8	10	70	1	5.57	5.26
75	limestone	Jose Ramos Leonardo	2	19 jun	320	36	8	10	70	2	5.53	4.90
144	limestone	Jose Ramos Leonardo	3	4 nov	320	36	8	10	70	1	5.29	5.22
156	limestone	Jose Ramos Leonardo	3	4 nov	320	36	8	10	70	2	5.36	5.11
112	limestone	Francisco Manuel Sixto	1	11 may	620	30	2	12	70	1	4.66	4.71
113	limestone	Francisco Manuel Sixto	1	11 may	620	30	2	12	70	2	4.40	4.34
65	limestone	Francisco Manuel Sixto	2	8 jun	620	30	2	12	70	1	5.40	4.66
58	limestone	Francisco Manuel Sixto	2	8 jun	620	30	2	12	70	2	5.44	4.33
155	limestone	Francisco Manuel Sixto	3	4 nov	620	30	2	12	70	1	4.97	4.54
148	limestone	Francisco Manuel Sixto	3	4 nov	620	30	2	12	70	2	4.83	4.28
61	limestone	Francisco Toribio Perez	1	11 may	720	30	2	12	70	1	6.05	5.89
77	limestone	Francisco Toribio Perez	1	11 may	720	30	2	12	70	2	5.97	5.53
64	limestone	Francisco Toribio Perez	2	8 jun	720	30	2	12	70	2	6.47	6.32
146	limestone	Francisco Toribio Perez	2	8 jun	720	30	2	12	70	1	6.16	6.16
159	limestone	Francisco Toribio Perez	3	4 nov	720	30	2	12	70	1	6.37	6.18
162	limestone	Francisco Toribio Perez	3	4 nov	720	30	2	12	70	2	7.04	6.93
79	limestone	Genaro Graciano Sixto	1	11 may	760	25	2	12	70	1	5.78	5.07
66	limestone	Genaro Graciano Sixto	1	11 may	760	25	2	12	70	2	5.50	4.66
56	limestone	Genaro Graciano Sixto	2	8 jun	760	25	2	12	70	1	5.57	5.31
70	limestone	Genaro Graciano Sixto	2	8 jun	760	25	2	12	70	2	5.15	4.82
152	limestone	Genaro Graciano Sixto	3	3 nov	760	25	2	12	70	1	5.63	5.45
145	limestone	Genaro Graciano Sixto	3	3 nov	760	25	2	12	70	2	5.24	5.03
114	limestone	Juan Marcos Agapito	1	11 may	720	25	2	12	70	1	5.18	5.05
100	limestone	Juan Marcos Agapito	1	11 may	720	25	2	12	70	2	5.55	4.72
82	limestone	Juan Marcos Agapito	1	11 may	720	25	2	12	70	2	5.73	4.73
57	limestone	Juan Marcos Agapito	2	8 jun	720	25	2	12	70	1	5.35	4.90
154	limestone	Juan Marcos Agapito	2	8 jun	720	25	2	12	70	2	4.49	4.44
117	limestone	Juan Marcos Agapito	3	3 nov	720	25	2	12	70	1	4.99	4.92
115	limestone	Juan Marcos Agapito	3	3 nov	720	25	2	12	70	2	5.25	4.84
80	limestone	Valentino Manuel Sixto	1	11 may	640	25	2	12	70	1	5.79	4.98
88	limestone	Valentino Manuel Sixto	1	11 may	640	25	2	12	70	2	5.78	4.81
63	limestone	Valentino Manuel Sixto	2	8 jun	640	25	2	12	70	1	5.27	4.83
67	limestone	Valentino Manuel Sixto	2	8 jun	640	25	2	12	70	2	5.33	4.43
149	limestone	Valentino Manuel Sixto	3	3 nov	640	25	2	12	70	1	5.19	4.85
161	limestone	Valentino Manuel Sixto	3	3 nov	640	25	2	12	70	2	5.06	4.64

Sample number	C	CICT	Ca	Mg	Na	K	N-Kjeldahl	C/N	bases	Saturation
	(%)	(cmol+/kg)	(cmol+/kg)	(cmol+/kg)	(cmol+/kg)	(cmol+/kg)	(%)		(cmol+/kg)	(%)
124	8.8	25.2	0.38	0.36	1.06	0.76	0.39	22.6	2.55	10.1
90		14.9	0.20	0.14	1.24	0.44	0.24		2.02	13.6
89	8.8	34.0	0.36	0.52	1.18	1.11	0.35	25.1	3.16	9.3
99		29.3	0.15	0.16	1.05	0.43	0.20		1.79	6.1
54	8.7	36.2	0.50	0.24	0.97	0.66			2.36	6.5
97	7.4	10.8	0.53	0.36	1.16	0.82	0.28	26.5	2.87	26.7
111	5.7	20.5	0.24	0.24	1.38	0.47	0.20	28.7	2.32	11.3
98	6.9	23.3	0.44	0.30	1.16	0.90	0.25	27.6	2.79	12.0
95	5.5	21.5	0.17	0.27	1.33	0.47	0.20	27.7	2.24	10.4
105	7.3	15.8	0.62	0.55	0.92	0.83	0.27	27.0	2.92	18.5
107	5.6	12.7	0.31	0.23	0.97	0.40	0.22	25.6	1.90	15.0
104	4.9	9.1	0.64	0.28	1.07	0.60	0.19	25.8	2.58	28.4
163	3.1	17.0	0.44	0.09	1.12	0.35	0.13	24.1	1.99	11.7
92	4.7	16.4	0.84	0.90	1.22	2.09	0.17	27.5	5.04	30.8
87	3.4	15.9	0.36	0.34	1.13	1.09	0.12	28.0	2.91	18.3
130		18.4	1.02	0.35	1.31	0.71	0.19		3.38	18.4
121		8.9	0.38	0.19	1.17	0.76	0.12		2.50	28.0
108		19.1	0.51	0.47	1.09	0.77	0.35		2.83	14.9
102		14.6	0.29	0.28	1.13	0.43	0.19		2.13	14.6
126		22.3	0.50	0.14	1.43	0.88	0.37		2.95	13.2
110		15.5	0.24	0.29	1.13	0.50	0.20		2.16	13.9
128		21.7	0.53	0.21	1.87	0.73	0.33		3.33	15.4
141		30.7	0.20	0.28	1.08	0.46	0.20		2.01	6.5
109	5.9	14.6	0.21	0.24	1.28	0.38	0.16	36.6	2.11	14.4
142		19.8	0.19	0.21	0.91	0.22	0.08		1.52	7.7
93	7.7	32.4	0.19	0.40	1.32	0.62	0.22	34.8	2.52	7.8
106		10.4	0.17	0.26	1.03	0.25	0.09		1.70	16.4
118		11.3	0.29	0.14	1.12	0.73	0.20		2.27	20.2
129		10.1	0.17	0.05	1.46	0.33	0.12		2.01	20.0
136		13.3	0.31	0.35	1.57	1.05	0.13		3.27	24.7
103		9.2	0.22	0.15	1.14	0.49	0.12		2.00	21.8
135		14.0	0.44	0.23	1.61	0.46	0.15		2.73	19.5
134		26.1	0.19	0.21	1.27	0.34	0.08		2.00	7.7
96		18.0	0.34	0.38	1.24	0.81	0.28		2.76	15.3
138		25.8	0.19	0.11	1.12	0.42	0.21		1.83	7.1
94		34.6	0.31	0.38	1.18	1.25	0.30		3.11	9.0
139		23.1	0.19	0.24	1.43	0.59	0.21		2.45	10.6
125		18.5	0.34	0.14	1.04	0.77	0.27		2.28	12.4
127		17.2	0.36	0.07	1.59	0.67	0.26		2.69	15.6
122		19.6	0.53	0.33	0.91	0.92	0.42		2.69	13.7
120		11.8	0.26	0.12	0.96	0.52	0.27		1.85	15.7
123		16.0	0.69	0.38	1.22	0.76	0.37		3.04	19.0
133		14.4	0.34	0.23	1.05	0.49	0.30		2.10	14.6
101	8.2	18.0	0.29	0.30	1.02	0.66	0.30	27.4	2.26	12.6
137	6.4	25.0	0.20	0.14	1.22	0.41	0.29	22.2	1.96	7.8
140	7.7	33.7	0.34	0.21	1.16	0.81	0.34	22.8	2.51	7.5
143	6.4	26.7	0.24	0.11	1.08	0.46	0.27	23.6	1.88	7.0
132	7.7	33.9	0.48	0.09	1.67	0.68	0.32	24.6	2.91	8.6
131	6.7	30.9	0.17	0.03	1.91	0.44	0.29	23.2	2.55	8.3
85		24.1	0.69	0.36	0.98	1.34	0.19		3.36	13.9
164		21.6	0.36	0.13	1.07	0.65	0.15		2.20	10.2
71		28.6	0.88	0.40	1.43	1.80	0.20		4.50	15.7
59		25.0	0.55	0.24	1.56	1.20	0.33		3.54	14.2
157		23.8	0.69	0.24	1.12	1.12	0.19		3.17	13.3
153		21.2	0.34	0.11	1.21	1.00	0.15		2.65	12.5
84	8.0	29.4	0.52	0.21	1.07	0.76	0.24	34.2	2.55	8.7
81	6.0	24.7	0.29	0.12	1.37	0.43	0.16	37.5	2.20	8.9
91	6.4	25.9	0.17	0.34	1.08	0.43	0.17	37.9	2.02	7.8
69	7.2	28.6	0.53	0.26	1.28	1.01	0.21	34.1	3.08	10.8
60	6.0	25.9	0.34	0.21	1.37	0.74	0.33	18.2	2.66	10.3
160	7.4	24.9	0.46	0.20	1.27	0.64	0.21	35.1	2.56	10.3
158	6.4	29.5	0.37	0.21	1.42	0.73	0.17	37.5	2.73	9.2
68		32.7	0.57	0.31	1.45	0.82	0.51		3.14	9.6
83		29.4	0.22	0.14	1.17	0.56	0.19		2.09	7.1
55		30.3	0.57	0.29	1.19	1.16	0.45		3.21	10.6
74	5.9	27.6	0.34	0.21	1.16	0.78	0.17	34.5	2.49	9.0
150		27.3	0.44	0.13	1.27	0.78	0.19		2.61	9.5
116		12.2	0.44	0.20	1.22	0.82	0.19		2.68	21.9
147	5.7	23.3	0.60	0.12	1.59	0.86	0.25	22.9	3.17	13.6
119	5.5	12.1	0.20	0.18	1.07	0.53	0.19	29.2	1.98	16.3

