

***LANDSCAPE DYNAMICS AND MANAGEMENT OF WILD PLANT
RESOURCES IN SHIFTING CULTIVATION SYSTEMS:***

***A Case Study from a Forest Ejido in the Maya Zone of Quintana Roo,
Mexico***

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of the requirements of the degree of Doctor of Philosophy

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ABSTRACT

Wild plant resources are harvested and managed by people in a variety of land-uses, but few studies examine the interactions of landscape dynamics and the use and availability of wild plant resources. I address this question using a case study of common property lands with a history of community forestry and traditional shifting cultivation. Specifically I ask: What is the perceived importance of plant resources obtained in agricultural and forest environments? Have forest and agricultural land-use/land covers changed? How do landscape changes, and in particular shorter fallow times, influence the availability and use of plant resources?

The perceived importance of wild plant resources was studied using free-listing and ranking exercises with focus groups of men and women. Remote sensing and interviews served to analyse landscape dynamics (1976-2000) and to identify local forest conservation regulations. The impact of shorter fallow times on the availability of forage and firewood in agricultural fields was assessed by sampling 26 fields derived from short to long fallows, while a household survey served to characterize patterns of firewood collection.

Men attributed highest importance to commercial forest products, while resources most valued by women were domestic resources obtained in a variety of environments. High rates of forest retention were observed; conservation was focused on forests with high densities of commercial products. The agricultural zones shifted from a mosaic of diverse successional stages to a homogeneous landscape dominated by younger fallows and shorter fallow periods; these changes led to reductions in the availability of firewood and some forage species. Firewood collection was related to accessibility; areas with the least amount of firewood available (short-fallow cycles and low forest cover) experienced the highest collection pressure.

The findings demonstrate that indigenous territories can be very dynamic, even when rates of forest conservation are high, and that changes in land-use and landscape structure have important implications for the availability and use of wild plant resources. A conceptual model linking landscape dynamics to wild plant use is proposed and the significance of the results for community-based conservation initiatives is discussed.

RÉSUMÉ

Les ressources végétales sont récoltées dans des habitats divers, mais peu d'études ont examiné les interactions entre la dynamique du paysage et la gestion de ces ressources. Je présente l'analyse d'un territoire autochtone avec une tradition de foresterie communautaire et d'agriculture itinérante pour répondre aux questions suivantes : Quelle est l'importance attribuée aux ressources végétales obtenues des habitats agricoles et forestiers et cette importance varie-t-elle selon le sexe des utilisateurs? Comment ces habitats ont-ils évolué et comment la dynamique du paysage influence-t-elle la disponibilité et l'utilisation des ressources végétales?

L'importance attribuée aux ressources végétales a été étudiée par l'entremise d'entrevues de groupe témoins des deux sexes. La télédétection a servi à analyser la dynamique du paysage (1976-2000). L'échantillonnage de 26 parcelles agricoles a permis d'évaluer l'effet de la réduction des temps de jachère sur la disponibilité de ressources végétales. Les patrons de récolte du bois pour le feu ont été caractérisés à l'aide d'entrevue.

Les hommes accordent une importance élevée aux ressources forestières commerciales, alors que les ressources dont l'utilisation est domestique sont plus valorisées par les femmes. Un taux de rétention élevé des couverts forestiers a été observé pour la durée de l'étude, les initiatives de conservation ayant été dirigées vers les secteurs ayant des densités importantes de ressources forestières commerciales. Les zones agricoles sont devenues plus homogènes et une réduction de la diversité des stades successionnelles et de la durée des temps de jachères ont été observées. Il en résulte une disponibilité réduite du bois pour le feu et de certaines plantes fourragères. Les zones avec le moins de bois sont aussi celles soumises à la pression de récolte la plus élevée puisque celle-ci est reliée à l'accessibilité.

Ces résultats démontrent que les territoires autochtones peuvent être très dynamiques et que les changements dans l'utilisation des sols ont des implications importantes pour la disponibilité et l'emploi des ressources végétales. Un modèle conceptuel décrivant les interactions entre la dynamique du paysage et les ressources végétales est proposé et une discussion sur les implications des résultats pour la conservation en milieux communautaires est présentée.

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Over the years I have come to appreciate Tim's unique style of supervision. Throughout my studies Tim always helped me decipher the lay of the land and the divergent paths that spread before me, patiently offering his advice on how to proceed, while bestowing on me the task of navigating my own unique course. This arm's length supervision was both challenging and encouraging, and I believe that much of the originality of this thesis can be attributed to the guided independence that I enjoyed throughout the project.

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by a desire to collaborate with Javier, whose work I have always highly esteemed. During the two years that I lived and worked in Mexico, Javier and his students and colleagues at the Jardín Botánico received me as one of their own, offering me their friendship and support, as well as an enriching and stimulating intellectual environment. Through my interactions with many people including Andrea Martínez Ballesté, Carlos Martorrell, Fabio Bandeira, Maria Eugenia (Maru) Correa, Maria Teresa Pulido, Martha Gonzalez, Cristina Mapes, Laura Cortés and Maestro Miguel-Angel Martínez, I learned much about ethnoecology and Mexico, and discovered many lasting friendships.

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imagined while also allowing me to be part of their family and community. The Poot Pat family fed, sheltered and cared for me as though they were my own family and were a constant source of support and good humour. **Dios bo'otike'ex, laaylie tin kaajske'ex.**

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AUTHORS' CONTRIBUTIONS

I was responsible for the conception of this project, literature review, development of objectives and methodology, field work, statistical analysis and preparation of the manuscripts. I obtained funding from several sources to support field work.

Throughout the course of the project my co-supervisors Dr. Timothy Johns and Dr. Sylvie de Blois, as well as my supervisor in Mexico, Javier Caballero, provided advice, suggestions and logistical support for different aspects of the research. Both Dr. Johns and Dr. de Blois provided advice in formulating the research questions and overall aims of the project. They provided advice on methodology (see below) and on proposals for obtaining funding for field work. They both reviewed and provided comments on the style and content of all parts of the thesis. Dr. Johns is a co-author for the manuscripts presented in Chapters 3 and 4 and Dr. de Blois for those in Chapters 4 and 5. Co-authorships were determined based on a significant contribution to the ideas, analyses and/or style and writing of the manuscripts. However, in all cases their input was based on drafts which I first prepared.

Dr. Javier Caballero introduced me to the Yucatan peninsula and facilitated my introduction to X-Maben (my field site), where he had an ongoing research project. He acted as my supervisor in Mexico (a requirement to obtain funding from several sources) and provided logistical support, including access to equipment, computers and desk space in his laboratory in Mexico City. I discussed the original formulation of the project, as well as the progress of field research and the interpretation of preliminary findings with Dr. Caballero throughout the course of the 2 years I spent in Mexico. Dr. Caballero provided comments regarding the content and style of the manuscript presented in Chapter 4, on which he is a co-author. Co-authorship was based on the same criteria as described above.

Methods for developing my relationship with the communities in X-Maben, for the focus groups (Chapter 3) and for participatory mapping exercises (Chapter 4) were discussed with Dr. Johns and Dr. Caballero. I worked closely with Dr. de Blois in developing the vegetation sampling methods (Chapter 5), and discussed with her the

statistical methods and interpretation of analyses carried out for both Chapters 4 and 5. Javier Caballero provided advice on the design of the household survey (Chapter 6).

In Mexico I collaborated with one of Dr. Caballero's Ph.D. students, Maria Teresa Pulido Silva, in the classification and verification of the satellite images. We worked as a team in both the field and in the lab to prepare a time series of land cover maps of X-Maben. This collaboration was based on the agreement that we would share the work of preparing this data set, but thereafter use the data independently within the context of our respective research projects. I therefore use this data set to analyze the dynamics of forest and agricultural land-covers in X-Maben (see Chapter 4), while Maria Teresa is using these data to model the demography of the palm *Sabal yapa* within the dynamics of the shifting cultivation system (see Pulido and Caballero 2006).

CHAPTER 1

Introduction

Wild plant resources play important roles in the livelihoods of people worldwide. This is especially true in many indigenous and peasant societies where wild plant gathering serves to meet at least part of people's food, medicine, fiber, fuel and other needs (Cotton 1996, p. 127, Grivetti and Ogle 2000, Qureshi and Kumar 1998, Shankar et al. 1998). While the majority of wild plant resources in a given region are often used mainly for subsistence purposes (Godoy et al. 2002), some have commercial value and may constitute an important source of cash income for some households (Coomes and Burt 2001, Hedge et al. 1996, McSweeney 2002).

Much attention focused on the role of tropical forests in providing plant resources to rural economies, and the potential for this is to motivate forest conservation on community lands. As a result, sustainable management of both timber and non-timber forest products has been advocated as an integrated conservation and development strategy (Freese 1997, Nepstad and Schwartzman 1992, Zarin et al. 2004). While forests are also valued for non-utilitarian purposes (Browder 1996, Ingles 1997, Mgumia and Oba 2003), there exist a number of examples of conservation motivated by forest products (e.g. Salafsky et al. 2001, Ticktin 2005).

However, wild plant resources used for both subsistence and commercial purposes are harvested and managed by people in a variety of habitats, vegetation types or land uses apart from forests (Alcorn 1981). For example, homegardens, agricultural fields and ruderal environments have been found to be important sources of medicinal and edible plants (Frei et al. 2000, Kohn 1992, Price 1997, Stepp and Moerman 2001, Voeks 1996), while other studies have shown fallow lands and secondary forests provide other types of resources (Chazdon and Coe 1999, Toledo et al. 1995). Indeed, it has been suggested that maintenance of diverse land-use systems, as well as the use of fire and techniques used to modify specific habitats serve to increase the diversity of plant resources in the landscape (Alcorn 1981, Coggins 2002, Toledo et al. 2003 Turner et al. 2003, Yibarbuk 2001). A variety of aquatic and other physiographic conditions may also increase the variety of environments and habitats contributing to the resource base for a given community (Toledo et al. 2003, Wilken 1970).

The diversity of both resources and habitats which are used and managed by rural people suggests that a landscape ecological approach could be especially valuable for analysing the management of such diversified resource use systems. Landscape ecology considers the dynamics of and interaction among the different land covers/land uses of a landscape such as cultivated fields, fallow lands, or forests, and aims to understand the causes and consequences of changes in the mosaic (Turner et al. 2001, pp. 2-7). Land-use practices are viewed as dynamic, shifting in response to changing economic, cultural or ecological circumstances. While ethnobotanists have emphasized the diversity of traditional land-use systems and other practices to manage wild plant resources, the dynamic nature of land-use practices and their implications for management of wild plant resources has received much less attention. Yet, landscape changes such as a decrease in forest cover or an increase in fallow land can affect the availability of resources, while conversely, the potential to access specific resources in a changing landscape might influence land-use decisions. Despite this obvious connection between land-use dynamics and the management and availability of wild plant resources, their dynamics and interaction remain a largely unexplored question in the ethnobotanical literature.

Research questions and case study

In this thesis, I employ an original landscape approach, as described above, to examine the interaction and dynamics of two land-uses, subsistence agriculture and community forestry, and their implications for the use and availability of wild plant resources in the landscape. These two land-uses are considered of specific relevance since they are often perceived to be in conflict. Indeed, community forestry and other forest-based economic activities are often promoted as a means to curb agricultural expansion. However, little research has focused on how agricultural land-uses and associated resources are modified in order to achieve conservation, and what the implications of such changes can be for local livelihoods. From this perspective, some important questions are: Are there trade-offs between forest conservation and subsistence agriculture? What implications do these have for resource use systems, and for wild plant resources in particular?

In this thesis, I consider a case study of common property lands managed by Maya communities in the state of Quintana Roo, Mexico which provides an appropriate context to examine the interaction of agriculture, wild plant resources and forest conservation. In this region, a state-wide community forestry initiative, called the “Plan Piloto Forestal” (PPF) has been active since the 1980s. Through this program, communities were encouraged to conserve forests on their lands by declaring reserves for timber extraction, in which agriculture would be prohibited, and were offered technical support to manage and market their products.

In general, this program has been considered successful, with high rates of forest retention (Bray et al. 2004), and a few notable communities having developed a strong economy based primarily on timber sales (Flachsenberg and Galletti 1998). However, in most cases, forestry remains a secondary activity to agriculture and other economic activities (Flachsenberg and Galletti 1998, Murphy 1990). For the indigenous Maya population in particular, the “milpa”, a system of shifting cultivation, holds high cultural and symbolic value (Re Cruz 1996, Villa Rojas 1992). Milpa, as well as the collection of wild plant resources, are activities in which nearly all households continue to participate (Murphy 1990). In an early evaluation of the community forestry program, Murphy (1990) suggested that the exclusion of milpa agriculture from the timber reserves could lead to increasing pressure on agricultural lands. This raises the question as to whether any conflicts may be posed by the forestry programs in relation to agricultural activities now or in the future, and what the implications this might have for the sustainability of both local livelihoods and forest conservation in the state.