Sample number	C (%)	CICT (cmol+/kg)	Ca (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	K (cmol+/kg)	N-Kjeldahl (%)	C/N	bases (cmol+/kg)	Saturation (%)
76	5.3	23.1	0.39	0.14	1.42	0.55	0.18	29.6	2.50	10.8
78		24.8	0.89	0.14	1.48	1.25	0.20		3.75	15.1
86		19.3	0.19	0.21	1.08	0.60	0.16		2.07	10.8
151		22.1	0.37	0.11	1.26	0.60	0.18		2.34	10.6
73		22.1	2.02	0.54	0.91	0.52	0.22		3.98	18.0
72		19.1	1.95	0.33	1.08	0.51	0.16		3.86	20.2
62		22.5	2.64	0.49	1.06	1.15	0.44		5.33	23.7
75		16.3	1.86	0.24	1.04	0.57	0.12		3.71	22.8
144		22.8	2.19	0.40	1.17	0.61	0.19		4.36	19.1
156		16.3	1.48	0.31	1.43	0.47	0.13		3.68	22.6
112		10.8	1.07	0.35	1.09	0.64	0.25		3.13	29.1
113		12.5	0.58	0.28	0.89	0.39	0.14		2.14	17.2
65		20.2	1.36	0.41	1.30	0.85	0.37		3.92	19.4
58		18.3	0.67	0.22	1.06	0.44	0.28		2.39	13.0
155		19.0	0.93	0.20	1.09	0.55	0.20		2.76	14.6
148		17.0	0.64	0.09	1.18	0.32	0.15		2.22	13.1
61	5.7	26.0	4.42	0.40	1.09	0.67	0.56	10.2	6.56	25.2
77	8.0	34.7	4.62	0.54	1.40	0.95	0.38	21.0	7.50	21.6
64	3.8	21.8	3.52	0.35	1.13	0.66	0.40	9.4	5.65	25.9
146	6.9	32.2	5.29	0.73	4.91	2.90	0.39	17.6	13.83	42.9
159	7.6	76.6	1.75	0.85	1.57	0.95	0.93	8.2	5.10	6.7
162	6.2	34.1	6.81	0.54	1.54	0.53	0.37	16.7	9.41	27.6
79	6.8	29.6	3.22	0.52	1.32	1.09	0.33	21.0	6.15	20.8
66	4.1	20.5	1.88	0.13	1.03	0.44	0.33	12.6	3.47	16.9
56		26.9	2.88	0.64	1.85	1.31	0.56	0.0	6.67	24.8
70	3.2	18.1	1.60	0.26	1.26	0.53	0.17	18.6	3.65	20.2
152	7.5	33.5	3.59	0.47	1.49	0.75	0.37	20.3	6.29	18.8
145	4.2	22.1	2.05	0.28	1.28	0.48	0.24	17.8	4.08	18.5
114		15.5	2.55	1.34	1.00	0.95	0.21		5.84	37.8
100		11.2	1.38	0.40	1.31	0.45	0.18		3.53	31.5
82		18.4	1.51	0.18	1.03	0.49	0.15		3.20	17.4
57	5.2	25.2	1.97	0.60	1.07	0.86	0.42	12.4	4.49	17.8
154	3.0	17.5	1.15	0.23	1.83	0.67	0.13	23.2	3.87	22.1
117		7.9	1.93	0.90	1.30	0.74	0.16		4.85	61.8
115		9.9	1.22	0.49	1.35	0.61	0.17		3.66	37.0
80	6.6	28.4	3.07	0.48	1.37	1.31	0.29	22.6	6.23	22.0
88	4.5	10.3	2.24	0.54	1.36	0.62	0.19	23.5	4.74	46.0
63	6.0	24.5	2.03	0.57	1.26	1.34	0.45	13.3	5.20	21.2
67	3.7	27.5	1.24	0.16	1.35	0.48	0.28	13.3	3.22	11.7
149	5.2	26.2	2.19	0.35	1.17	0.74	0.27	19.2	4.44	16.9
161	4.7	21.7	1.69	0.34	1.09	0.73	0.21	22.4	3.84	17.7

Annex 11. Values of parameters in soils sampled for monitoring change on the long term.

Sample number	Year of sampling	Name of farmer	Lithology	Altitude (masl)	Age (years)	Number of burns	Time since cutting of primary vegetation (years)	N-Kjeldahl (%)
1	92	Aniceto Martinez Canseco	sandstone	700	4	3	10	0.45
2	92	Ciriaco Perfecto	sandstone	800	7	8	50	0.26
3	92	Felipe Martinez Canseco	sandstone	700	8	3	20	0.40
5	92	Fidel Agapito	sandstone	1000	5	5	20	0.63
9	92	Juan Marcos Agapito	sandstone	1000	8	4	30	0.42
11	92	Manuel Augustin	sandstone	560	6	9	50	0.63
12	92	Venancio Casiano Felix	sandstone	800				0.70
15	93	Francisco Toribio Perez	sandstone	800	10	6	50	0.18
18	93	Juan Marcos Agapito	sandstone	800	18	3	33	0.19
25	93	Ciriaco Juan Toribio	sandstone	280	4	6	24	0.16
47	94	Lucas Gonzalez	sandstone	660	0	1	0	0.34
49	94	Ciriaco Perfecto	sandstone	680	8	4	26	0.75
51	94	Basilio Benjamin	sandstone	640	7	9	56	0.22
52	94	Francisco Manuel	sandstone	560	6	6	42	0.48
55	94	Pablo Sixto	sandstone	720	18	3	40	0.25
56	94	Jose Ramos	sandstone	670	8	4	30	0.29
69	94	Francisco Toribio	sandstone	640	10	4	40	0.34
E	92	Remigio Martinez Hilario	sandstone	700	40	0	0	0.39
16	93	Laurentino Hernandez Osor	schist	1000	5	2	5	0.32
17	93	Simon Osorio Cuevas	schist	960	8	5	34	0.30
20	93	Hipolito Lopez Garcia	schist	680	3	7	38	0.26
22	93	Andres Jose Antonio	schist	760	5	6	30	0.24
23	93	Casimiro Garcia Cuevas	schist	1080	4	8	35	0.24
24	93	Apolinar Hernandez Osorio	schist	1420	6	2	6	0.14
26	93	Felipe Osorio Martinez	schist	1500	4	2	4	0.11
28	93	Francisco Hernandez Cecil	schist	1520	0	1	0	0.10
32	94	Lorenzo Osorio	schist	1320	8	3	15	0.45
38	94	Gildardo Osorio	schist	1400	9	5	40	0.46
40	94	Leopoldo Merced	schist	1100	5	2	5	0.59
41	94	Alfredo Hernandez	schist	1100	0	1	0	0.70
42	94	Abel Osorio	schist	800	12	3	18	0.37
45	94	Andres Jose	schist	1040	12	2	12	0.33
48	94	Fulgencio Gonzalez Hernan	schist	920	6	6	29	0.56
53	94	Laurentino Hernandez Osor	schist	880	9	2	9	0.63
61	94	Alfonso Hernandez	schist	1100	10	4	21	0.51
62	94	Armando Osorio	schist	1320	0	1	0	0.34
A	94	Albino Osorio	schist	1280	5	7	45	0.50
C	94	Calixto Hernandez	schist	960	7	9	51	0.51
F	93	Francisco Hernandez Cecil	schist	1520	0	0	0	0.15
FA	94	Fausto Osorio	schist	1280	5	5	21	0.32
G	94	Gabriel Ortega	schist	880	7	10	60	0.44
Q	94	Quirino Valdez	schist	1000	5	5	20	0.56
R	94	Raymundo Osorio	schist	1200	5	4	19	0.64

Sample number	sand (%)	clay (%)	loam (%)	Total-N (unmilled) (%)	Total-N (milled) (%)	Total-P (unmilled) (ppm)	Total-P (milled) (ppm)	P-Dabin	C-Walkley & Black (%)	C/N (unmilled)
1				0.47	0.40	281.3	285.6	52.05	5.85	12.5
2				0.21	0.19	222.5	250.6	27.06	3.05	14.3
3				0.36		266.3		24.23	5.15	14.4
5				0.57	0.50	658.8	641.9	57.24	7.40	13.0
9				0.26		232.5		38.38	6.00	23.2
11				0.54	0.59	535.0	595.6	58.18	7.90	14.6
12				0.65		682.5		53.94	7.65	11.7
15	48.7	29.9	21.3	0.39		268.8		26.59	6.73	17.4
18	50.8	27.3	21.9	0.38		258.8		23.76	6.14	16.2
25	57.5	25.1	17.3	0.33	0.36	251.3	261.9	29.42	5.06	15.5
47	56.7	17.6	25.7	0.33		283.8		29.42	7.42	22.8
49	66.2	17.5	16.3	0.26	0.45	296.3	441.3	39.32	6.24	24.2
51	65.6	15.4	19.0	0.22	0.28	296.3	424.4	33.19	4.22	19.5
52	45.4	25.3	29.3	0.27	0.27	353.8	325.0	27.06	4.23	15.6
55	54.8	19.1	26.1	0.24		231.3		29.89	5.14	21.2
56	61.3	21.6	17.1	0.20	0.36	247.5	378.8	28.01	5.10	25.5
69	61.2	15.8	23.0	0.33		308.8		28.48	5.30	16.1
E				0.35					5.10	14.6
16				0.49	0.54	871.3	996.9	67.14	6.87	14.2
17	51.1	25.4	23.5	0.58		813.8		38.85	7.57	13.1
20	44.3	27.7	28.1	0.49		486.3		30.36	6.45	13.3
22	25.7	39.8	34.5	0.45		437.5		28.48	6.17	13.7
23	42.9	29.0	28.0	0.36		656.3		43.56	6.20	17.2
24				0.26	0.23	607.5	578.1	59.59	4.03	15.3
26	33.0	31.8	35.2	0.23	0.19	305.0	264.4	23.76	4.49	19.8
28	32.2	31.8	36.0	0.21		452.5		45.92	3.46	16.2
32	58.7	17.6	23.7	0.30	0.54	627.5	784.4	30.36	6.95	23.0
38	51.9	20.5	27.6	0.41		555.0		21.88	6.39	15.7
40	66.9	12.7	20.4	0.47		813.8		44.98	10.00	21.5
41	64.0	13.8	22.2	0.52	0.49	1288.8	1295.6	120.88	7.47	14.4
42	46.4	24.3	29.3	0.41		570.0		28.95	4.62	11.3
45	55.5	16.7	27.8	0.44		467.5		25.18	6.24	14.2
48	62.1	16.0	21.9	0.27		417.5		28.95	7.98	29.1
53	59.1	18.3	22.6	0.41	0.57	923.8	1260.6	56.29	6.75	16.4
61	51.6	17.1	31.3	0.33		376.3		30.83	7.47	23.0
62	46.9	26.1	27.0	0.27	0.42	446.3	576.3	30.36	6.39	24.1
A	61.9	18.1	20.0	0.39	0.45	781.6	812.5	34.37	6.84	17.5
C	61.8	14.2	24.0	0.35	0.62	799.1	1319.4	35.55	6.92	19.6
F				0.18						
FA	43.5	28.5	28.0	0.24	0.30	361.9	452.5	36.14	4.52	19.1
G	55.2	18.3	26.5	0.40	0.53	764.5	999.4	27.89	6.22	15.4
Q	57.3	20.4	22.4	0.45		826.3		40.26	7.69	17.2
R	69.7	11.6	18.7	0.49	0.62	658.6	853.2	37.55	9.81	20.1

Sample number	C/N (milled)	pH-KCl	CIC-pH7	Bases-pH7	CEC-BaCl2	Na	K	Ca
			(cmol (+) / kg)	(cmol (+) / kg)	(cmol (+) / kg)	(cmol (+) / kg)	(cmol (+) / kg)	(cmol (+) / kg)
1	14.6	3.30	22.80	2.55	9.3	0.05	0.30	2.25
2	16.5	4.05	17.00	3.54	7.6	0.03	0.36	3.47
3		3.70	20.90	2.70				
5	14.9	4.64	23.60	4.98	14.1	0.07	0.43	10.12
9		3.85	22.85	5.19				
11	13.4	4.21	30.20	4.29	10.0	0.04	0.39	6.54
12		4.05	28.90	3.94				
15		3.81	27.97	2.67				
18		3.80	27.50	2.67				
25	14.2	4.04	22.07	2.82	7.6	0.08	0.44	1.62
47		3.92	18.33	2.27				
49	13.9	3.82	17.00	2.48	7.7	0.00	0.30	4.09
51	15.2	4.15	10.75	2.11	5.6	0.00	0.24	3.44
52	15.7	3.82	9.26	1.99	5.6	0.00	0.24	1.83
55		3.92	12.10	1.78				
56	14.2	3.98	12.73	2.12	5.9	0.01	0.28	3.02
69		3.81	8.57	1.77				
E		3.10	17.04	1.53				
16	12.7	4.02	14.93	2.41	6.0	0.02	0.17	1.67
17		3.88	31.90	2.22				
20		3.89	17.63	2.56				
22		3.98	13.73	2.18				
23		3.80	16.97	2.45				
24	17.9	3.89	12.60	2.79	6.0	-0.01	0.33	2.52
26	23.6	3.20	18.07	1.72	5.9	0.03	0.07	0.22
28		3.52	11.40	2.13	4.8	0.00	0.16	0.82
32	12.9	4.18	13.76	2.08	8.3	0.01	0.23	3.41
38		3.87	13.45	2.15				
40		4.30	23.10	2.90				
41	15.3	3.72	17.40	2.53	10.5	0.00	0.56	3.76
42		3.67	14.40	2.76				
45		3.80	13.89	1.73				
48		3.98	18.55	2.23				
53	11.8	4.15	18.47	3.25	11.9	0.04	0.24	7.91
61		3.81	17.28	1.92				
62	15.2	3.46	18.51	1.70	8.9	0.02	0.21	0.29
A	15.4	4.38	17.83	3.53	11.6	0.03	0.36	7.27
C	11.1	4.45	16.40	3.59	14.2	0.01	0.18	10.91
F		3.15						
FA	15.2	3.70	12.08	1.80	6.2	0.05	0.29	1.98
G	11.8	4.62	15.56	3.89	12.4	0.00	0.17	11.38
Q		3.82	18.96	2.42				
R	16.0	4.45	20.11	3.00	10.6	0.03	0.32	6.07

Sample number	Mg	sum of bases	Al	Mn	Saturation	Al-saturation	N-element	Soluble total-N	Soluble NO3
	(cmol (+) / kg)	(cmol (+) / kg)	(cmol (+) / kg)	(cmol (+) / kg)			(%)	(ppm)	(ppm)
1	0.84	3.43	5.67	0.20	1.00	0.63			
2	1.10	4.96	1.71	0.23	0.90	0.26			
3									
5	2.57	13.18	0.60	0.44	1.01	0.07			
9									
11	1.58	8.55	1.85	0.23	1.06	0.21			
12									
15									
18									
25	0.54	2.68	3.38	0.08	0.81	0.45			
47									
49	0.64	5.03	2.69	0.16	1.02	0.37	0.51	55.80	18.10
51	0.67	4.36	1.22	0.20	1.02	0.25		44.50	5.90
52	0.71	2.78	2.73	0.21	1.02	0.53	0.36	53.20	14.90
55									
56	0.92	4.23	2.11	0.18	1.11	0.39	0.40	47.40	13.20
69									
E									
16	0.56	2.43	3.34	0.19	1.00	0.59		80.70	25.90
17									
20									
22									
23									
24	1.04	3.88	1.71	0.87	1.08	0.43			
26	0.33	0.66	5.43	0.01	1.03	0.92		43.70	0.70
28	0.49	1.48	2.33	0.28	0.85	0.54			
32	0.95	4.60	2.31	0.23	0.86	0.31			
38									
40									
41	0.86	5.17	4.34	0.32	0.94	0.45			
42									
45									
48									
53	1.43	9.62	1.56	0.23	0.96	0.15			
61									
62	0.25	0.77	8.16	0.03	1.01	0.92	0.46	68.20	21.60
A	1.98	9.64	2.09	0.24	1.02	0.26	0.58	46.45	0.00
C	1.80	12.89	0.74	0.20	0.97	0.07			
F									
FA	0.72	3.03	2.65	0.24	0.97	0.47		53.75	0.15
G	2.82	14.37	0.26	0.30	1.20	0.05	0.64	70.20	27.25
Q									
R	1.68	8.10	1.56	0.27	0.92	0.20	0.80	82.00	25.40

Sample number	Soluble NH4	Soluble P	Soluble Na	Soluble K	C-element 1	C - element 2	C-element (avg)	Soluble C	pH-CaCl2
	(ppm)	(ppm)	(ppm)	(ppm)	(%)	(%)	(%)	(ppm)	
1									3.66
2									
3									
5									
9									
11									
12									
15									
18									
25									
47									
49	16.50	0.0	10.8	71.9	6.78	7.49	7.14	382.0	4.43
51	20.10	0.0	6.2	56.5				254.3	4.69
52	19.70	0.0	7.6	66.0	4.52	4.91	4.72	308.4	4.30
55									
56	16.10	0.0	8.9	69.1	5.39	5.32	5.36	296.1	4.50
69									
E									
16	28.50	0.0	13.0	48.8				428.8	4.25
17									
20									
22									
23									
24									
26	16.40	0.0	14.8	25.7				450.8	3.49
28									
32									
38									
40									
41									
42									
45									
48									
53									
61									
62	24.60	0.0	10.8	51.0	6.94	7.16	7.05	385.7	3.91
A	25.00	0.0	9.5	79.5	7.69	8.20	7.95	415.9	4.75
C									
F									
FA	27.95	0.0	11.7	71.2				405.0	4.21
G	14.40	0.0	7.3	38.7	7.66	7.28	7.47	411.9	5.20
Q									
R	31.75	0.0	13.6	75.7	10.54	11.11	10.83	518.4	4.76

Annex 12. Use-history and general data on fields sampled for crop performance.