Within the context of this case study I therefore pose the following questions:

- (1) What types of wild plant resources are obtained in agricultural and forest environments and what is the perceived importance of these?*
- (2) To what extent has forest cover been conserved on community lands? Has forest conservation led to increased pressure on agricultural lands?*
- (3) How does increased pressure on agricultural lands (and in particular shorter fallow times) impact the availability and use of wild plant resources important to local livelihoods?*

In asking the above questions, I seek to gain a better understanding of the implications of forest conservation for the management and use of wild plant resources by Maya communities in Quintana Roo, Mexico. It is important to note that community forestry initiatives in Mexico, including the Plan Piloto Forestal (PPF) in Quintana Roo, have been proposed as a “global model for sustainable landscapes” (Bray et al. 2003) and the PPF model is being adopted in other countries in Latin America (Merino Pérez, pers. comm.). Therefore, results from this thesis hold relevance for many other tropical regions where similar conservation and development initiatives are being considered, and contribute to a broader literature evaluating such initiatives (e.g. Acharya 2002, Agarwal 2001, Gupte 2004, Merino Pérez 2004, Sekher 2001, Smith et al. 2003, Song et al. 2004, Timsina 2003). Finally, on a theoretical level, I aim through this case study to consider the significance of employing a landscape perspective for examining dynamics of plant use in ethnobotany.

Outline of the thesis

This thesis is comprised of a comprehensive literature review, four chapters presenting the results of this study, and an overall conclusion. Three of the four empirically-based chapters (Chapters 3-5) are presented in manuscript format.

The literature review provided in Chapter 2 serves to establish the main contributions of the thesis in relation to current knowledge. The main bodies of literature covered include ethnobotany, tropical land-use and land-cover change and successional processes in shifting cultivation systems. In this chapter I also provide background on the ecology and history of the study area (the Maya zone of Quintana Roo), as well as a summary of research specific to the region dealing with land and resource use.

In considering the relationships of land-use change with wild plant resources, a first step is to understand the resources which are available in different landscape units, and the relative importance or value attributed to such resources. However, perceptions of plant resources and their importance can vary considerably within a community, with gender being one important source of differentiation that is often overlooked by both development projects and researchers. With this in mind, Chapter 3 begins by considering gender differences in the perception of non-crop plant resources obtained in

fields, fallows and forests, using data obtained from free-listing and ranking exercises conducted with focus groups of men and women. Within the context of this thesis these data are later used to interpret the significance of land-use changes for the availability and use of plant resources.

While Chapter 3 sets the stage by identifying wild plant resources valued by the Maya population in X-Maben, Chapter 4 delves into analyzing the spatial and temporal dynamics of change in the land-covers from which these resources are obtained. Remote sensing and geographic information system (GIS) techniques are used to examine the extent to which forest cover has been conserved, to quantify spatial changes in land cover and fallow periods in the most accessible areas most used for agriculture over a 24 year period (1976-2000). In addition, interviews with community leaders and local farmers are used to identify the nature and extent of local land-use regulations aimed at forest conservation, and to interpret the patterns of land-cover change over the 24-year period. A modified version of this manuscript has been published in *Forest Ecology and Management* (Dalle et al. 2006).

In Chapter 5, I examine the impact of one of the land-use changes identified in Chapter 4 – changing fallow times – on the availability of two non-crop resources: firewood and forage. These resources are both harvested from shifting cultivation fields and in Chapter 3 were found to be of particular importance to women. Using data collected in a vegetation survey of 26 one-year old fields representing a gradient of short to long fallow cycles, I show that firewood as a whole, and some forage species are negatively impacted in shorter fallow cycles. These findings are discussed in terms of the ecological processes occurring in short vs. long fallow cycles and the potential implications for local livelihoods are considered.

Results from Chapters 4 and 5 suggest important landscape changes that affect the availability of firewood. As a first step in understanding how people's resource-use strategies respond to ecological change, in Chapter 6, I examine households' use of different landscape units for firewood collection. The data presented are derived from a survey of 41 households, and provide insights into the dynamics of resource use in this changing landscape.

The thesis concludes with a general discussion (Chapter 7) which integrates the findings from these four chapters to consider the interactions of land-use dynamics and the use of wild plant resources, and the relevance of the findings for community-based conservation.

CHAPTER 2

Literature Review

In the thesis I aim to understand the interactions between landscape dynamics and the availability and use of plant resources. These interactions are studied in a shifting cultivation system of the Yucatan peninsula which is characterized by a dynamic mosaic of land uses, a collective mode of land tenure, and community forestry programs. The thesis draws on different areas of scientific inquiry including ethnoecology, ethnobotany, resource management, landscape research, and plant ecology. In this chapter, I first examine the ways in which landscapes have been generally considered in the ethnobotanical and ethnoecological literature and review findings on land-use/land cover changes in the tropics. I then review current knowledge on vegetation succession processes in shifting cultivation systems. Finally, I focus on the particular relevance of the study area to address these issues by reviewing the literature on land and resource-use in the Yucatan peninsula. This comprehensive literature review serves to establish the main contribution of the thesis in relation to current knowledge.

Landscape research in ethnoecology and ethnobotany

Ethnoecology has been defined by Toledo (1992) as the integrative study of the relationship between people's knowledge and perception of the natural environment (which he defines as the "corpus") and the ways in which they use and manage natural resources (the "praxis"). Ethnobotany can be considered a subdiscipline of ethnoecology, focusing specifically on the use and management of plants.

In this thesis, I propose that a landscape approach to ethnoecological research can provide important insights into the use and management of natural resources. In particular I suggest that consideration of landscapes as dynamic and spatially heterogeneous is important for understanding both the changing availability of resources in the landscape, and spatial patterns of use and harvesting.

In the following sections, I review three ways in which landscapes have been examined either implicitly or explicitly in the ethnoecological literature. These include folk classification and perception of landscapes, habitat and landscape management, and the distribution of wild plant resources among different habitats or land-uses. These

approaches have emphasized the heterogeneity and diversity of management practices and resources in the landscape. I then outline how consideration of two additional aspects of landscapes – spatial structure and temporal dynamics – can be better addressed in ethnoecology.

Folk classification and perception of landscapes

Landscapes have been considered in ethnoecology primarily through folk classification and perception of landscapes and landscape units, such as soils, vegetation types and successional stages, and geomorphic or topographic units (e.g. Baker and Mutitjulu Community 1992, Barrera-Bassols and Toledo 2005, Bandeira et al. 2002, Casagrande 2004, Fleck and Harder 2000, Frechione et al. 1989, Johnson 2000, Jungerius 1998, La Torre-Cuadros and Ross 2003, Scarpa and Arenas 2004, Shephard et al. 2001, Wilkerprins 1999, Wilkerprins and Barrera-Bassols 2004). This body of research shows that folk classifications can vary substantially from one culture to the next, with attributes of the landscape being perceived and identified in different ways. For example, in the Amazon researchers have described landscape perceptions being influenced by species compositions and faunal associations (e.g. Fleck and Harder 2000, Shephard et al. 2001), while the Gitksan of Northwestern British Columbia perceive the landscape primarily in reference to drainage and topography (Johnson 2000).

As compared to scientific classification schemes, folk classifications have sometimes been shown by these studies to be very detailed in describing more fine-scale variation in local landscape conditions (e.g. Barrera-Bassols and Toledo 2005, Shephard et al. 2001) or to be based on different criteria (Casagrande 2004, Johnson 2000). These differences have been discussed in terms of their potential for informing scientific inquiry, for example by elucidating details of ecological relationships at the local level by Shephard et al. (2001) and Winklerprins (1999, 2001), while others have cautioned that an understanding of local perceptions of the environment can be important for improving collaborations between local communities and outsiders. For example, Casagrande (2004) found that the many Tzeltal Maya identify “primary forest” by the size of its trees and humidity and suggests that conservationists should be careful in promoting conservation based on species diversity which may not be valued by the local

people. As evidenced in this thesis (see Chapter 7), an understanding of folk classification can be important to understand what kinds of forests are protected, and thus to analyse patterns of land and resource management.

Management of habitats and plant resources in the landscape

Ethnoecological research has also described the ways in which indigenous and other people manage habitats and plant resources within the landscape, and the consequences of these practices for creating heterogeneity in the landscape. For instance, at the habitat level, fire is often used as a means to promote early successional growth to attract game or to improve the productivity of plant resources (Anderson 1996, Coggins 2002, Gott 2005, Turner et al. 2003), while techniques to manipulate the soils and drainage patterns of aquatic environments can be used to extend or create the habitats of desired species (Turner et al. 2003).

Attention has also been drawn to the ways in which diversified agricultural production systems (e.g. pastures, agroforests, homegardens) (Toledo et al. 2003) and the use of fallowing or other rotational techniques in agropastoral systems (Berkes et al. 2000, Finegan and Nasi 2004) promote diversity in the landscape. In a few cases, the landscape diversity resulting from traditional land management practices has been assessed using remote sensing and vegetation sampling. For example, work by Bowman and colleagues has shown that Aboriginal people in Northern Australia manage numerous low intensity fires to produce a fine-scaled mosaic of burned and unburned patches which conserve several threatened species and habitats as compared to regions without Aboriginal burning (Bowman et al. 2004, Yibarbuk et al. 2001). Similarly, Deil (2003) showed that modern land-uses in southern Spain created a more uniform landscape with lower plant diversity in many land-uses, as compared to landscapes resulting from traditional land-use practices in Morocco.

In addition to these habitat-level practices, other management techniques aimed at individual plants (such as sparing, protection, planting, transplanting, or dispersal) can be used to promote the availability of resources in desired locations (Alcorn 1981, Casas et al. 1996). For example, traditional people often manage the species composition of tropical forests (Alcorn 1983, Anderson et al. 1995), as well as that of swidden fallows

(de Jong 1996, Padoch et al. 1985) thereby influencing the availability of key plant resources. In a Runa community of the Ecuadorian Amazon, Irvine (1989) showed that these types of plant management techniques increased the diversity of the tree canopy in swidden fallows.

In her seminal paper on Huastec Maya plant management Alcorn (1981) proposed that these plant-level management techniques occur within the broader context of the anthropogenic vegetation zones created by habitat-level manipulation (or in her terms, “vegetation *en-masse* manipulation”). Description and analysis of management techniques at both levels have been an important contribution of ethnobotanical research since they have revealed ways in which people actively manage their environment in habitats often assumed by outsiders to be wild or unmanaged.

Distribution of wild plant resources in the landscape

A third way in which landscapes have been studied in ethnobotany has been through research comparing the diversity and distribution of wild plant resources among different habitats or land-uses (e.g. Caniago and Siebert 1998, Chazdon and Coe 1999, Fujisaka et al. 2000, Kvist et al. 2001, Price 1997, Salick et al. 1995, Stepp and Moerman 2001, Toledo et al. 1995, Voeks 1996). These studies have revealed substantial differentiation in the distribution of plant resources among habitats or land-uses. For example in Brazil, Voeks (1996) found the diversity of medicinal trees to be much higher in secondary forests and primary forests to be more rich in construction materials, whereas fuel, timber, food and ritual/magic plants were relatively similar in both habitats. As reviewed by Ticktin (2004), other research has shown the demography and productivity of wild plant resources varies across land-uses. These studies thus attest to the relationship between landscape management (described in the previous section) and the distribution of wild plant resources.

Future directions for landscape research in ethnoecology

The literature reviewed above emphasizes cultural diversity in landscape perception and management and the heterogeneity of wild plant resources in the landscape. However, little ethnoecological research has investigated the consequences of

the spatial structure of the landscape for how plants are actually harvested and used (but see Cunningham 2001, pp. 192-221 for a general discussion). For example, Frei et al. (2000) found that two indigenous groups in Mexico, the Mixe and the Zapotec, gathered more medicinal plants in homegardens, ruderal, and early successional environments compared to forest. Interestingly, the tendency was strongest amongst the Mixe who had more restricted access to forests due to the more concentrated settlement pattern, as compared to the Zapotec whose settlements are dispersed throughout the landscape. This points to the importance of considering how the spatial distribution and access to different land-uses influence how plants are harvested. In this thesis, this spatial perspective is taken into account explicitly by evaluating the distribution of land-uses (Chapter 4) as well as patterns of firewood use (Chapter 6) in relation to accessibility.

Moreover, the above approaches have tended to emphasize the diversity of resources and management practices rather than processes of change in these cultural landscapes. As described in more detail in the following two sections, land-use practices are dynamic even in traditional or indigenous societies, and these can have important implications for the availability of plant resources. For example, in a study examining metapopulation dynamics of a non-timber forest product, Ticktin (2005) found that secondary forest populations were more likely to go extinct than those in old-growth forests due to higher incidence of anthropogenic fires and outplanting. Despite the fact that previous research had shown secondary forest populations to be more resilient to harvest, these were more vulnerable to land-use decisions made in the agricultural matrix. While in recent years much emphasis has been placed on evaluating sustainable rates of harvest for non-timber forest products and other wild plant resources (e.g. Peters 1996, Ticktin 2004), these findings illustrate the importance of also considering landscape dynamics. Overall, this thesis thus contributes to the ethnobotanical literature by linking explicitly landscape dynamics (Chapter 4) to the availability (Chapter 5) and use (Chapter 6) of plant resources.