Sample	Name farmer	Village	Site	Altitude	Lithology	Age	Number of burns	Time since cutting of primary vegetation
64	Ciriaco	S.Tlatepusco		360	limestone	6	5	24
30	Eleuterio	S.Tlatepusco		640	limestone	4	10	50
46	Nicolas	S.Tlatepusco		960	limestone	3	2	3
35	Genaro	S.Tlatepusco		860	limestone	8	4	31
60	Timoteo	S.Tlatepusco		720	limestone	8	4	38
A	Albino	S.C. Tepetotutla	Monte Pan	1280	schist	5	7	45
61	Alfonso	S.C. Tepetotutla	Monte Tierra	1100	schist	10	4	21
41	Alfredo	S.C. Tepetotutla	Arr. Algodon	1050	schist	0	1	0
45	Andres	S.C. Tepetotutla	Monte Peste	1040	schist	12	2	12
62	Armando	S.C. Tepetotutla	Monte Pan	1320	schist	0	1	0
C	Calixto	S.C. Tepetotutla	Monte Pan	960	schist	7	9	51
FA	Fausto	S.C. Tepetotutla	Mi Djoh	1280	schist	5	5	21
48	Fulgencio	S.C. Tepetotutla	Monte Pan	920	schist	6	6	29
G	Gabriel	S.C. Tepetotutla	Loma Gavilan	880	schist	7	10	60
38	Gildardo	S.C. Tepetotutla	Monte Tejon	1400	schist	9	5	40
42	Jorge	S.C. Tepetotutla	Monte Pan	840	schist	12	3	18
53	Laurentino	S.C. Tepetotutla	Monte Gusano	880	schist	9	2	9
40	Leopoldo	S.C. Tepetotutla	Arr. Algodon	1080	schist	5	1	5
32	Lorenzo	S.C. Tepetotutla	Monte Pan	1320	schist	8	3	15
Q	Quirino	S.C. Tepetotutla	Monte Pan	1000	schist	5	5	20
R	Raymundo	S.C. Tepetotutla	Monte Pan	1200	schist	5	4	19

N.B.: sample numbers refer to the soil samples in Annex 11.

Annex 13. Crop performance in the limestone area and in the area of "selva alta perennifolia de montaña".

Legend

First row: names of farmers whose crop was sampled. Data in 4 colums for each crop.

n grains, l cob, lwg, gt: data on individual ears.
n grains = number of kernels in rows on ear
l cob = length of ear
lwg = length of rows of kernels
gt = thickness of kernels
mean: mean of n grains, l cob, lwg, gt
st. dev = standard deviation of data n grains, l cob, lwg, gt
c.v. = coefficient of variation

p. grano; p. olote; n maz: fresh weght of grains and cob in a sample of ears
p. grano = fresh weight of grains
p. olote = fresh weight of cob
n maz = number of ears

p m gr f; p m gr s; % hum gr, p m ol f; p m ol s; % hum ol: fresh and dry weight of grains and cobs in a sample, and % humidity.
p m gr f = weight of a sample of fresh grains
p m gr s = weight of the sample of grians after sundrying
% hum gr = % humidity in fresh sample of grains
p m ol f = weight of a sample of fresh cobs
p m ol s = weight of the sample of cobs after sundrying
% hum ol = % humidity in fresh sample of cobs

n plt; p tal; p hoj; ps ta/plt; ps ho/plt; pf mu ta; ps mu ta; %hu ta; p f mu ho; ps mu ho; % hu ho: data determined for calculation of airdry biomass.
n plt = number of plants taken
p tal = fresh weight of stalks
p hoj = fresh weight of leaves
ps ta/plt = dry weight of stalks averaged over the number of plants
ps ho/plt= dry weight of leaves averaged over the number of plants
pf mu ta = fresh weight of a sample of stalks
ps mu ta = dry weight of the sample of stalks
%hu ta = percentage humidity of sample of stalks
p f mu ho = fresh weight of sample of leaves
ps mu ho = dry weight of the sample of leaves
% hu ho = percentage humidity of sample of leaves

dens = density = number of plantholes on surface area of 100 m^2
dens prom = average density
pend prom = average slope angle

n plt; n b mz; n m mz; pf: data on yield per planthole, determined in 30 – 40 plantholes.
n plt = number of plants in planthole
n b mz = number of well formed ears in planthole
n m mz = number of deformed, damaged ears in planthole
pf = fresh weight of ears in planthole

prom; std. dev; C.V. %: average, standard deviation and coefficient of variation of planthole-data
prom = average
std. dev = standard deviation
C.V. % = coefficient of variation

p.f.; n mt; n plt; n maz b; p maz b; n maz m; p maz m; p f/ mt; p f g/mt; p s g/mt: data determined in plots in order to calculate yields.
p.f. = fresh weight of ears from harvested plantholes
n mt = number of plantholes
n plt = number of plants
n maz b = number of well formed ears
p maz b = fresh weight of well formed ears
n maz m = number of badly formed or damaged ears
p maz m = fresh weight of badly formed or damaged ears
p f/ mt = fresh weight of ears averaged over the number of plantholes
p f g/mt = fresh weight of grains averaged over the number of plantholes
p s g/mt = dry weight of grains averaged over the number of plantholes

Y kg/ha; slope (d); slope (r); Yc kg/ha; slope avg; cos sl a: yield per hectare and data on slope to refer yield to horizontal surface.
Y kg/ha = sundry grain yield in kg per hectare
slope (d) = slope measured in degrees
slope (r) = slope in radials
Yc kg/ha = yield corrected for slope, by dividing Y kg/ha by the cosinus of the slope angle
slope avg; = average of the slopes of the harvested plots
cos sl a = cosinus of slope avg

BIOMASSA; TA+ HO/PT; PT/MT; MT/HA; PSG/PT; PSO/PT: calculated biomass and data used for calculus.
BIOMASSA = biomass in kg/ha
TA+ HO/PT = sundry weight of stalks and leaves averaged over the number of sampled plants
PT/MT = number of plants per planthole
MT/HA = number of plantholes per hectare
PSG/PT = dry weight of grains per plant
PSO/PT = dry weight of cob per plant

Limestone area

	ELEUTERIO				CIRIACO				NICOLAS				GENARO J.				TIMOTEO			
cob	n grains	l cob	lwg	gt					n grains	l cob	lwg	gt	n grains	l cob	lwg	gt	n grains	l cob	lwg	gt
1	28	16.4	3.1	0.48	7	13.0	7.0	0.86	32	18.6	3.5	0.47	36	17.9	1.2	0.46	38	23.5	7.5	0.42
2	24	14.1	2.2	0.50	26	15.0	1.5	0.52	25	17.3	3.5	0.55	37	16.5	1.0	0.42	36	10.6	2.0	0.24
3	33	18.5	3.6	0.45	30	16.0	2.5	0.45	29	14.3	0.3	0.46	21	12.1	1.2	0.52	28	10.9	5.8	0.18
4	31	13.7	0.5	0.43	36	16.0	0.5	0.43	15	11.0	4.0	0.47	15	9.6	2.2	0.49	26	13.5	2.5	0.42
5	23	13.8	2.6	0.49	29	14.5	1.0	0.47	31	15.5	1.8	0.44	34	16.2	1.2	0.44	20	12.8	3.3	0.40
6	28	15.7	3.2	0.45	15	12.0	3.6	0.57	33	15.7	3.0	0.38	24	11.0	1.1	0.41	25	16.2	3.5	0.51
7	14	9.6	1.8	0.56	16	10.5	2.0	0.53	25	13.0	0.2	0.51	38	15.9	0.5	0.41	18	10.5	2.0	0.47
8	24	13.7	1.2	0.52	26	13.3	3.3	0.38	29	15.8	1.8	0.46	34	17.0	0.5	0.49	33	16.6	3.4	0.40
9	17	11.6	4.2	0.44	32	13.0	1.2	0.37	38	18.0	0.9	0.45	11	8.6	1.8	0.62	16	10.7	4.0	0.42
10	24	17.7	4.0	0.57	28	16.7	3.0	0.49	30	20.9	5.0	0.53	36	17.8	1.3	0.46	35	16.3	2.0	0.41
11	36	17.2	2.2	0.42	28	11.9	2.0	0.34	38	16.5	0.3	0.43	18	10.2	1.9	0.46	34	15.2	1.0	0.42
12	38	19.0	3.1	0.42	25	11.0	0.2	0.43	28	14.7	0.8	0.50	24	10.4	0.8	0.40	30	12.5	0.1	0.41
13	29	16.9	1.6	0.53	25	13.0	1.8	0.45	32	15.0	1.2	0.43	30	12.7	2.1	0.35	32	14.6	1.5	0.41
14	27	12.6	0.8	0.44	26	11.3	0.5	0.42	18	9.8	3.0	0.38	40	18.1	1.7	0.41	20	13.0	2.8	0.51
15	28	16.1	3.7	0.44	22	13.3	1.7	0.53	34	18.0	3.8	0.42	40	17.9	2.1	0.40	27	14.7	1.0	0.51
16	21	11.1	0.3	0.51	27	12.5	1.1	0.42	28	14.7	1.1	0.49	28	11.9	0.5	0.41	32	15.2	2.0	0.41
17	14	11.9	3.4	0.61	29	15.3	3.0	0.42	29	17.0	1.0	0.55	41	16.2	0.6	0.38	25	17.0	5.0	0.48
18	24	12.3	1.8	0.44	30	14.9	0.9	0.47	19	11.5	2.8	0.46	35	16.3	0.9	0.44	23	13.0	2.5	0.46
19	14	9.6	0.8	0.63	33	15.6	1.3	0.43	18	11.5	4.5	0.39	21	12.8	1.8	0.52	35	18.0	0.9	0.49
20	27	13.2	3.8	0.35	34	16.0	0.3	0.46	32	21.5	4.6	0.53	29	15.2	1.4	0.48	36	13.2	0.5	0.35
21	28	12.7	1.2	0.41	36	16.0	0.9	0.42	18	11.0	2.7	0.46	36	17.2	1.1	0.45	32	14.0	1.5	0.39
22	32	13.7	0.6	0.41	27	14.8	2.5	0.46	16	11.0	3.3	0.48	34	16.0	0.6	0.45	31	18.1	4.8	0.43
23	30	13.7	0.6	0.44	26	13.9	1.5	0.48	14	13.0	5.0	0.57	13	7.6	1.2	0.49	26	14.1	1.6	0.48
24	19	13.5	4.8	0.46	32	14.7	2.5	0.38	18	13.0	4.5	0.47	32	16.2	0.4	0.49	23	11.4	2.1	0.40
25	17	12.6	3.8	0.52	24	11.9	2.6	0.39	34	16.2	2.1	0.41	12	7.2	0.8	0.53	35	17.5	1.0	0.47
26	22	13.2	3.4	0.45	30	15.2	1.5	0.46	30	16.5	2.7	0.46	28	13.8	0.4	0.48	28	14.9	2.5	0.44
27	21	11.2	2.2	0.43	14	10.8	2.8	0.57	19	10.2	2.0	0.43	33	16.2	1.7	0.44	35	17.0	1.7	0.44
28	28	15.8	2.3	0.48	16	8.4	0.7	0.48	28	14.1	2.8	0.40	24	10.1	0.6	0.40	28	18.2	1.5	0.60
29	24	10.9	1.0	0.41	33	14.4	0.8	0.41	31	16.2	2.6	0.44	29	15.5	0.8	0.51	30	17.0	2.0	0.50
30	36	18.7	3.2	0.43	31	16.2	0.9	0.49	16	9.2	2.9	0.39	31	17.2	1.2	0.52	32	12.5	0.1	0.39
31	23	11.2	2.0	0.40	31	16.5	1.8	0.47	29	15.2	0.8	0.50	19	10.5	0.6	0.52	35	16.0	0.1	0.45
32	17	14.7	5.3	0.55	21	10.8	0.8	0.48	23	14.5	2.6	0.52	21	9.5	0.4	0.43	17	8.5	1.0	0.44
33	32	15.6	2.7	0.40	24	14.4	1.1	0.55	23	12.5	0.6	0.52	35	15.2	0.5	0.42	17	13.0	2.0	0.65
34	26	15.9	4.6	0.43	23	13.6	0.8	0.57	25	14.6	1.2	0.54	32	15.5	0.3	0.48	28	15.0	4.0	0.39
35	26	16.5	3.7	0.49	16	11.7	3.6	0.51	16	11.2	4.1	0.44	35	15.3	1.1	0.41	37	15.0	0.5	0.39
36	17	10.8	1.5	0.55	18	13.8	1.2	0.70	17	12.7	3.5	0.54	28	14.0	0.3	0.49	22	12.1	1.5	0.48
37	14	12.7	3.5	0.66	24	14.6	4.1	0.44	26	14.8	3.0	0.45	31	13.1	0.6	0.40	25	12.5	1.7	0.43
38	27	16.6	3.6	0.48	30	14.9	1.8	0.44	22	12.0	2.6	0.43	23	8.8	0.6	0.36	25	14.5	4.0	0.42
39	20	14.6	3.1	0.58	36	17.3	1.2	0.45	30	15.6	0.8	0.49	22	9.1	0.2	0.40	25	12.0	2.0	0.40
40	20	12.0	2.1	0.50					33	19.2	5.6	0.41	32	13.7	1.0	0.40	27	13.6	1.5	0.45
mean	24.6	14.0	2.6	0.48	26.1	13.8	1.8	0.48	25.78	14.58	2.56	0.47	28.55	13.65	1.01	0.45	28.18	14.37	2.26	0.44
st-dev.	6.4	2.5	1.3	0.1	6.7	2.1	1.3	0.1	6.8	3.0	1.5	0.1	8.1	3.3	0.6	0.1	6.1	2.8	1.6	0.1
C.V.	25.9	17.9	50.8	14.4	25.9	14.9	71.3	19.3	26.4	20.3	57.4	10.9	28.3	23.9	55.6	12.2	21.6	19.4	70.9	17.6

	ELEUTERIO	CIRIACO	NICOLAS	GENARO J.	TIMOTEO
p- grano	3436	3486	4474	5040	3860
p- olote	856	765.4	1086	738	1232
n maz	40	39	40	40	40
p m gr f	1192	599	1167	1252	1232
p m gr s	972	489.5	977.5	1082.5	1104
% hum gr	18.46	18.2805	17.6	13.5	10.4
p m ol f	392	340	437	224	296
p m ol s	261.5	215	258	162	226
% hum ol	33.29	36.7647	41.0	27.7	23.6
n plt	43	34	37	37	38
p tal	5950	3350	9600	10350	5550
p hoj	3025	2650	3525	4400	2550
ps ta/plt	59.13	70.65	113.67	123.55	57.26
ps ho/plt	64.50	62.19	84.99	106.62	65.18
p f mu ta	593.2	506.2	553.5	561.5	871
p s mu ta	253.5	364	292.5	248	341.5
% hu ta	57.27	28.09	56.2	55.8	60.8
p f mu ho	539.3	525	556	490.5	348
p s mu ho	494.5	389.5	496	448	338
% hu ho	8.31	25.81	10.8	8.7	2.9
dens 1	64	79	75		69
2	66	73	71		70
3	62	73	73		80
4	61		73		67
dens prom	6325	7500	7300	7069	7150
pend prom	24.25	31.7	26.8	30.25	38.25

				0.653				0.670				0.663				0.754				0.679
plant hole	n plt	n b maz	n m maz	p f	n plt	n b maz	n m maz	p f	n plt	n b maz	n m maz	p f	n plt	n b maz	n m maz	p f	n plt	n b maz	n m maz	p f
1	6	6	0	784	5	4	0	574	5	5	1	713.5	5	3	2	410	3	3	2	503
2	6	6	0	739	6	4	2	553	2	2	0	244.5	5	2	3	337	5	5	0	692
3	3	1	1	141	4	4	0	610	4	3	0	399.6	6	3	2	688	6	6	0	858
4	3	4	1	580	5	6	0	690	4	2	2	372	5	2	2	374	4	3	0	392
5	6	6	0	704	3	1	2	222	5	3	1	488.1	4	3	0	369	6	4	1	637
6	1	1	0	189	4	2	2	284	5	5	0	679.6	4	2	0	316	5	5	0	706
7	3	3	0	458	4	2	1	250	3	3	0	477	4	2	0	261	5	5	0	660
8	5	5	0	895	4	3	0	445	5	5	0	789.4	5	3	2	577	6	2	2	379
9	4	3	0	368	5	3	2	554	5	5	0	647.3	4	2	1	440	5	3	1	531
10	4	2	3	302	4	2	1	299	5	4	0	532.2	5	5	1	475	5	3	1	526
11	3	3	0	596	5	5	0	642	5	4	0	555	3	1	2	164	5	4	2	816
12	6	5	0	741	4	3	1	559	3	2	2	288	6	6	0	752	5	2	1	325
13	6	6	2	868	5	3	0	426	5	6	0	710.5	5	3	2	616	4	1	3	267
14	2	1	1	310	5	2	1	356	5	4	1	690.5	5	5	0	605	6	4	2	663
15	3	3	1	457	4	0	1	56	5	5	0	730.5	5	2	3	464	5	5	0	670
16	5	3	2	564	4	1	6	423	5	4	2	488	5	5	0	738	4	2	1	371
17	6	4	1	559	5	2	0	334	5	3	2	416	4	3	0	357	6	5	1	682
18	6	5	0	594	4	2	0	263	5	4	1	474.5	6	4	1	540	4	2	2	379
19	4	2	1	315	4	3	1	404	5	3	1	509.5	4	3	3	352	5	2	3	376
20	6	5	0	671	4	1	0	103	5	3	3	587	2	2	1	303	5	4	1	673
21	5	5	0	716	5	5	0	844	4	4	0	565	4	4	0	570	2	0	1	73
22	3	1	0	153	3	2	0	326	5	4	0	553	6	5	0	787	5	3	2	457
23	6	6	0	793	5	4	0	512	4	4	1	617.5	5	2	3	439	6	5	1	672
24	3	3	0	483	5	4	1	462	5	4	0	584	4	3	0	495	5	2	1	332