Land-use/land cover changes in the tropics

While not well integrated in ethnobotanical studies, landscape dynamics have, nevertheless, been the focus of a large and growing area of research aimed at

understanding anthropogenic transformations of the environment. Increasingly, studies examining land-use/land cover dynamics make use of remote sensing and GIS techniques (especially for studies at broad scales). However, other methods such as land and farm surveys, as well as interviews on local decision-making processes are also employed.

In the tropics, much of this work has focused on explaining deforestation patterns, especially at global, continental and regional scales (e.g. Meyer and Turner 1994). A number of studies have correlated these patterns with socio-economic, demographic and other “driving” forces. Bawa (1997), for example, compared rates of deforestation between Latin America, Africa and Asia and found that the socio-economic correlates varied between regions, with cattle density being the most significant variable in explaining deforestation in Latin America. Within Latin America, geographical and historical analyses of land-use change and deforestation are available for a number of countries and regions. In Mexico, land-use/land cover change has been assessed at national (Masera et al. 1997) and regional levels (Cairns et al. 2000, de Jong et al. 1999, Garcia-Romero et al. 2004, Trejo and Dirzo 2000, Velázquez et al. 2003).

While many of these large-scale studies have aimed to quantify land-use change for purposes of modelling global ecosystem changes (Meyer and Turner 1994), other research has focused on understanding more localized processes at the level of a watershed, community or at other landscape scales more relevant to management (e.g. Kammerbauer and Ardon 1999). Studies at these scales have the advantage of interpreting changes in relation to specific socio-economic, demographic, historical or cultural factors (e.g. Brondizio et al. 1994, Sierra 1999, Umezaki et al. 2000), sometimes uncovering unexpected results. In Kalimantan, Indonesia, for example, increased rates of deforestation by shifting agriculturalists was attributed to uncertain land-tenure as opposed to soil degradation or population growth (Lawrence et al. 1998). Land-use changes have also been investigated in relation to household decision-making processes (e.g. Abizaid and Coomes 2004, Coomes et al. 2000, Smith et al. 1999). Other efforts have been made to develop predictive models of land-use decisions, verifying these with remote sensing data (e.g. Deadman et al. 2004, de Koning et al. 1999, Duffy et al. 2001, Evans et al. 2001, Gilruth et al. 1995).

Of particular note in this line of land-use research is a large research project studying trends in deforestation and land-use/land cover change in the southern portion of the Yucatan peninsula, a frontier region was the focus of a government-sponsored colonization program and suffered high rates of deforestation in the 1970s and 80s. Incorporating a multidisciplinary research team from a number of universities and institutions (especially Clark University and El Colegio de la Frontera Sur (ECOSUR)), the project aims to integrate information generated from economic, institutional and other analyses of land-use practices, remote-sensing data on land cover change and detailed studies of ecological and biophysical processes (see Klepeis and Turner 2001 and Turner et al. 2001 for an overview of the approach). Important contributions integrating these data include (1) modeling efforts which link information from household surveys on land-use practices to remote sensing data (e.g. Geoghegan et al. 2001, 2005, Vance and Geoghegan 2002); (2) studies of the impact of policy on the land-use dynamic (Klepeis and Vance 2003, Klepeis 2003); and (3) a book chapter by Lawrence et al. (2004) which summarizes advances on linking the ecological studies with the land-use/land cover data.

Much of the land-use literature in the tropics has concentrated on understanding processes of deforestation and fragmentation, especially in frontier zones where deforestation rates have been high. However, fewer studies have been conducted in traditional or indigenous communities (Ochoa-Ganoa 2001). There is equally a need to understand trends of conservation (Bray et al. 2004) and to monitor the impacts of specific governmental and non-governmental policies and programs (e.g. Keese 1998). To this end, a growing number of studies have evaluated land-cover dynamics in areas with community conservation programs (Bray et al. 2004, Gautam et al. 2002, Jackson et al. 1998, Smith 2003), sometimes comparing these to areas under other management systems or tenure regimes (e.g. protected areas, government forests) (Browder 2002, Duran et al. 2005, Gautam et al. 2004, Hayes et al. 2002, Semwal et al. 2004). These studies have often revealed trends of improvement or maintenance of forest cover on community lands; however, as noted by Browder (2002) such correlations do not indicate whether forest conservation is due specifically to the external conservation interventions or to other conditions prevalent at such sites. Furthermore, little attention

has been focused on the dynamics of other land-covers such as agriculture (Dougill et al. 2001, Semwal et al. 2004) in areas with such conservation programs. Because of this, it is sometimes not clear whether successful forest conservation is the result of intensification or restrictions on other land-uses, or whether these conserved landscapes simply experience little agricultural pressure.

Chapter 4 of this thesis therefore contributes to the literature on tropical land-use/land cover change by analysing the landscape dynamics of an indigenous territory, and more specifically by assessing both some of the local institutions promoting forest conservation as well as the dynamics of agricultural land-uses within the context of a community forestry program.

Shifting cultivation systems and succession dynamics

Shifting cultivation systems are an important form of agricultural production in the tropics and historically were important in many temperate regions (Kellman and Tackaberry 1997, p. 210). Many different systems exist and can employ different means of land preparation (burning or mulching), cropping patterns, and fallow management (active or not) (Brookfield and Padoch 1994, Conklin 1961, Kass and Somarriba 1999, Ramakrishnan 1992). However, production systems referred to as shifting cultivation are usually identified by the temporary cultivation of fields followed by a longer fallow period (Conklin 1961), and generally require few external inputs of energy (Kellman and Tackaberry 1997, p. 210).

Because they are so widespread, shifting cultivation systems often play an important role in driving landscape dynamics in the tropics. Although often blamed for causing deforestation, this view has been modified as the diversity and dynamics of shifting cultivation have become better understood. Ecological studies have demonstrated the role of the fallow period as a weed break (de Rouw 1995, Misra et al. 1992, Staver 1991) and to restore soil nutrients (Kleinman et al. 1995, Szott et al. 1999). The resulting mosaic of successional stages can increase landscape diversity and harbour species of conservation value (Finegan and Nasi 2004). Furthermore, it has been argued that if secondary forests are included in definitions of “forest cover”, shifting cultivation does not result in permanent deforestation, but rather represents a cycle of field, fallow

and secondary forest (Sunderlin 1997). Since most of these characteristics depend on maintenance of relatively long fallow periods (e.g. Metzger 2003), there has been an increasing effort to distinguish such systems from “forest pioneer farming” (where slash and burn techniques are used as a means to clear forest for the establishment of more permanent land-uses) or from shifting cultivation where the fallow period has been substantially reduced (Sunderlin 1997).

Shifting cultivation fields and associated successional vegetation are sources of wild plant resources (Alcorn 1981, Colfer et al. 1997, Frei et al. 2000, Levy Thatcher and Hernandez Xolocotzi 1992, Schmidt-Vogt 1997). Being collected primarily from the spontaneous weed and successional vegetation, the availability of such resources depends largely on succession processes. In the last 20 years an extensive body of research has examined forest recovery and succession in sites following shifting cultivation events and other agricultural land-uses in the tropics (for detailed reviews of this literature see Finegan 1996, Guariguata and Ostertag 2001). This has produced an overall picture of floristic change and of structural and functional development, and a number of mechanisms influencing successional pathways have been identified (Guariguata and Ostertag 2001).

Among factors influencing tropical succession, the type and intensity of past land-use has been found to be especially important (e.g. Aide et al. 1995, Fernandes and Sanderson 1995, Mesquita et al. 2001, Nepstad et al. 1996, Rivera and Aide 1998, Uhl et al. 1988). For shifting cultivation, succession is more rapid than following other land-uses, such as pasture and intensive monocultures (Ferguson et al. 2003, Steininger 2000; see also Guariguata and Ostertag 2001), while species composition and vegetation development is influenced by the length of the cropping period (Ekeleme et al. 2000, Fujisaka et al. 2000, Purata 1986).

Relatively few studies have examined the role of past fallow history on succession in shifting cultivation. Indeed, most studies have analysed succession in shifting cultivation as a linear process, with forests recovering after an initial slash-and-burn/cultivation event, instead of as a cyclical system in which succession might be influenced by the length and duration of cycles. One notable exception is a study by Lawrence and collaborators which demonstrated significant changes in soil nutrients,

biomass accumulation, tree diversity and species composition in secondary forests following one to ten cycles of shifting cultivation in Borneo (Lawrence 2004, Lawrence 2005, Lawrence and Schlesinger 2001, Lawrence et al. 2005). A few other studies have examined succession processes following different fallow lengths. For example, plant density, species richness and composition have been compared in shifting cultivation fields felled from short versus long fallow periods (de Rouw 1995, Fujisaka et al. 2000, Illsley Granich 1984, Saxena and Ramakrishnan 1984, Staver 1991). These have generally shown an increase in the density and biomass of herbaceous vegetation accompanied by a concomitant decrease in woody species with shortened fallow periods.

The above studies indicate that changes in land-use and fallow management practices could have important impacts on the availability of wild plant resources in shifting cultivation systems, although few, if any, studies have specifically examined the influence of these on specific resources important to local people. Furthermore, it is important to note that nearly all of the research on succession in shifting cultivation systems has been carried out in tropical wet environments, with comparatively few studies being available for seasonally dry tropical environments (Ewel 1980, Guariguata and Ostertag 2001). As discussed by Ewel (1980), some succession processes can be expected to differ in tropical dry environments. One important difference is the propensity for trees in dry tropical environments to reproduce through coppicing (Ewel 1980) and it has been suggested that such species may be favoured in repeated shifting cultivation cycles (Lawrence 2004, Lawrence et al. 2005). For this reason, more studies of succession processes and shifting cultivation systems in such environments are needed. Chapter 5 contributes to the literature on ecological dynamics in shifting cultivation by examining the impact of past fallow history on the availability of wild plant resources in a tropical dry forest environment.

The study area: human-environment interactions in the Yucatan peninsula

The above literature review has situated the current research within the broad context of several bodies of ethnobotanical and ecological literature. In this section, I provide a general description of the Yucatan peninsula where the research for this thesis

was conducted and then review and situate the present research in the literature specific to this region.

Brief history of the Yucatan peninsula

The Yucatan peninsula is located in the southeastern portion of Mexico, and comprises the three modern states of Yucatan, Campeche and Quintana Roo (Figure 2.1). It consists of a limestone plateau which emerged from the sea between the Cretaceous and Quaternary periods. The karstic landscape is characterized by thin, limestone-derived soils (mostly lithosols and rendzinas in X-Mabén), and a system of underground drainage systems and sinkholes (Flores and Espejel Carvajal 1994). Average annual temperatures are 25-26°C, while a gradient of increasing average annual precipitation extends from northwest (600 mm/y) to southeast (1500 mm/y). Vegetation types follow a similar gradient, ranging from *selva baja caducifolia* (“low deciduous tropical forest” with a maximum stature 8 m) to *selva alta perennifolia* (“high evergreen tropical forest” with a maximum stature 30 m), according to the classification of Miranda and Hernández Xolocotzi (1963). Several intermediate forest types are found between these two extremes, while inundated vegetation types occur on poorly drained gley soils especially in the southern and eastern portions of the peninsula (Flores and Espejel Carvajal 1994, UADY 1999). In the Holdridge life zone classification system all forests of the peninsula are classified as “dry tropical forest” (White and Darwin 1995). Hurricanes are an important form of natural disturbance influencing the dynamics of the Yucatec vegetation (Whigham et al. 1991).

This physical and biological environment has been the setting for a long and continuous history of human-environment interactions, with lowland Maya culture having been present in the region for approximately 3000 years (Colunga-GarcíaMarín and Zizumbo-Villarreal 2004). The ancient Maya developed one of the most important civilizations in the Americas, with high population densities (in some cases estimated near 100 people/km² or more) concentrated in many settlements and urban centres, and construction of monumental ceremonial centres peaking in the Classic Maya period between A.D. 300 and 1000 (Turner et al. 2001, UADY 1999, p. 306). From A.D. 800 to 1000 the classic Maya civilization collapsed, population numbers declined, the

ceremonial centres were abandoned (Turner et al. 2001), and the remaining population dispersed into smaller chiefdoms and settlements (Villa Rojas 1992).

Despite a second population crash following the arrival of the Spanish, the Yucatec Maya culture and language has persisted through the colonial period to the present day and adapted to new circumstances that these eras have brought. In the last national census (INEGI 2000), the Yucatec Maya population was estimated at approximately 0.8 million, representing 24% of the population of the peninsula as a whole (Barrera-Bassols and Toledo 2005), although this percentage is much higher in specific regions. Distinct experiences during the colonial and postcolonial periods have led to differentiated economic regions in the peninsula. Traditional land-use patterns (described below) are most prominent in the eastern portion (mostly corresponding to the state of Quintana Roo), while cattle raising, cash cropping and citrus production have been more dominant activities in the central and northern areas (especially in the state of Yucatan) (Caballero 1994).

Study area: Central Quintana Roo

The present research was carried out in the Ejido X-Maben, located in the Municipality of Felipe Carrillo Puerto in the central portion of the state of Quintana Roo (Figure 2.1). During the colonial period, the majority of Quintana Roo was outside of Spanish control. The region served as a refuge for Maya fleeing Spanish domination, and the population of the region continued to practice traditional subsistence activities (Villa Rojas 1992, p. 45). From 1847 to 1901, Quintana Roo was the holdout of the Maya rebels who fought against the Mexican government in the 50-year Caste War (Reed 1964). The communities of X-Maben pertain to the X-Cacal group, descendants of the last Maya rebels who resisted government control until as late as the 1930s (Hostettler 1996, Villa Rojas 1992).

Since then the X-Cacal communities have gradually become integrated into Mexican national life. One of the important factors which motivated this integration was the extraction of natural chewing gum (“chicle” in Spanish) (Hostettler 1996), derived from the latex of one of the dominant forest canopy trees, *Manilkara zapota* (L.) Van Royen. Destined for American and other foreign markets, commercial extraction of

chicle underwent a boom in Quintana Roo (peaking in 1929) which brought many newcomers to the region (Villa Rojas 1992). Chicle extraction became an important source of cash income for the Maya communities of X-Cacal and fear of incursions on their territory by outsiders motivated the 1936 petition to the federal government to legalize their land rights in the form of an ejido (Hostettler 1996). In Mexico, the ejido is a form of collective land tenure in which the government grants usufruct rights (e.g. allowing use of the land without conferring property rights) to a group of members or ejidatarios¹. Following the establishment of the ejido X-Maben, schools and roads were eventually established in the area, with corresponding changes in the regional economy. Chicle extraction remained the main source of cash income for the X-Cacal communities until as late as the 1980s and is still practiced today, but has declined in importance. Since the 1970s, opportunities for wage labour have emerged both locally and in the tourist zone of Cancun, while other forest-based sources of income became available with the establishment of the community forestry program in the mid-1980s (the Plan Piloto Forestal) (Hostettler 1996). Despite these changes, Maya culture, language and identity remain strong in the region, as do traditional patterns of land-use (described in more detail below).

Central Quintana Roo provides an interesting case study for examining the interaction of land-use dynamics and the availability and use of wild plant resources for several reasons. First, the area is of regional and international conservation interest, forming part of the proposed Mesoamerican Biological Corridor (a network of forest patches expected to link southern Mexico to the Isthmus of Panama) and being located in the buffer zone of Sian Ka'an, a UNESCO Biosphere Reserve. Land tenure in Quintana Roo is primarily collective, with most areas being designated as ejidos, which are administered by an assembly in which all ejidatarios have a voice. This is the main decision-making body for establishing local regulations pertaining to land-use. With an estimated 80% of Mexico's forests falling under collective land tenure regimes (Bray et al. 2003), conservation on community lands is critical to regional conservation efforts.

¹ Note that as a consequence of the Mexican Agrarian law passed in 1992 ejido lands can now be divided among ejidatarios who then have the right to rent, sell or mortgage their parcels to non-ejidatarios. Despite this, most Maya ejidos in the study area, including X-Maben, have not initiated this process and continue to manage their lands collectively.

One way in which this has been promoted has been through the state-wide community forestry program (the Plan Piloto Forestal).

Second, as described in more detail below, the Maya communities in this region maintain a diversified land-use system which includes shifting cultivation and collection of wild plant resources in addition to a number of market-oriented activities, including community forestry (Hostettler 1996, Murphy 1990). Rather than being specific to Quintana Roo, this is characteristic of many indigenous and peasant societies in many parts of the tropics (McSweeney 2000, p. 278, Toledo et al. 2003). Furthermore, research from community forestry experiences in other regions (especially Southeast Asia) has increasingly highlighted hardship for some segments of the communities (in particular women) ensuing from a lack of attention to subsistence activities such as wild plant collection (Agarwal 2001, Gupte 2004, Mehta and Kellert 1998). As pointed out by several authors (e.g. Mazhar and Buckles 2000, Pinedo-Vazquez et al. 1992), wild plant resources are often overlooked by development planners. Consideration of the interaction of different land-uses and management objectives (e.g. conservation, agriculture and wild plant resources) is thus important for conservation and community development efforts in Quintana Roo and elsewhere.

Finally, better understanding of contemporary Maya resource management and subsistence practices can provide insights relevant to scholarly debates on Ancient Maya civilization and, in particular, on the causes for its collapse (Gomez-Pompa 2003). While it is beyond the scope of this chapter to review these debates, the thesis contributes to this literature by advancing knowledge on the dynamics of resource use and management by Maya communities.

In the following sections, I review the literature on the vegetation and land and resource-use in the Yucatan peninsula with the goal of showing the ways in which this thesis builds on previous research in this fascinating region.

Vegetation

The Yucatan peninsula has been described floristically since the early 20th century (e.g. Lundell 1934, Standley 1930). The flora is estimated at approximately 2300 species of vascular plants (Duran et al. 1998; see this publication for a complete

account of floristic investigations in the peninsula). The Flora of Guatemala (published between 1966 and 1977 by Paul C. Standley and various others as volume 24 of *Fieldiana – Botany*) is an important botanical resource for the Peninsula, as are several species checklists available for Quintana Roo and surrounding regions (Balick et al. 2000, Martínez et al. 2001, Sousa and Cabrera 1983, Téllez Valdes and Cabrera 1987).

Pollen and lacustrine records suggest widespread forest clearance with the expansion of Maya culture and agricultural activities (beginning around 1000 B.C.); forests subsequently recuperated following the Maya collapse (Rosenmeier et al. 2002, Steinberg 2005). Old-growth forests in the peninsula are thus generally thought to have been subject to agriculture in the past. Vegetation associated with Maya ruins has been found to be floristically distinct from other forests (White and Darwin 1995), and it has been suggested that this and other features of the present day vegetation is a result of ancient Maya silvicultural practices (Edwards 1986, Gomez-Pompa 1987, Gomez-Pompa et al. 1987) or land-use (Steinberg 2005). However, the silvicultural hypothesis has been questioned by a few studies suggesting such floristic differences at Maya ruins are primarily due to ecological conditions prevalent at these sites (e.g. Lambert and Arnason 1981, Rico-Gray and Garcia-Franco 1991).

Recently quantitative vegetation studies have aimed at better characterizing variations in community types and especially of mature forests (e.g. Rico-Gray et al. 1988, Sanchez-Sanchez and Islebe 2002, White and Darwin 1995, White and Hood 2004). A number of studies have also compared different successional stages of vegetation derived from milpa, as well as from more intensive land-uses (e.g. Ceccon et al. 2002, Correa Cano 2004, Cruz Martínez 2000, Gonzalez-Iturbe et al. 2002, Illsley Granich 1984, Levy Thatcher et al. 1991, Mizrahi et al. 1997, Perkulis et al. 1997). In X-Maben, Rewald (1989) examined the resprouting behaviour of tree species in milpas. To my knowledge, only one other study in addition to Chapter 5 of this thesis is available which compares vegetation patterns in milpas following different fallow times (Illsley Granich 1984), and detailed analyses of variations in early successional communities for the peninsula are relatively few.

Ethnobotany and traditional land-use

The Yucatec Maya are one of the best studied ethnic groups in Mesoamerica (Toledo et al. 2002), and there is a broad body of literature that addresses many aspects of Maya culture, history and subsistence. Comprehensive reviews of the ethnobotanical and ethnoecological research in the region are offered by Anderson (2003) and Barrera-Bassols and Toledo (2005). As summarized by these authors, a number of studies have produced inventories of wild plants, animals and plant genetic resources used by both Ancient and contemporary Maya communities, and the folk classification of vegetation, soil and plants have also been the focus of research (an excellent synthesis of this work is provided by Barrera-Bassols and Toledo 2005).

Barrera-Bassols and Toledo (2005) also provide a summary of research pertaining to traditional Yucatec Maya land-use, which they characterize as a multiple use system, based primarily on shifting cultivation, gardening (especially in homegardens) and hunting, but also including agroforestry, bee-keeping, gathering and fishing. Like other peasant societies in Mesoamerica, these mostly subsistence activities are combined with a variety of commercial activities. Although shifting cultivation and gathering of wild plant resources are carried out by nearly all households (Murphy 1990), livelihood portfolios can differ substantially among households (Hostettler 1996).

The main crop in the shifting cultivation system practised by the Yucatec Maya is maize, however it is usually planted as a polyculture with beans and squash; other crops, such as various types of tubers, watermelon, and gourds can be interplanted among these main crops (Hernandez X 1985, Teran and Rasmussen 1995). In Mesoamerica corn fields are referred to by Spanish-speakers as “milpa” (in Yucatec Maya, **kool**). Although in some regions of Central and Northern Mexico milpa does not always include a fallow period, in this thesis I refer both to the corn fields and the shifting cultivation system practised by the Yucatec Maya as “milpa”.

Several ethnoecological studies from the Yucatan peninsula have examined the heterogeneity and management of wild plant resources in the landscape. These include inventories of useful plant species in different successional stages created by milpa agriculture (Correo Cano 2004, Cruz Martínez 2000), as well as studies of the demography and management of *Sabal* spp. (a thatch palm) in different land-uses

(Caballero 1994, Martínez-Balleste et al. 2002) and within the mosaic of successional stages created by shifting agriculture (Pulido and Caballero 2006).

Ethnobotanical studies with a gender focus have been relatively few. Lope-Alzina (2004) discussed the roles of men and women in crop varietal selection in both homegardens and milpa, while Greenberg (2003) examined the role of women and their culinary preferences in conserving traditional crop varieties in homegardens of immigrant Yucatec Maya in the touristic zone of Quintana Roo. A number of other studies have examined the diversity and management of Yucatec homegardens (Caballero 1992, De Clerck and Negreros-Castillo 2000, Gillespie et al. 2004, Nieves Delgado 2003, Rico-Gray et al. 1990), and in some cases the role of women is described (e.g. Herrera Castro 1994). Nimis (1982) and Pohl (1982) have reported on the role of women in livestock production in both ancient and contemporary Maya societies, and Acosta Bustillos et al. (1998) provide a description of the use and management of forage plants for livestock raised in the homegarden. Overall, ethnobotanical studies from the Yucatan with some gender content have thus focused primarily on the homegarden. Two exceptions are Sánchez González's (1993) study of firewood use and management in which she quantified the relative participation of different family members (including women) in firewood collection, and La Torre-Cuadros and Ross' (2003) comparison of men and women's knowledge of the species composition of different forest and vegetation types. Chapter 3 contributes to this body of knowledge by providing a gender analysis of the knowledge and perception of environments besides the homegarden, in this case agriculture and forests.

Community forestry

The Plan Piloto Forestal (PPF) of Quintana Roo has been the subject of a growing number of studies. Several book chapters and other works provide general descriptions of the program's origins, goals and evolution (Bray et al. 2003, Bray et al. 2005, Galletti 1998, Kiernan and Freese 1997, Merino Pérez 1997). Institutional and organizational aspects of the community forestry enterprises have been examined by several authors (Bray 2000, Flaschenberg and Galletti 1998, Merino Pérez 2004, Taylor and Zabin 2000). Research by Snook and collaborators (Snook 1998, Snook and Negreros-Castillo

2004, Snook et al. 2005) has investigated the ecology and proposed improved management strategies for the most valued timber species, Mahogany (*Swietenia macrophylla* King).

While the above studies deal primarily with the forestry operations themselves, other research has considered the ecological impacts of the program. At a regional scale, Bray et al. (2004) used a time series of land cover maps and other spatial data to examine trends in land cover change in an area of 7300 km² comprising most of the communities of the Municipality of Felipe Carrillo Puerto participating in the Plan Piloto Forestal and forming the Organización de Ejidos Productores Forestales de la Zona Maya (OEPFZM). Results from this study indicate high levels of forest retention, with forest cover being best conserved in the older, larger ejidos with greater volumes of commercial timbers, and a history of chicle extraction (such as X-Maben). Duran et al. (2005) compared this same region and another community forestry initiative in the state of Guerrero with 74 protected areas in Mexico, finding no significant differences in land cover dynamics between community forests and protected areas. Studies of the diversity and structure of forests subject to community timber extraction are being carried out by Vester and Navarro-Martinez (2005).

A few studies have examined the broader economy and land-use patterns of ejidos participating in the PPF. Merino Pérez (1997) provides a typology of ejidos forming the OEPFZM, (based on whether they have a history of chicle extraction, patterns of traditional Maya land-use or are composed mostly of non-Maya colonists) and describes variations among these in their participation in community forestry activities and other forest-based activities. In Merino Pérez's analysis X-Maben was characterized as a Maya ejido with chicle tradition. Based on a survey of economic activities in X-Maben, Murphy (1990) showed that nearly all households participated in subsistence forest uses such as milpa and gathering of forest products while fewer engaged in chicle extraction and cutting of railroad ties. Based on this analysis, she proposed that the PPF should incorporate the requirements of these subsistence activities in their management plans, an observation which was influential in defining the objectives of this thesis (see Chapter 1). The present study thus contributes to the

literature on the Plan Piloto Forestal and on community forestry in general by providing an analysis of the dynamics and management of milpa and wild plant gathering.