	ELEUTERIO				CIRIACO				NICOLAS				GENARO J.				TIMOTEO			
25	5	5	0	714	4	0	0	0	5	5	0	841	4	3	0	397	4	3	1	491
26	6	4	2	734	5	4	0	452	4	4	0	591	2	1	0	120	1	2	0	278
27	4	4	0	524	5	2	1	264	5	5	0	793.5	5	3	2	471	2	1	1	168
28	6	2	4	427	6	5	1	788	5	5	0	724	4	3	0	561	5	3	1	505
29	6	5	1	669	5	4	1	668	4	3	2	436	5	4	0	424	3	3	0	368
30	6	3	3	584	5	4	0	498	4	4	0	537	4	2	1	371	6	4	4	560
31	6	4	1	478	4	2	2	466	5	4	1	623.5	3	2	2	379	4	4	0	602
32	6	6	2	875	4	3	1	397	5	5	0	798.5	5	3	3	630	6	3	3	493
33	6	4	2	625	5	3	1	327	5	3	0	608	5	4	2	637	3	2	0	313
34	5	4	1	611	5	5	0	668	5	5	2	929.5	4	5	0	790	6	4	2	529
					5	4	2	706	5	5	0	748	6	5	0	721	5	3	2	590
					5	4	1	591	5	3	0	520.5	2	2	0	386	6	4	2	668
					4	1	1	203	5	5	0	872.5	5	5	2	812	5	3	1	449
					5	4	1	551	1	1	0	155					5	3	1	482
					4	3	2	372	5	5	0	785					5	4	0	509
					4	2	2	448	5	4	0	514					5	3	2	510
prom	4.74	3.02	0.85	565.32	4.53	2.95	0.93	439.75	4.65	3.93	0.55	587.98	4.46	3.16	1.08	495.69	4.70	3.23	1.20	504.38
std. dev	1.46	1.60	1.08	203.43	0.68	1.43	1.12	192.65	0.90	1.10	0.85	169.86	1.07	1.28	1.14	182.37	1.22	1.29	1.02	170.98
C.V.(%)	30.9	42.0	126.2	36.0	15.0	48.5	120.9	43.8	19.9	27.9	153.8	28.9	24.0	40.5	105.4	36.8	26.0	40.0	84.8	33.9
p.f.	16500	18000	18350	19221	16700	19750	16100	17590	24900	19025	19100	23519.2	22400	16700	18400	18348	21600	21600	15950	22245
n mt	40	40	40	34	41	40	40	40	40	42	40	40	40	34	34	37	38	42	40	40
n plt	212	210	207	161	165	151	163	161	187	180	174	182	177	133	146	165	191	218	167	209
n maz b	105	140	114	130	111	143	106	118	145	124	110	157	121	106	105	117	138	122	109	145
p maz b	12250	14950	14400		13600	18350	13350		23000	16725	15250		18350	15075	16050		19250	17650	14250	18845
n maz m	79	59	69	29	57	36	51	37	37	49	67	22	57	32	37	40	39	75	36	52
p maz m	4250	3050	3950		3100	1400	2750		3900	2300	3850		4050	1625	2350		2350	3950	1700	3400
p f/mt	412.5	450.0	458.8	565.3	407.3	493.8	402.5	439.8	622.5	453.0	477.5	588.0	560.0	491.2	541.2	495.9	568.4	514.3	398.8	556.1
p f g/mt	330.2	360.3	367.3	452.6	334.0	404.9	330.0	360.6	500.9	364.5	384.2	473.1	488.5	428.4	472.1	432.6	430.9	389.9	302.3	421.6
p s g/mt	269.3	293.8	299.5	369.0	272.9	330.8	269.7	294.7	412.5	300.2	316.4	389.6	422.3	370.4	408.1	374.0	386.1	349.4	270.9	377.8
dens prom	6325				7500				7300				7069				7150			
Y kg/ha	1703	1858	1894	2334	2047	2481	2023	2210	3011	2191	2310	2849	2965	2619	2885	2644	2761	2498	1937	2701
slope (d)	24	25	24	24	34	32	29	31	23	27	28	29	33	35	27	26	40	35	40	38
slope (r)	0.42	0.44	0.42	0.42	0.59	0.56	0.51	0.54	0.40	0.47	0.49	0.51	0.58	0.61	0.47	0.45	0.70	0.61	0.70	0.66
Tc kg/ha	1864	2050	2073	2555	2469	2926	2313	2578	3271	2459	2616	3252	3560	3197	3238	2941	3604	3049	2520	3420
slope avg	0.42				0.55				0.47				0.53				0.67			
cos sl a	0.91				0.85				0.89				0.86				0.79			
BIOMASSA		6897				7627				10487				11710				9229		
TA+HO/PT		323.64				133.04				198.66				232.16				122.44		
PT/MT		5.24				3.96				4.43				4.22				4.80		
MT/HA		6325				7500				7300				7068.75				7150		
PSG/PT		54.85				73.51				77.20				95.10				69.76		
PSO/PT		11.18				12.49				13.43				11.65				18.97		

Area of "selva alta perennifolia de montaña"

[illegible]

cob	P gt	P grains	P 1 cob	P lvg	AP gt	AP grains	AP 1 cob	AP lvg	FAUSTO gt	FAUSTO grains	FAUSTO 1 cob	FAUSTO lvg	FULGENCIO gt	FULGENCIO grains	FULGENCIO 1 cob	FULGENCIO lvg	Gabriel D gt	Gabriel D grains	Gabriel D 1 cob	Gabriel D lvg	N gt	N grains	N 1 cob	N lvg	P gt	P grains	P 1 cob	P lvg	AP gt	AP grains	AP 1 cob	AP lvg	GILDARDO gt	GILDARDO grains	GILDARDO 1 cob	GILDARDO lvg	JORGE gt	JORGE grains	JORGE 1 cob
PROM	0.46	25.65	35.65	4.35	0.46	25.68	35.26	3.43	0.45	22.9	34.5	4.3	0.46	24.4	33.7	3.0	0.46	26.00	35.63	3.95	0.46	25.04	35.75	4.34	0.47	26.38	35.45	3.58	0.46	26.95	35.34	3.57	0.44	25.9	36.6	4.3	0.50	25.6	35.3
STD	0.0	7.0	8.7	1.2	0.1	4.1	8.1	1.3	0.1	7.0	8.9	1.3	0.0	7.6	3.5	1.5	0.1	6.7	8.6	1.4	0.04	6.40	8.54	1.50	0.07	5.07	2.08	1.29	0.07	6.68	8.66	1.29	0.04	6.4	8.1	1.4	0.1	1.8	1.3
c.v. (%)	10.6	27.2	37.5	29.1	14.9	15.9	13.0	35.0	13.0	50.4	80.1	32.9	10.7	31.2	25.1	51.9	35.2	25.8	36.6	35.2	8.7	25.6	36.3	34.6	15.1	88.1	13.5	36.1	14.7	24.6	37.4	36.1	9.6	24.7	35.1	33.3	22.2	11.1	20.4

	P	AP	FAUSTO	FULGENCIO	Gabriel D	N	P	AP	GILDARDO	JORGE
p. gran	3353	3236	3662	3048	3900	2670	3272	4380	4235	2710
p. olot	687	651	604	635.5	835	563	670	886	974.5	562
n maz	51	50	43	37	40	87	53	40	14	88
a gr f	1881	1154.2	1036	968	1018.5	1130	1070	1108	962	1027.5
a gr s	1040	965	825.5	870.5	898	1086	786.5	963.8	810	900
hum gr	33.29	36.39	18.75	9.58	12.4	30.8	30.6	33.0	15.80	12.41
a ol f	889	839	297.5	846	858	863.5	888.5	297.5	838	863.5
a ol s	360.5	375	300	396	398	800	234	243.5	383.5	801.5
hum ol	89.95	85.78	39.30	80.97	81.7	24.3	29.8	30.8	35.50	65.33
n plt	42	43	44	39	42	88	35	31	39	31
p tal	9680	10000	8180	6730	7500	4973	6085	6800	6850	4730
p hoj	3533	4300	2850	3650	4525	3785	3375	4225	3350	2420
ta/plt	68.72	74.07	43.94	39.29	68.75	59.34	77.56	93.06	54.50	96.83
ho/plt	73.60	90.70	51.08	42.74	56.61	78.05	54.80	69.02	78.41	62.32
f au ta	3362	844	1066.5	565	746.7	907.2	650.2	579.70	1132	608.5
s au ta	340.5	863	833	814.5	887.5	303	887.5	858	886.5	230.5
% hu ta	70.70	69.08	76.88	44.27	63.3	66.6	36.0	37.8	74.24	69.43
p f au l	997.5	580	997.5	336	736.7	823.7	786.7	1034.2	257	873.7
s au ho	308.5	442	471	307.5	304.5	445	413	708.5	836	838.5
% hu ho	34.90	33.33	80.84	0.96	47.3	45.8	43.2	46.1	8.37	80.37
dens 1	75	73	76	55	68	68	65	66	66	83
2	74	74	68	57	70	70	70	70	64	88
3	72	72	63	39	66	66	66	66	53	60
4	61	61	75	52	78	78	78	78	65	
dens pr	6980	6950	7050	5475	7000	7000	7050	7090	6350	5825
pend pr	39	39	38.75	37	36	38	36	38	33.25	37.33