Conclusion

Each of the four empirical chapters presented in the pages that follow provides important contributions to specific bodies of literature. Specifically, Chapters 3 and 6 advance knowledge in ethnobotany by comparing gender differences in the perception of resources from agricultural and forest environments, and by providing insights on the importance of landscape structure and accessibility in understanding patterns of plant use; Chapter 4 contributes to the literature on tropical land-use/land cover change and community-based conservation by evaluating patterns of land-use and land-cover change on an indigenous territory and by quantifying the dynamics of agricultural land covers in relation to conservation areas; and Chapter 5 provides one of the only studies examining the impacts of shorter fallow times on non-crop plant resources in a dry tropical environment. Overall, the thesis provides a novel contribution to ethnoecology by integrating research on landscape dynamics and the management of wild plant resources and in doing so improves current knowledge of contemporary Maya land and resource management.


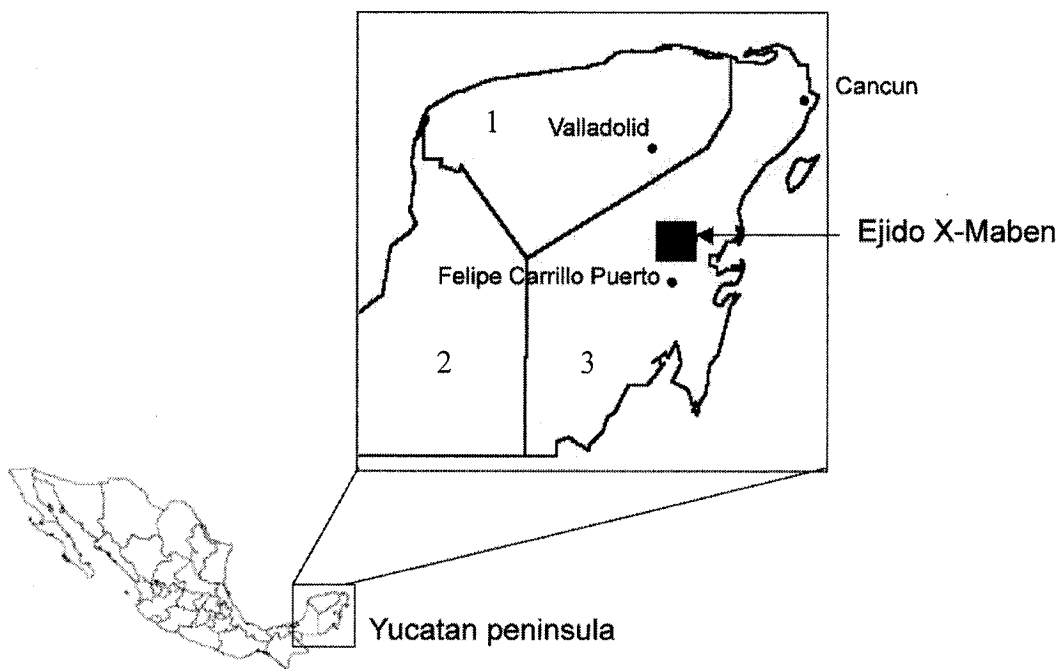


Figure 2.1 Locational map of study area (Ejido X-Maben). The three states comprising the peninsula are indicated by numbers: 1 = Yucatan, 2 = Campeche, and 3 = Quintana Roo.



PREFACE TO CHAPTER 3

In considering the relationships of land-use change with wild plant resources, a first step is to understand the resources which are available in different landscape units, and the relative importance or value attributed to such resources. Perceptions of plant resources and their importance, however, can vary considerably within a community (Rocheleau and Edmunds 1997). Gender is one important source of differentiation, which has been shown to influence plant knowledge and development priorities (Howard 2003, Pfeiffer and Butz 2005). Furthermore, women's opinions regarding natural resource management are often overlooked, since this is often considered a man's domain.

In this first manuscript, gender differences in the knowledge and perception of plant resources obtained in fields, fallows and forests are examined, contributing to the scarce ethnobotanical literature on gender differences. In the context of this thesis, these data are later used to interpret the significance of land-use changes for the availability and use of plant resources.

CHAPTER 3

Gender differences in perception and knowledge of wild plant resources managed in agricultural and forest environments

Sarah Paule Dalle and Timothy Johns

Introduction

Equity in the design and implementation of conservation and development initiatives has drawn increasing attention. Indeed, the concerns and involvement of segments of communities, especially women and the poor/landless, have not been well incorporated in many conservation and resource management projects, despite being participatory in nature (Agarwal 2001, Gupte 2004, Johnson 2004, Mehta and Kellert 1998). A failure to recognize the role of women in agriculture and forest product use (Fortmann and Rocheleau 1984) as well as the use of methods for eliciting participation that favour existing power structures (Agarwal 2001, Johnson 2004) are among factors that reduce the probability that marginal social groups are included.

One response has been the development and promotion of improved participatory methodologies (e.g. Armitage and Hyma 1997, De Paula et al. 2003, FAO 1993). However, a more detailed understanding of the role of social stratification in patterns of ethnobiological knowledge and resource use and management is also important, as such an approach can help better identify stakeholders (Coomes et al. 2004) or select key species for conservation and resource management projects.

Although social stratification in general, and gender differences in particular, have received relatively little consideration in the ethnobotanical literature (Howard 2004, Nazarea et al. 1998, Pfeiffer and Butz 2005), the few studies that compare men and women's plant knowledge have found important differences. For example, in Latin America men often have more knowledge for trees and palms used for construction or commercial purposes (Byg and Balslev 2004, Luoga et al. 2000, Stagegaard et al. 2002), whereas women show greater knowledge of medicinal and edible plants (Caniago and Siebert 1998, Hanazaki et al. 2000, Kothari 2003, Voeks and Leony 2004). Typically, this difference in plant knowledge is attributed to the gendered division of labour,

although as Howard (2003) points out differences in plant knowledge are also related to gendered use of spaces, social networks and more generally are “embedded in cosmologies, beliefs and norms about appropriate behaviours” (p. 24). Nonetheless, the net outcome is that men and women generally have more limited knowledge of the resources or environments managed or used primarily by the opposite sex (Howard 2004).

Little ethnobotanical research has examined gendered differences in the perceived importance of different plant resources and environments. Yet, this is important for evaluating local priorities for natural resource management. Although it might be expected that men and women value the resources and environments most associated to their respective responsibilities, it is important to note that in many situations men and women cooperate in producing goods (Lope-Alzina 2004, Rocheleau 1999). Thus, even when agricultural and forest environments are primarily managed by men, women are frequently responsible for the preparation and processing of these products (Howard 2003, Kainer and Duryea 1992). Men, on the other hand, may contribute resources or labour in spaces where women have more authority (e.g. building structures in homegardens). This suggests that both men and women could potentially attribute value and have concerns regarding resources in environments managed by the opposite sex, underlining the importance of consulting both sexes with regard to their priorities in relation to natural resources.

In this paper, we present a pilot study aimed at exploring qualitative differences in the perceptions of ethnobotanical resources, and the relevance of these to promoting equitable natural resource management. Specifically, we examine men and women’s perception of the relative importance and knowledge of (1) plant resources obtained from agricultural and forest environments, predominantly managed by men, and (2) species used for two use categories highly valued by women (forage and firewood). This is done using free-listing and ranking exercises with focus groups. Although the study is exploratory in nature, we offer it in response to the paucity of ethnobotanical research on this topic with the aim of encouraging more in depth research in the future.

Study Area

Research was conducted in the village of Señor, located in Ejido X-Maben, in the state of Quintana Roo, Mexico. Señor has a population of approximately 2,362 people (INEGI 2000), nearly all of whom are Yucatec Maya. A paved highway connecting the nearby town (30 km away) of Felipe Carillo Puerto to Valladolid runs through the village. The land tenure system is the *ejido*, which is a form of common property in Mexico in which the federal government grants usufruct land-use rights to a group of members, or *ejidatarios*. These generally tend to be men, although *ejido* rights are sometimes passed on to widows.

The local economy is based on a combination of subsistence and cash-oriented activities. Subsistence activities include shifting cultivation (*milpa*), production of edible and medicinal plants and livestock in the homegarden, and collection of a variety of wild plant resources (such as thatch, building materials, firewood, forage, medicines and edibles) as well as hunting and to a lesser degree, fishing. In general, women are primarily responsible for small livestock (pigs, turkeys, chickens) and other homegarden products, whereas the *milpa* is a mainly male activity. However, both women and men participate to varying degrees in *milpa* and homegarden management respectively.

Cash-oriented activities have shifted over the years. Since the early 20th century, men in X-Maben have participated in collection of latex from the chicle tree (*Manilkara zapota* (L.) v. Royen), a non-timber forest product which is used as the basis of natural chewing gum (Hostettler 1996, Villa Rojas 1992). Since the 1980s, a community forestry program (the *Plan Piloto Forestal*) has promoted the commercialization of tropical timbers and railroad ties (Flaschenberg and Galleti 1998, Kiernan and Freese 1997, Merino Pérez 1997, 2004). Through this program, communities were encouraged to conserve forests on their lands by declaring reserves for timber extraction, and were offered technical support to manage and market their products. Profits from the community forestry program are distributed to *ejidatarios*. Other economic opportunities in X-Maben include small scale commercial activities, wage labour, sale of handicrafts, commercial honey, horticultural and livestock production, ecotourism (Hostettler 1996, Sullivan 1987), and sale of firewood and some other wild plant resources.

Geologically, Quintana Roo occupies the eastern portion of the limestone platform which constitutes the Yucatan peninsula. In X-Maben, average annual temperatures are approximately 26°C, while average annual precipitation ranges from 1200-1500 mm/year (Instituto de Geografía 1990), with a marked dry season occurring from January to April. The vegetation is generally described as medium semi-deciduous tropical forest (*selva mediana subperrenifolia*) in the Mexican classification system, with a maximum stature of approximately 15 m, shedding 25% of its foliage in the dry season, and dominated by the canopy species *Brosimum alicastrum* Swartz and *Manilkara zapota* (Flores and Espejel Carvajal 1994, Pennington and Sarukhán 1998). Several inundated vegetation types are found in small extensions on gley soils particularly in eastern part of the ejido.

Methods

Information on perception of the importance of plant resources from different successional environments was obtained through a series of focus groups held in Señor in December 2002 and May 2003 (Table 3.1). Participants were recruited according to a “lottery system” whereby two sets of 20 households were randomly selected from a map of Señor. Invitations were sent to the senior woman of each household from the first sample and to the senior man of each household from the second. The lottery system was used since it was considered a fair method of selection by the villagers, and thus avoided pressure from those people already known to the first author (SPD) who may have wanted to participate. However, the groups which consisted of 5-12 people (Table 3.1), cannot be considered representative samples of the community as a whole. The participants ranged from approximately 30 to 50 years of age, with the exception of one woman and one man, about 70 years old who sometimes was present.

Women and men’s focus groups were held on separate days, and were hosted in a house rented by SPD in the village. The meetings lasting between 60 and 90 minutes were held primarily in Yucatec Maya. Aid in translation (Maya to Spanish) and in facilitation was provided by a local research assistant (a man for the men’s focus groups and a woman for the women’s group).

In the first set of focus groups, free-listing was used to develop a list of resources harvested from milpas, fallows or secondary forests and mature forests (in Yucatec Maya: **kool**, **hubche'** and **nukuch k'áax**). Participants were asked to list the resources that they knew for each habitat type, and the use of each resource. In the second set, a pile-sorting exercise was conducted in which participants were asked to sort cards with the names of each of the resources mentioned in the free-listing exercise in order of how their perceived "importance". The participants were free to define "importance" as they wished, but had to achieve a consensus among members of the group. Because the number of resources mentioned by the men's free-listing exercise (focus group 1) was very large, we decided to reduce the number of resources included for the ranking exercise from 86 to 58. The selection represented a range of uses and habitats; in addition, any resources included in the women's focus groups were also retained.

Further interviews were carried out in June 2003 to collect information on the knowledge and perceived importance of firewood and forage plants, two resources identified as important to women in focus group 2. To develop a list of species, we conducted individual free-listing interviews with 8 of the men and 11 of the women who had participated in the initial two focus groups. Interviews were conducted in the participant's home with each person asked to recall as many forage and firewood plants as they could. A third set of focus groups followed in which participants were asked to review the species lists and to rank species in terms of importance (Table 3.1). Notes were taken on the qualities of the firewood species, as well as the animals for which each forage plant was used. All species mentioned in the women's free-listing interviews were included in the men's focus group to permit comparison in their rankings. However, the opposite was not done in order to avoid presenting the women with a large number of species with which they might not be familiar.

Results

Plant resources from milpa, fallow and forest

In the free-listing exercises (focus group 1), men mentioned more than twice as many plant resources as women. The difference was especially pronounced for resources associated to secondary forests (5 vs 40 plants for women and men,

respectively), whereas women mentioned a similar number of resources for milpa and early fallows as compared to men (Table 3.2).

The most common plant-use mentioned by both women and men was medicinal (16 and 20 uses, respectively); in the women's group this represented nearly 40% of all plant uses identified (Figure 3.1). In contrast, men also mentioned large numbers of species used as commercial forest products, for construction, and which serve as food for wild animals. Women mentioned slightly more plants used for handicrafts and forage for domestic animals than men. In both groups, firewood and poles used in construction were mentioned as categories rather than in reference to specific species. In contrast, railroad ties were identified as a broad category by women whereas men listed a number of specific species used for this purpose.

In the importance ranking exercises (focus group 2), some similarities were encountered in comparing men and women's rankings of plant resources (Table 3.3). For example, both men and women differentiated between the most commonly used/important medicinals and those less frequently used. In addition, both groups considered the thatch palm (*Sabal yapa* C. Wright ex Beccari) of prime importance, whereas plants used for basketry and other utensils, as well as plants eaten by wild animals, were ranked as intermediate to low in importance.

The most striking difference was in the resources identified as of greatest importance. In general, women highly valued plants used for domestic/subsistence purposes (firewood, brooms, the most frequently used forage and medicinal plants), the majority of which were stated to be used on a nearly weekly basis. In contrast, commercial forest products such as timber, railroad ties and chicle dominated the men's highest ranking (Table 3.3). Notably, all but one species most esteemed by the men's group are obtained only in mature forest, whereas the species ranked highest by the women's group are harvested from milpa, fallows and forest (Figure 3.2).

Some of the resources ranked high by one sex were ranked very low by the opposite. For example, poles used for house walls, firewood, and forage for pigs were ranked high by women but low by the men's group (Table 3.3). On the other hand, the women's group ranked railroad ties as low in importance. However, in two cases there was disagreement within the focus groups as to how to rank resources considered

important by the opposite sex. For instance, one man wanted to rank firewood as important (in rank 2 instead of rank 5), whereas one of the women argued that mahogany should be included in the most important plants since it provides cash income to many families.

Further differences in men and women's rankings appear in comparisons of the reasons stated for rankings of specific species or resources evaluated by both focus groups (Table 3.4). For example, the palm *Sabal yapa* and the tree *Piscidia piscicula* (L.) Sarg. were the only two species considered equally important by both men and women, but the reasons differed. For example, *Piscidia piscicula* was ranked high by the men because it is the best species for house posts, while the women noted its importance as the preferred firewood species. For *Sabal yapa*, both groups mentioned its use for thatch roofs but the women also considered its frequent use in the preparation of traditional underground ovens (**piib**) and for many smaller constructions in the homegarden as important. Among other species differing in their reasons for ranking wild *Carica papaya* L. was ranked highly by the men as an important emergency medicine for snakebites but discarded as an important forage stating it is "only for pigs". On the other hand, the men placed *Stizalobium pruriens* (L.) Medic. in the second most important group due to its historical importance for purging parasites while women ranked it low, mentioning that it is no longer used. Finally, women tended to emphasize domestic uses of many of the plants ranked high by the men for commercial value (e.g. *Swietenia macrophylla*, *Manilkara zapota*, *Cordia dodecandra* A. DC.), whereas resources used in the domestic realm for which many species could be used (firewood, poles) were ranked lower by men than by women.

Forage resources

In the free-listing exercises for forage (individual interviews), the women mentioned 21 forage plants while the men identified 36. Eight species mentioned were unique to the women's free-list, whereas 24 forage plants (used mostly for horses, cattle and sheep) were free-listed only by the men.

In the ranking exercises for forage plants (focus group 3), both men and women identified three groups based on their perceived importance (high, medium and low

importance), while a few species were said to not be known to the group, or in their opinion not used as forage. In general, women attributed greater importance to forage plants that could be used for both small livestock and ruminants, reserving their highest ranking to such multipurpose plants which are fed to pigs (4 of 21 species) (Table 3.5a). In contrast, the men considered a larger group of forages as important (22 of 45 species), including 15 species used for ruminants (horses, cattle, sheep) only. Of the 21 forage plants from the women's free-list, men considered 67% (14 species) as high in importance, while women's rankings for these species varied (Table 3.5b). The remaining species were considered of moderate to low importance by both men and women.

Firewood

Women and men free-listed 14 and 51 firewood species, respectively. Two were mentioned only in the women's free-list, while men mentioned 39 species not listed by the women. The women ranked the 14 species from their free-list in three groups (high, moderate, and low importance) whereas the men identified five groups for the 53 species they evaluated. These groups had the following characteristics:

- 1) Best firewood species, which burn slowly, sometimes even if green (10 species)
- 2) Those good for kindling, but which burn quickly (14 species)
- 3) Second-choice species, used only if not enough of the first two groups is found (9 species)
- 4) Poor firewood species that do not burn well (9 species)
- 5) Species which are good for firewood but are more appreciated for construction or are prohibited to cut due to their commercial value; may be used for firewood if found as dead wood or as stumps (11 species).

Interestingly, 12 of the 14 species free-listed by the women were classified by the men as good quality firewood (groups 1, 2 or 5) (Table 3.6). Two species (*Gymnopodium floribundum* Rolfe and *Dipholis salicifolia* (L.) A.DC.) which were highly ranked by the men (groups 1 or 2) but considered of low importance by the women were noted to be heavy and hard to cut by the women, whereas a third such species (*Psidium sartorianum* (Bergius) Niedenzu) was said to be good quality but not frequently used. Otherwise,

men and women's perceptions of the quality of the 14 common firewood species were similar (Table 3.6).

Discussion

Gendered differences in plant knowledge and perception

We expected men to be more knowledgeable about resources obtained in the agricultural and forest environments, since these are spaces managed primarily by men. Our results indicate that while this was especially true for secondary forests, this was less so for mature forest and especially milpa. The milpa is mainly the domain of men (Lope-Alzina 2004), but it is not uncommon for women to assist in certain tasks, especially the harvest (Murphy 1990), and women may occasionally make their own trips to the milpa (often accompanied by older children). In contrast, although women may pay cursory visits to nearby forests to collect firewood, our field observations suggest that women have much less contact with secondary and mature forests as compared to the milpa. Thus, the comparable number of resources listed by women and men for milpa may reflect the greater contact that women have with this environment. On the other hand, the fairly large number of resources mentioned for mature forest (17 vs. 25 for men) more likely reflects the salience of some of these resources to the local economy. For example, most forest products mentioned by women would be collected by men but are used in the domestic realm (e.g. materials used in construction, basketry and other handicrafts, trees providing edible fruits and forage). Women's knowledge probably stems from their role as end-users of many products, rather than through direct experience with harvesting in the habitat.

Other studies have emphasized the gendered division of labour as an important factor influencing gendered differences in plant knowledge (Byg and Balslev 2004, Caniago and Siebert 1998, Gemedo-Dalle et al. 2005, Hanazaki et al. 2000, La Torre-Cuadros and Ross 2003, Luoga et al. 2000, Stagegaard et al. 2002). The influence of such a division is apparent in various aspects of our results. For example, men mentioned large numbers of plant uses related to primarily male activities such as hunting (e.g. plants eaten by wild game), construction, commercial forestry (railroad ties, chicle harvesting and timber species), and tending of ruminants such as cattle, horses and

sheep, and accorded high importance especially to species used as commercial forest products and high quality construction materials. On the other hand, women ranked highly species used frequently in the household and the homegarden and mentioned domestic uses for many of the commercial species.

However, it is important to note that some of these differences may reflect perception more than plant knowledge *per se*. For example, some uses not mentioned by the women are certainly known to them, such as *Manilkara zapota* for chicle or *Piscidia piscicula* as a house post, and the reverse is probably true for some of the uses not mentioned by men. To verify this, more detailed interviews on the specific uses of each species would be necessary. However, our results reflect what is considered most salient by men or women, and this is highly influenced by their respective responsibilities and activities.

Examining perceptions of the relative importance of species revealed that for specific purposes, women's knowledge may be focused on those species most commonly used. For example, while men free-listed 51 species used for firewood, they later ranked over one third of these as low quality. In contrast, 12 of the 14 firewood species free-listed by the women were ranked as good or high quality by the men. Similarly, men seemed to attribute more value to resources with historical importance. For example, while men ranked chicle and railroad ties as first in importance, the women's group ranked them lower saying that very few people still participate in these activities. Other examples are a famine food (*Arrabidaea pubescens* (L.) A.H. Gentry) which was heavily relied upon by the Maya rebels (of which Señor's population are the direct descendents) during the Caste War in the late 19th century, as well as *Stizalobium pruriens* which in the past was commonly used to purge abdominal parasites. In addition, forage plants used for large ruminants such as horses and cattle, animals which today very few families still raise, were ranked by men as just as important as those used for pigs and small fowl which are kept by nearly all households.

These findings are interesting since many ethnobotanical studies have emphasized potential uses, and on this level women have often been found to be less knowledgeable (e.g. Stagegaard et al. 2002). Yet, when actual use is considered it is often found that a much smaller number of preferred species are harvested in practice

(e.g. Kvist et al. 2001, Stagegaard et al. 2002). Our data suggest that women's knowledge may be a good indicator for these resources, possibly since they interact with them primarily at the stage of their processing and use.

Interaction of gendered priorities for natural resource management and land-use decisions

By examining perceptions of the relative importance of different resources, our study provides information relevant to understanding local priorities for natural resource management. Particularly striking is the men's high ranking of commercial and other products derived from mature forests. Thus, in terms of the availability of non-crop plant resources, the men appear to attribute greater value to forests than to milpa or younger fallows and secondary forests. In contrast, resources highly ranked by women were derived from a range of successional habitats, and included domestic rather than commercial forest products. Forest resources prioritized by women included the palm *Thrinax radiata* used for brooms, poles used for house construction, as well as the fodder tree *Brosimum alicastrum*, while forage and a medicinal plant were important resources from the milpa. The thatch palm (*Sabal yapa*) and firewood were listed by women for both agricultural and forest environments.

This raises the question of how domestic resources valued by women are managed by men in the agricultural and forest environments for which they are primarily responsible. For the forest environments, one might assume that management decisions aimed at favouring commercial forest products would also favour those used more for domestic purposes. Indeed, in a related study, we found that large extensions of forest cover in X-Maben have been conserved due to their importance for extraction and management of commercial forest products (Chapter 4). However, closer examination reveals that these areas are primarily located in the more inaccessible parts of the *ejido*. Although a few forest patches have been conserved as a source of domestic forest products, overall forest cover in the more accessible areas have been greatly reduced in the past 20 years (Chapter 4). Reduced access to nearby forest may be especially problematic for collection of domestic forest resources which are needed on a frequent basis, such as firewood, and may be of specific concern for women, children or other

individuals more limited in their ability to travel longer distances by bike or other means. The women in the focus group expressed concern over the increased scarcity of firewood noting that Señor was now surrounded by “puro sakab” (pure young fallow), and many people in Señor commented on the degraded state of the remaining forest patches (field obs).

The fact that men did not prioritize any plant resources from agricultural environments suggests that they may not consider non-crop plant resources when making decisions about milpa. For example, non-crop plant resources in agricultural environments can be negatively affected by application of herbicides (Mazhar and Buckles 2000, Vazquez-Garcia et al. 2004), and we have found that in X-Maben availability of firewood and some forage resources are influenced by fallow management practices (Chapter 5). Little research has considered how non-crop plant resources influence agricultural decisions, and even less is known about how resources mainly valued by women might fare. Lope-Alzina (2004) has suggested that crop varietal selection can be seen as a negotiation process between the sexes, in which men and women may influence each other’s decisions in their respective production spaces. Thus, such a dynamic might also be important for management decisions affecting non-crop resources, at least within a household. However, some non-crop plant resources can be harvested in other households’ fields (e.g. forage in this study), and, in these situations, it may be more difficult for women or other people depending on such arrangements to influence agricultural decisions. For example, Fortmann and Rocheleau (1984) report a case in the Dominican Republic where women’s access to palm fiber was based on harvesting palms from pastures where landowners spared the palms due to their value as hog feed. However, following an epidemic of swine fever, landowners began felling the palm for cheap construction material, and women’s access to the resource was compromised. This example, therefore, illustrates that consideration of tenure arrangements and gathering rights may be important for examining how the priorities of women and/or other marginal groups play out in natural resource management.

Conclusion

In this study we have attempted to go beyond simply quantifying the number of uses known by gender – an approach which has usually concluded simply that “women know less” about male dominated spaces – to exploring more qualitative differences in the perceptions of ethnobotanical resources. Results from this exploratory study suggest that women’s knowledge, while generally emphasizing different plant uses for a given species, may also better indicate those resources most commonly used in the household, as opposed to the broader ecological knowledge held by men.