FAUSTO COR POR TOTOMOXTLE FULGENCIO COR POR TOTOMOXTLE GILDARDO-COR POR TOTOMOXTLE JORGE COR POR

n plt n b maz n s maz p f n plt n b maz n s maz p f n plt n b maz n s maz p f n plt n b maz n s maz p f n plt n b maz n s maz p f n plt n b maz n s maz p f n plt n b maz n s maz p f n plt n b maz

cob	lwp	pt	LAURENTINO grains	1 cob	lwp	pt	LEOPOLDO grains	1 cob	lwp	pt	LENCHO grains	1 cob	lwp	pt	Raymundo grains	D 1 cob	lwp	pt	K grains	1 cob	lwp	pt	P grains	1 cob	lwp	pt	NP grains	1 cob	lwp	pt	QUIRINO grains	1 cob	lwp	pt
1	5.5	0.45	30	29	11.2	0.53	36	18.5	3.2	0.58	27	14.6	1.2	0.42	25	14	3.7	0.49	30	19.3	5.1	0.48	30	15	3.8	0.46	30	15.7	2.8	0.43	22	15.5	3.8	0.53
2	3.4	0.44	36	20.7	4.3	0.46	36	13.2	1.6	0.52	23	14.0	1.4	0.46	38	17.3	1.3	0.54	20	12.5	2.6	0.49	30	30	4	0.47	29	17.3	2.4	0.51	25	15.9	4.3	0.46
3	3.2	0.50	30	18.2	4.5	0.46	30	14.0	4.2	0.43	26	14.9	4.5	0.37	30	12.2	5.6	0.48	25	15.3	1.5	0.48	23	16.6	5.1	0.50	24	14.9	2.5	0.52	26	16.2	3.7	0.48
4	4.3	0.51	29	18.6	4.6	0.48	32	16.2	2.3	0.49	28	15.9	3.1	0.44	30	17.5	3	0.48	33	19.3	5.1	0.43	25	17.3	6.1	0.44	25	16.3	4.8	0.46	20	12.1	3.5	0.43
5	6.2	0.66	37	9.8	2	0.46	36	9.8	2.8	0.44	31	16.7	1.2	0.44	28	14.2	3.3	0.39	25	12.5	6.1	0.46	26	16.9	6.2	0.49	22	17.2	5.8	0.52	29	14.3	5.1	0.40
6	3	0.43	28	13.6	2.1	0.40	60	10.3	1.6	0.43	25	16.2	4.0	0.49	15	11	2.9	0.54	29	15.3	1.6	0.47	22	14.5	4.5	0.43	32	14.7	3.1	0.36	27	17.4	2.8	0.54
7	4.5	0.47	31	22.1	8	0.45	22	15.1	1.1	0.64	29	15.2	3.1	0.42	33	18.4	5.4	0.45	27	14.5	2.7	0.45	24	14.2	3.2	0.46	29	18	4.9	0.45	27	17.4	6.2	0.43
8	5	0.43	32	17.3	4.2	0.41	38	12.1	3.9	0.46	31	19.8	1.1	0.54	24	14.5	3	0.48	38	19.6	4.1	0.41	26	18.3	5	0.50	23	13.1	1	0.53	29	16.6	1.7	0.44
9	4.5	0.45	25	16.8	1.5	0.53	37	14.2	3.6	0.61	30	16.9	4.0	0.41	28	18.1	4.7	0.48	30	14.5	3.2	0.44	26	19.1	4.1	0.54	21	12.1	1.8	0.50	21	14.1	1.6	0.42
10	5.6	0.42	30	15.7	3.6	0.40	7	11.2	6.5	0.67	24	14.7	2.4	0.51	32	16	2.1	0.43	33	17.9	3.4	0.47	38	21.2	5.2	0.42	24	12.4	1.7	0.45	24	17.8	4.8	0.54
11	4.6	0.42	25	15.1	2	0.52	29	14.7	8.2	0.43	27	17.6	6.4	0.42	25	14.4	4	0.42	33	17.7	1.5	0.43	9	9.5	2.5	0.78	26	19.6	4.7	0.50	20	13.7	4.0	0.49
12	4.4	0.39	30	17.3	4.4	0.45	31	8.3	0.0	0.66	31	17.7	4.5	0.40	23	14	2.2	0.51	24	16.2	5.3	0.45	23	14	4	0.45	29	15.1	1.5	0.46	26	12.6	2.5	0.40
13	3.5	0.61	31	20.3	4.9	0.50	36	18.0	5.5	0.78	25	17.0	4.6	0.50	26	12.5	3.6	0.41	26	12.5	0.6	0.42	29	15.5	2.4	0.45	29	13.6	1.6	0.52	28	17.5	1.2	0.51
14	2	0.45	26	16.9	3.6	0.46	33	10.3	2.0	0.65	24	13.1	3.3	0.41	36	10.7	2.3	0.53	29	19	3.6	0.33	24	17.2	3.1	0.39	30	13.5	5	0.47	29	16.1	3.9	0.49
15	3.2	0.49	29	15.8	4.1	0.40	7	10.5	4.5	0.66	32	15.2	1.6	0.41	37	12	3.7	0.49	36	14.3	5.4	0.49	23	13.5	3.6	0.42	26	13.7	1.1	0.41	29	16.7	4.3	0.43
16	4.2	0.43	34	21.1	4.4	0.49	38	9.2	0.5	0.48	30	16.8	4.2	0.42	24	14.5	2	0.43	36	20.3	2.5	0.49	24	14.2	3.6	0.44	31	18.5	1.6	0.45	15	10.9	1.8	0.47
17	4.2	0.46	24	14.9	2.3	0.53	8	6.5	2.0	0.36	33	10.3	3.3	0.52	36	11	3.3	0.49	29	17	3.6	0.50	23	11.7	3.7	0.43	30	15.5	1.1	0.46	26	15.7	3.6	0.47
18	4.8	0.61	16	11	3.3	0.62	7	9.2	5.5	0.53	19	11.6	3.1	0.45	15	12	4.2	0.52	16	16.1	5.6	0.57	22	15.5	4.6	0.49	31	19.1	3.4	0.51	30	15.1	2.0	0.44
19	3.2	0.52	37	20.2	3.7	0.45	26	18.5	3.5	0.46	8	6.1	2.5	0.45	19	12.1	2.6	0.50	21	17	4.7	0.59	30	12.4	7.4	0.50	35	15.4	1.5	0.40	21	14.0	3.3	0.51
20	4.5	0.44	19	14.7	1.9	0.67	29	17.3	4.3	0.46	16	12.1	3.3	0.60	12	10	2.3	0.61	34	18.9	3.6	0.44	30	18.3	5.6	0.67	26	17.6	4.7	0.46	35	17.2	3.5	0.39
21	3.3	0.43	16	10.5	3.3	0.46	29	16.3	3.5	0.44	26	16.2	3.5	0.49	19	11.5	2.5	0.47	28	21	5.5	0.55	33	16	3.3	0.48	29	14.3	4.5	0.41	25	15.4	3.3	0.49
22	5.5	0.47	26	16.7	4.8	0.41	25	19.0	7.2	0.47	26	14.4	3.0	0.45	30	10.5	4.3	0.42	22	15.1	4.8	0.47	27	17.3	4.3	0.48	31	18.5	1	0.47	26	12.6	3.5	0.43
23	5.5	0.48	27	21	5.3	0.50	30	16.2	2.0	0.47	15	7.9	1.2	0.45	29	16.3	3.8	0.42	31	17.9	2.6	0.46	22	14.6	3.4	0.50	26	15.8	3.1	0.45	31	16.6	4.5	0.45
24	4.3	0.45	34	19	4.3	0.43	31	18.4	3.5	0.46	10	8.2	2.4	0.56	34	12.6	1.3	0.66	36	15.1	5.6	0.52	22	14.3	4.7	0.44	27	14	1.6	0.45	38	10.1	2.4	0.41
25	4.6	0.55	21	13.1	1.8	0.44	29	16.8	4.7	0.42	23	12.9	3.1	0.43	35	10.8	3.1	0.51	80	12	1.1	0.45	21	15.3	5.1	0.49	39	14.5	5.5	0.47	38	11.1	3.1	0.45
26	5.1	0.42	38	15.6	5.1	0.50	29	17.4	4.5	0.44	19	9.4	1.5	0.48	21	13.1	1.3	0.46	22	11.2	1.6	0.53	31	19.5	4.2	0.49	25	13	2	0.44	26	16.3	1.6	0.56
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
31			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																	[illegible]	[illegible]	[illegible]	[illegible]
32			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																	[illegible]	[illegible]	[illegible]	[illegible]
33			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																	[illegible]	[illegible]	[illegible]	[illegible]
34			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																	[illegible]	[illegible]	[illegible]	[illegible]
35			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																	[illegible]	[illegible]	[illegible]	[illegible]
36			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																	[illegible]	[illegible]	[illegible]	[illegible]
37			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																	[illegible]	[illegible]	[illegible]	[illegible]
38			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																	[illegible]	[illegible]	[illegible]	[illegible]
39			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																	[illegible]	[illegible]	[illegible]	[illegible]
40			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																	[illegible]	[illegible]	[illegible]	[illegible]
							29	17.0	3.5	0.47																								
PROM	4.5	0.47	27.5	17.0	4.1	0.48	32	18.5	6.6	0.50	22.8	11.2	1.1	0.45	20.93	13.42	3.34	0.50	27.10	16.29	3.41	0.48	24.33	15.07	4.02	0.30	26.72	15.69	3.22	0.47	24.8	14.9	3.5	0.46
STD	0.9	0.1	5.4	5.4	2.0	0.1	29	14.6	2.5	0.42	6.7	3.2	1.1	0.1	6.5	2.6	1.2	0.1	5.9	2.5	1.6	0.0	6.5	2.6	1.4	0.1	4.4	2.5	1.6	0.0	4.7	2.3	1.1	0.0
cv (%)	21.0	32.8	19.7	19.8	49.4	33.6	31	14.1	2.0	0.39	29.2	24.4	33.8	12.4	33.3	19.6	36.5	33.9	23.7	35.4	45.6	9.8	26.8	16.1	35.9	15.3	16.1	15.7	50.8	6.5	19.1	15.8	31.8	9.4
							25	16.7	5.5	0.45																								

	LAURENTINO	LEOPOLDO	LENCHO	Raymundo D	K	P	NP	QUIRINO
p. gran	4480	4788	1062	0.80	0.78	0.78	0.79	3949
p. olote	960	899	651	0.20	0.22	0.22	0.21	836
n maz	40	42	40	30				39
a gr f	1078.5	1186	1064	829	1060	769	1145	906
a gr s	920	1002	927.5	635.2	794.7	595	852.7	780.5
hum gr	13.95	13.80	14.67	23.38	25.48	22.63	25.53	13.16
a ol f	299.5	296	250.5	213	301	280	296	244
a ol s	213	390	175	120.6	150.3	135.2	166.2	165.5
hum ol	28.88	25.78	30.14	43.29	50.07	47.64	44.29	32.17
n plt	38	44	42	48	43	42	44	44
p tal	9650	9050	6250	6075	10975	10800	11125	6980
p hoj	9960	5180	3240	3900	5700	4650	6150	2875
ta/plt	71.82	108.70	45.56	27.98	52.57	46.92	46.04	44.11
ho/plt	66.95	108.01	61.93	50.24	75.23	72.14	65.80	43.65
f au ta	967	485	1066	932	937	933	939	1013.5
s au ta	273.5	235.5	252	155	193	177.5	171	223
% hu ta	71.72	51.44	76.60	83.37	79.40	80.98	81.79	78.00
p f au h	589.7	309	427	624	940	862	751	546
s au ho	498	283.5	341	109.5	533.5	538.5	463	192
% hu ho	16.57	8.25	19.67	56.37	43.24	37.53	38.62	88.21
dens 1	66	68	62	71	71	71	71	74
2	64	73	61	64	64	64	64	76
3	60	67	59	63	65	63	63	71
4	56	62	61	66.5	66.5	66.5	66.5	69
dens pr	6025	6700	6075	6632.5	6632.5	6632.5	6632.5	7300
pend pr	39.5	32.85	35	36.75	36.75	36.75	36.75	37

TOTOMOXTLE LAURO COR POR TOTOMOXTLE LEOPOLD COR POR TOTOMOXTLE LORENZO COR POR TOTOMOXTLE QUIRINO
n a maz p f n plt n b maz n a maz p f n plt n b maz n a maz p f n plt n b maz n a maz p f n plt n b maz n a maz p f

	LAURENTINO	LEOPOLDO	LENCHO	Raymundo	M	P	NP	BURINO
1–40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
prom	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
st. dev	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C.V. (%)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
p.f.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
n st	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
n plt	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
n maz o	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
p maz h	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
n maz e	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
p maz e	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
p f/st	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
f p/st	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
s p/st	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
dens pr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Y kg/ha	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
slope t	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
slope c	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Yc kg/ha	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
slope a	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
cos x1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BIOMASS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TAHAO/P	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PT/HT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HT/HA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PSG/PT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PSO/PT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Annex 14. Rainfall in Santa Cruz Tepetotutla in 1994-1995.

	1994								1995												1996				
day	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	0	0	0	0	100	0	0	58	5	0	0	8	0	0	0	0	5	0	0	0	5	5	5	0	0
2	0	0	0	0	3	32	8	0	0	0	0	30	0	0	0	0	0	0	0	0	2	0	10	10	0
3	0	5	0	10	66	2	0	0	0	0	0	10	0	0	10	0	5	0	10	0	5	1	1	5	0
4	0	0	12	42	38	10	4	0	5	0	0	15	0	0	10	0	3	0	105	0	0	0	15	0	0
5	0	0	0	20	38	110	0	0	6	0	0	5	0	0	5	10	0	5	25	0	10	10	0	10	0
6	0	12	9	60	10	2	0	0	2	0	0	8	0	0	0	5	6	10	100	0	0	0	2	0	7
7	0	0	2	4	28	1	0	0	10	0	0	4	0	0	32	0	20	2	29	0	15	0	0	3	18
8	0	0	5	38	3	0	10	11	0	0	0	0	0	0	64	0	5	50	5	0	0	0	6	0	3
9	0	15	3	10	3	3	0	0	0	0	0	0	0	0	38	0	5	0	0	0	25	10	0	20	0
10	0	0	14	8	5	0	0	0	0	0	0	0	0	0	60	20	20	0	0	50	0	0	0	11	15
11	0	0	0	9	0	0	0	58	0	0	0	5	0	0	5	30	0	0	0	100	5	0	10	0	33
12	0	7	0	100	45	0	8	0	0	0	0	0	0	0	10	107	0	0	100	0	0	0	0	0	5
13	0	0	0	65	9	4	0	0	0	0	0	5	0	0	95	35	20	0	0	0	2	5	0	45	35
14	0	0	22	4	0	0	0	5	0	0	0	8	0	0	0	50	60	60	0	0	0	0	15	0	0
15	0	17	7	35	0	5	0	0	10	15	0	0	0	0	11	2	2	30	0	10	6	0	10	0	30
16	0	0	25	14	13	0	0	0	0	0	0	0	60	0	38	23	20	0	0	5	0	1	0	24	10
17	0	0	28	0	32	0	20	12	0	5	0	0	0	8	0	30	5	0	0	0	4	0	30	0	5
18	0	0	0	13	96	10	15	0	0	0	0	0	0	0	25	0	0	0	0	10	0	0	14	0	15
19	0	32	0	0	10	19	0	15	9	0	0	0	0	30	0	80	0	0	0	5	6	10	0	36	10
20	0	12	4	21	0	1	0	0	9	0	0	0	0	80	0	100	5	0	20	20	10	0	12	0	0
21	0	29	0	10	12	0	0	0	5	2	0	5	0	68	0	100	0	60	100	0	1	0	0	2	0
22	0	9	36	6	0	2	20	5	0	0	0	0	0	28	0	12	0	20	0	50	0	5	22	0	0
23	0	0	4	7	0	0	20	20	0	0	4	26	0	0	10	20	68	0	0	15	5	0	0	10	0
24	0	5	0	36	0	0	14	15	0	5	5	4	0	0	35	0	0	15	99	10	0	0	0	0	0
25	0	15	12	4	1	5	0	10	0	2	0	0	0	0	37	2	0	20	0	0	10	15	28	0	0
26	0	5	0	1	4	8	0	5	20	5	10	10	0	150	0	20	60	0	0	0	0	0	0	5	0
27	0	13	0	15	0	2	0	2	20	15	2	0	10	0	100	15	0	0	0	15	20	0	82	0	0
28	0	17	0	3	0	0	0	11	10	0	0	0	40	10	10	25	0	0	0	20	0	8	0	0	0
29	0	7	0	0	0	40	0	0	4		3	0	0	30	5	260	0	0	0	100	40		0	9	0
30	0	0	0	3	0	32	54	10	10		5	0	25	0	0	250	0	5	0	10	0		0	30	0
31	0		0	0		0		0	0		10		0	0		60		20		0	80		0		0
	0	200	183	538	516	288	173	237	125	49	39	143	135	404	600	1256	309	297	593	420	253	70	262	220	186

About the author

Johannes Cornelis van der Wal was born in Leeuwarden, Friesland, in the northern part of the Netherlands. He studied Tropical Crop Science at Wageningen University from 1974 to 1983.
Interest for shifting cultivation was born during his stay in an Mayan village in Yucatán, México, in 1980 - 1981.

From 1985 to 1996 the author worked at Mexico's National Autonomous University in the program on Integral Management of Natural Resources of the Laboratory of Ecology. From 1985 he was stationed in the Guerrero Mountains to do experimental work on rainfed agriculture. From 1989 to 1996 he worked in the Chinantla on shifting cultivation. Both assignments were an oportunity to work in interdisciplinary groups with local independent organizations of farmers.

After the writing of this thesis, the author was assigned by the Mexican Government to coordinate the mexican part of the Mesoamerican Biological Corridor Project in the states of Quintana Roo, Yucatán, Campeche, Tabasco and Chiapas (a rather complicated but fascinating job).