Secondly, perceptions of the importance of resources differed markedly between the sexes, with women prioritizing resources from both agricultural and forest habitats, as opposed to the commercial forest products considered most important by men. This finding is important to consider in development projects and ethnobotanical research which frequently consult men about management priorities from such spaces. It also draws attention to the need to better understand how women are able to influence management decisions which affect resources they considered important. Within the context of this thesis, the findings from this chapter were used to guide selection of resources for further study (see Chapters 5 and 6), thereby contributing to a gender-sensitive approach in ethnobotanical research.

While effectively highlighting some interesting gender differences in knowledge and perception of resources in male-dominated environments, one limitation of this study is the lack of replication in the focus groups. This precludes analysis of intra-group heterogeneity (for example, with regard to age, socio-economic status, or social networks) among women and men. Further ethnobotanical research should aim to develop a more nuanced understanding of the trends described in this exploratory study. This could include a larger number of focus groups or in-depth interviews directed at more specific social groups (e.g. young vs. older women) as well as surveys applied to a larger, representative sample of the population.

Table 3.1. Summary of interviews conducted and number of participants

Interview	Activity	# of participants	
		♀	♂
Focus group 1	Free-listing resources from different successional stages (milpa, secondary forest, mature forest)	12	11
Focus group 2	Ranking of perceived importance of resources from different successional stages	2 groups of 8-9 ^a	6
Individual interviews	Free-listing of forage and firewood species	11	8
Focus group 3	Ranking of perceived importance of forage and firewood species	2 groups of 10 ^b	5

^a Half of the women participated in the ranking of perceived importance; the other half conducted a similar exercise ranking the same species according to the frequency of use

^b The group was divided in two, such that 10 women ranked the forage species and 10 ranked the firewood species.

Table 3.2. Number of plant resources mentioned by men and women’s focus groups by successional stage.

Successional habitat	# plants reported	
	♀	♂
Milpa and early fallow (1-2 y)	23	28
Secondary forest *	5	
Young secondary forest (3-5 y)		19
Older secondary forest (>8 y)		21
Mature forest (nukuch k’áax)	17	25

* “Secondary forest” category used in the women’s group only; men separated this category into young and old secondary forest (following two entries).

Table 3.3. Summary of importance rankings for resources from different successional stages. The number of species corresponding to each entry is indicated in parentheses.

Rank	Focus group	
	♀	♂
1 <i>Most important</i>	Most important forage for pigs (3) Firewood (2) Poles for fences, house walls (2) Thatch palm (1) Palm used for brooms (1) Most important medicinal plant (1)	Commercial timber and railroad ties (7) Best species for house posts (3) Thatch palm (1) Chicle (<i>Manilkara zapota</i>) (1)
2	Plants for scrubbing pots and for fiber, tying (2) Mahogany for furniture (1)* Important railroad tie (1) Plant for "limpias" (mystical) (1) Less used forage plant (1)	Most used/important medicinals (5) Historically important plants, one used as famine food, another as medicine to purge parasites (2) Plant used in chicle production (1)
3	Various medicinal plants less commonly used (9) Plants for basketry, utensils (3) Edibles (2) Forage for horses, deer (2) Less important railroad tie (1)	Plants for basketry, latching, tying (5) Edibles, harvested in the forest, sometimes sold (2) Best meliferous plant, plant eaten by deer (2)
4	Rarely used medicinals (6) Food for wild animals (2) Railroad ties in general (2) Edible (1)	Certain firewood species (5) Forage plants for horses, cattle; one eaten by wild animals (4) Poles for house in general (1) Edible (1), Medicinal (1)
5	N/A	Firewood in general (2)* Meliferous (1) Plant for curing hides (1)
6 <i>Least important</i>	N/A	Less used medicinal plants (7) Plants eaten by wild animals (3) Forage for pigs (1) Low quality chicle plant (1) Edible (1) Plant toxic to honey bees (1)

*Resources for which there was disagreement within the focus group as to its importance

Table 3.4. Comparison of men and women's importance rankings and reasons for classification for 24 plant resources common to both groups. Substantially different rankings or reasons for classification are shown in bold face.

Maya name	Scientific name	Family	Voucher	Importance		Reason for classification	
				♀	♂	♀	♂
Ja'abin	<i>Piscidia piscicula</i> (L.) Sarg.	Fabaceae	SD 255	1	1	Used daily for firewood, and in winter to warm the below the hammock when sleeping	Best species for house post
Xa'an	<i>Sabal yapa</i> C. Wright ex Beccari	Areaceae		1	1	Thatch, for structures in the homegarden and for underground oven (piib); many people use for their house and to repair their roofs	Thatch for roofs
Tipteak'	Unidentified			1	2	Medicine, used in many home remedies, for stomach pains	Frequently used medicine
Púut ch'iich'	<i>Carica papaya</i> L.	Caricaceae	SD 362	1	2	Forage for pigs, also helps purge parasites in pigs	Medicine, very effective to control snake bite poisoning
Che'il naj	Poles in general			1	4	Poles used for walls of the house	Many species can be used
Óox	<i>Brosimum alicastrum</i> Swartz	Moraceae	SD 283	1	4	As medicine to calm asthma, the fruit is edible, and used daily as forage for domestic animals	Forage for domestic animals
Sii	Firewood in general			1	5	Firewood is used everyday	Many species can be used
Iis ak'il	<i>Ipomoea</i> spp.	Convolvulaceae	SD 331	1	6	Forage for pigs, used daily, the pigs fatten faster	Eaten by wild boar
Caoba	<i>Swietenia macrophylla</i> King	Meliaceae	SD 329	2	1	To construct furniture	Precious timber, it's money!
Ch'u'ulte'	<i>Pseudobombax ellipticum</i> (H.B.K.) Dugand	Bombacaceae	SD 354	2	1	Latching	Commercial timber
K'óopte'	<i>Cordia dodecandra</i> A. DC.	Boraginaceae	MEC 149	2	1	Leaves used to scrub pots, but now many people don't use	Commercial timber
Tsalam	<i>Lysiloma latisiliquum</i> (L.) Benth.	Fabaceae	SD 270	2	1	Railroad tie	Commercial timber
Chechem	<i>Metopium brownei</i> (Jacq.) Urban	Anacardiaceae	MEC 259	3	1	Railroad tie	Good as housepost and for house frame, the main species cut for railroad tie

Table 3.4. continued

Maya name	Scientific name	Family	Voucher	Importance		Reason for classification	
				♀	♂	♀	♂
Ya'	<i>Manilkara zapota</i> (L.) v. Royen	Sapotaceae	SD 318	3	1	Edible fruit, can be prepared in traditional oven (piib)	Chicle and as housepost
E'ki'ixil	<i>Russelia campechiana</i> Standley	Scrophulariaceae	MEC 131	3	3	Leaves used to coagulate blood of a wound	Latching
Janan	<i>Desmoncus</i> sp.	Arecaceae	MEC 364	3	3	Basketry	Basketry
K'an jool	<i>Abutilon gaumeri</i> Standley	Malvaceae	MEC 1, 68	3	3	For wooden spoons used in cooking	For handicrafts and as strap for carrying loads
Ak'	Vines in general			3	3	Basketry	Basketry, latching
Kitamche'	<i>Caesalpinia gaumeri</i> Greenm.	Fabaceae	SD 352	3	4	Deodorant	Very good for firewood
Ya'axnik	<i>Vitex gaumeri</i> Greenm.	Verbenaceae	SD 266	3	4	Forage for horses, used to prepare corn ("piibil nal") in thanksgiving ritual	Railroad tie, but not the best; only some use for forage and firewood
X-pica pica	<i>Stizalobium pruriens</i> (L.) Medic.	Fabaceae	SD 323	4	2	Medicine for purging parasites, also used to make beverage, but not used anymore	In the past was very important and effective medicine, for purging parasites
K'atal oox	<i>Swartzia cubensis</i> (Britton & P. Wilson) Standley	Fabaceae	SD 350	4	4	Railroad tie	Firewood
Chi' kéej	<i>Cryosophyllum mexicanum</i> T.S. Brandegee ex. Standley	Sapotaceae	MEC 59	4	5	Edible fruit	Edible fruit, but only if you find it
X-Jochok	<i>Nectandra coriacea</i> (Lundell) Kostermans	Lauraceae	SD 290	4	5	Medicine, to encourage chickens to hatch	Firewood

Table 3.5. Comparison of men and women's importance rankings for forage species.

a) Overall rankings				
♀	<i>High</i>	<i>Med</i>	<i>Low</i>	<i>Unknown</i>
Sm. livestock & ruminants*	4	5	1	
Sm. livestock only			2	
Ruminants only		2	3	
Not used			1	
Total	4	7	7	3
♂	<i>High</i>	<i>Med</i>	<i>Low</i>	<i>Unknown</i>
Sm. livestock & ruminants	6	1	1	
Sm. livestock only	1			
Ruminants only	15	7	1	
Not used			10	
Total	22	8	12	3
b) Rankings for 21 common species				
		♀		
	<i>High</i>	<i>High</i>	<i>Med</i>	<i>Low</i>
	<i>Med</i>	4	6	4
	<i>Low</i>			1
♂	<i>Unknown</i>			2
			1	2
				1

*Small livestock = pigs, chickens and turkeys; ruminants = cattle, sheep, horses

Table 3.6. Comparison of men and women's importance rankings for 14 firewood species. Substantially different rankings among men and women are shown in bold face.

Maya name	Family	Species	Voucher	Importance ranking		# Mentions (free-listing)		Comments
				♀ ^a	♂ ^b	♀	♂	
Ja'abin	Fabaceae	<i>Piscidia piscicula</i> (L.) Sarg.	SD 255	1	1	11	8	burns slowly, doesn't produce smoke
X-Jochok	Lauraceae	<i>Nectandra coriacea</i> (Lundell) Kostermans	SD 290	1	1	9	6	burns nicely, easy to cut, burns quickly
Boob	Polygonaceae	<i>Coccoloba spicata</i> Lundell	MEC 129	1	1	4	4	burns even when green, lasts a long time
Kitamche'	Fabaceae	<i>Caesalpinia gaumeri</i> Greenm.	SD 352	1	1	3	7	can use even when green, good for underground oven (piib)
Tsalam	Fabaceae	<i>Lysiloma latisiliquum</i> (L.) Benth.	SD 270	2	2	7	5	sends out sparks if not completely dry
Taasta'ab	Rubiaceae	<i>Guettarda combsii</i> Urban	SD 292	2	2	4	3	burns quickly but easy to cut
Pe'eresk'uuch	Euphorbiaceae	<i>Croton arboreus</i> Millsp.	SD 251	2	2	1	0	burns well when completely dry
Sabakche'	Rubiaceae	awaiting id		2	2	1	2	burns quickly
Chakte'kok	Rubiaceae	awaiting id	SD 286	2	5	3	5	burns quickly

^aWomen's ranks : 1=high important, 2=moderate importance, 3=low importance.

^bMen's ranks : 1=best firewood species, burn slowly sometimes even if green, 2=good for kindling but burn quickly, 3=second-choice species, used only if not enough of the first two groups found, 4=poor firewood species, 5=good firewood species which are more appreciated for construction or commercial value.

Table 3.6. continued

Maya name	Family	Species	Voucher	Importance ranking		# Mentions (free-listing)		Comments
				♀ ^a	♂ ^b	♀	♂	
Ts'its'il che'	Polygonaceae	<i>Gymnopodium floribundum</i> Rolfe	SD 201	3	1	1	3	hard to cut, heavy, only in forest
Ts'its'il ya'	Sapotaceae	<i>Dipholis salicifolia</i> (L.) A.DC.	MEC 140, 271	3	2	1	1	hard to cut
Pichi'che'	Myrtaceae	<i>Psidium sartorianum</i> (Bergius) Niedenzu	SD 293	3	2	1	0	doesn't burn out quickly, but only used infrequently
Cha'ka'	Burseraceae	<i>Bursera simaruba</i> (L.) Sarg.	MEC 52	3	3	2	4	burns quickly
Ya'axnik	Verbenaceae	<i>Vitex gaumeri</i> Greenm.	SD 266	3	4	1	2	ash is black (not appreciated for making tortillas), must be very dry to use

Figure 3.1. Number of resources mentioned by use category by men and women's focus groups in the free-listing exercise for different successional stages (focus group 1).

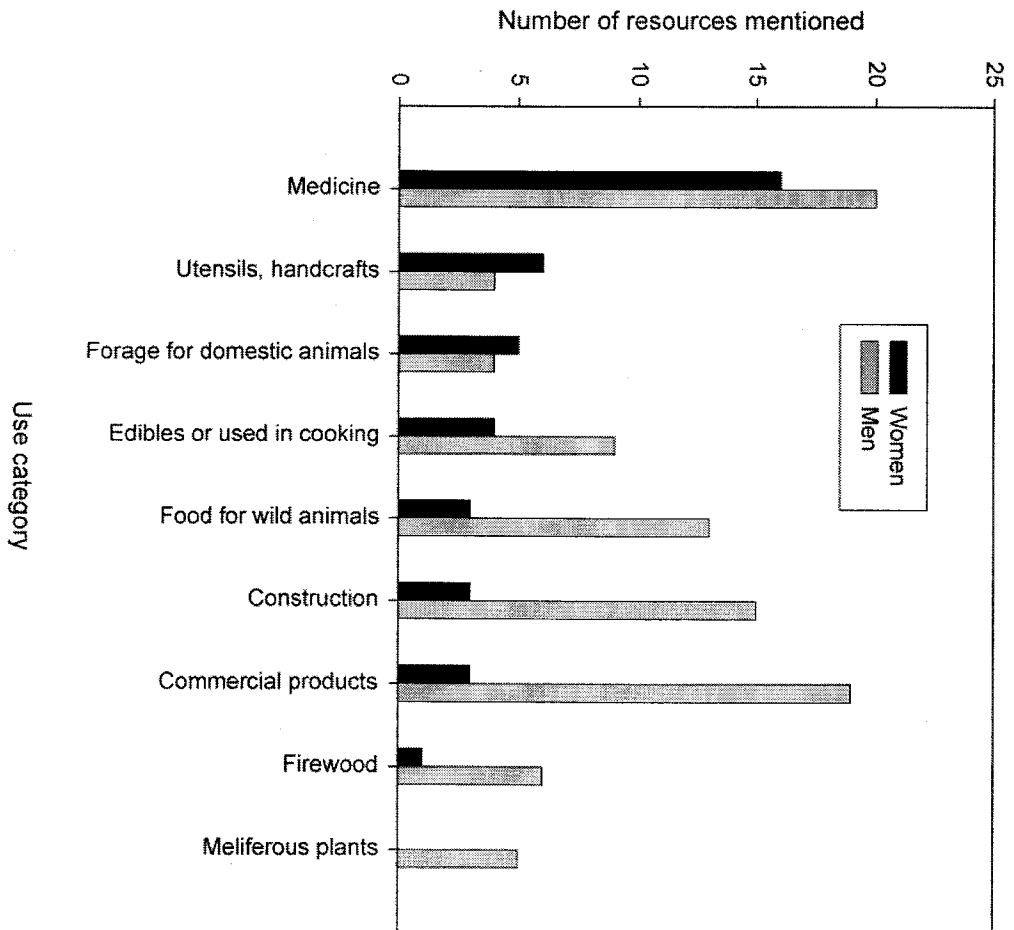
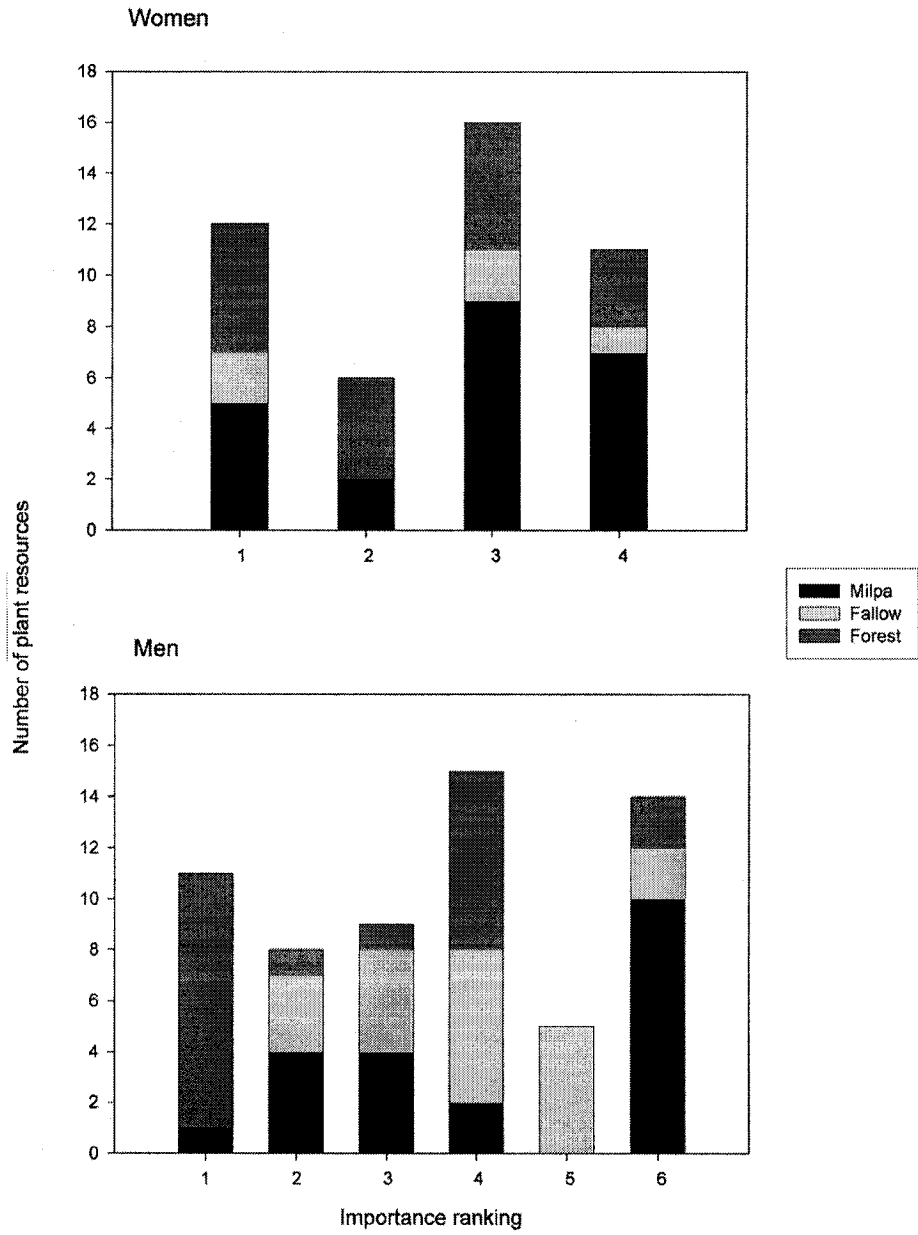


Figure 3.2. Number of plant resources from each of the three successional stages (milpa, fallow, forest) for each importance rank identified in the men and women's focus groups. Rankings: most important = 1; least important = 4 (women), 6 (men).



PREFACE TO CHAPTER 4

In Chapter 3, I found that men attributed especially high importance to commercial forest products, such as valuable timbers, chicle, and railroad ties, while those resource most highly valued by women were derived from both agricultural and forest environments, and contributed to the domestic economy.

In this manuscript, I examine quantitatively the spatial and temporal patterns of change of both agricultural and forest land covers from which the above resources are derived. In doing so, my goals are twofold.

First, I examine the extent to which forest cover has been conserved in X-Maben, and compare the trends in forest conservation with local rules and regulations governing land-use. Consistent with Chapter 3, I find that the commercial forest species valued by men are an important motivation for forest conservation.

Second, I contrast the overall pattern of land-use change at the scale of the entire ejido with the patterns of change in the areas most used for agriculture, from which domestic plant resources are most commonly gathered. Significance of these changes in the agricultural landscape for domestic plant resources become the focus of Chapters 5 and 6.

CHAPTER 4

Assessing the success of community-based forest conservation: dynamics of forest and agricultural land-uses and influence of local institutions

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Introduction

Forest conservation efforts increasingly have sought the collaboration or involvement of local communities. This has been done by implementing various programs that encourage forest-based economic activities like commercial timber and non-timber product extraction (Salafsky et al. 2001), eco-tourism (e.g. Al-Sayed and Al-Langawi 2003), or more recently carbon mitigation (Klooster and Masera 2000). In other instances, co-management arrangements for previously government-controlled forests have been developed (Plummer and Fitzgibbon 2004). The assumption underlying these initiatives is that increased control over and benefit derived from forests will increase local communities' incentives to maintain forest cover in relation to other land-uses, combining goals of biodiversity conservation, social equity and economic development/poverty alleviation.

In some areas where programs of this type were initiated in the 1970s and 1980s, a growing literature has begun to evaluate such conservation experiences in light of the different goals embodied (e.g. Acharya 2002, Agarwal 2001, Gupte 2004, Merino Pérez 2004, Sekher 2001, Smith et al. 2003, Song et al. 2004, Timsina 2003). In terms of conservation objectives, an important step is to assess changes in forest cover following the implementation of community-based conservation programs. Remote sensing has increasingly been used to this end, and in some cases has revealed improvement or maintenance of forest cover (Bray et al. 2004, Browder 2002, Duran et al. 2005, Gautam et al. 2002, 2004, Jackson et al. 1998, Smith 2003), while in others continued degradation of community forests has been reported (Semwal et al. 2004).

At the landscape scale, however, another important – but often neglected – spatial dimension of forest conservation is its effect on other non-forest land-uses. In most regions where community-based conservation has been promoted, agriculture continues

to play an important role in local livelihoods, as does the management and use of resources such as fodder and firewood from agricultural environments. Nonetheless, most assessments of community conservation programs have focused primarily on analyzing trends in forest cover. The success of community-based conservation approaches, however, most certainly depends on maintaining a balance between forest-based land uses and other livelihood activities (Dougill et al. 2001, Semwal et al. 2004). Increased pressure on agricultural lands could lead to conflicts over land-use, reduced incentives for conservation, or undue hardships for segments of the population most dependent on agriculture. Research should, therefore, focus greater attention on the interaction and evolution of both forest and agricultural (or other) land-uses in community-based conservation.

In addition to quantifying land-use/land cover changes, it is also critical that research on community-based conservation identify the conditions which produce successful conservation outcomes (Berkes 2004), and the role – if any – of external conservation interventions in contributing to these. For example, several studies have reported higher levels of forest conservation or forest improvement in areas with formal community forestry or integrated development and conservation programs, as compared to protected areas or government forests (Browder 2002, Duran et al. 2005, Gautam et al. 2004). However, as noted by Browder (2002) such correlations do not indicate whether forest conservation is due specifically to the external conservation interventions or to other conditions prevalent at such sites. Yet this is important to understand, especially when a particular model of forest conservation, found to be successful in one area, is considered for application elsewhere.

One important factor which can affect community conservation practices are the local institutions governing land-use and the management of natural resources. Berkes (2004) describes local institutions as the set of “working rules” enforced by the community, including both formal rules, laws or constitutions, as well as informal norms or conventions governing behaviour. These may include traditional or locally-initiated norms or rules as well as other regulations promoted by external agencies and implemented at the local level. In the latter case, it is important to consider that conservation measures conceived and promoted by external organizations may be

interpreted and implemented differently by local communities. It is, therefore, necessary to analyse the local perceptions, interpretations and implementation of both internal and external rules and regulations. Combined with studies of land-use/land cover change, such an approach can help to better elucidate the relative influence of local and external initiatives in forest conservation, while examining the extent to which specific rules and regulations produce observable effects on the spatial and temporal patterns of land-use/land cover dynamics.

In the present paper, we evaluate changes in agricultural and forest land covers and their relationship to local land-use rules in the “Mayan zone” of Quintana Roo, Mexico. We present a case study of a “forest *ejido*” which since the mid-1980s has participated in a state-wide community forestry program called the “Plan Piloto Forestal” (PPF) (Flaschenberg and Galleti 1998, Kiernan and Freese 1997, Merino Pérez 1997, 2004). The success of this and other community forestry programs in Mexico has led to them being proposed as a “global model for sustainable landscapes” (Bray et al. 2003). This model is being adopted in other countries in Latin America (Merino Pérez, pers. comm.), underlining the importance of better evaluating the successes and problems associated with these programs.

Specifically, our goals were to:

- 1) Document and analyze local perceptions of forest conservation rules and regulations, considering both regulations initiated by the local communities as well as those introduced or promoted by external organizations;
- 2) Quantify the spatial and temporal patterns of forest conservation and agricultural expansion. This was assessed at the scale of the entire *ejido*, as well as in the accessible areas most used for agriculture; and
- 3) Based on both of the above, evaluate the extent to which internal and external forest conservation measures have affected trends in land-use/land cover changes.

Our analysis spans a 24-year period (1976-2000), thus enabling analysis of the association between land use/land cover change, and conservation rules and regulations before and after the initiation of the PPF in the mid 1980s.

Study area

Location and population

The study was carried out in the *Ejido* X-Maben (hereafter referred to as “X-Maben”). X-Maben is located in the Central part of Quintana Roo, in a region locally referred to as the “Maya Zone”. The *ejido* measures over 730 km², and spans two paved highways leading from the nearby town of Felipe Carrillo Puerto to the cities of Valladolid and Cancun. The X-Maben *ejido* land grant was petitioned in the 1930s, and the grant was formalized in 1955.

The population is almost entirely Yucatec Maya, most of whom are descendants of the Maya rebels who fought against government forces in the Caste War (1847-1901) (Reed 1964). The oldest villages in the region are thought to have been settled near the end of the war, although the region was inhabited throughout the war, serving as a refuge for the rebels (Hostettler 1996, pp. 47-58, Sullivan 1987).

In 2000, X-Maben had an estimated population of approximately 2,849 (average population density 4 people/km²) (INEGI 2000), approximately 83% of which is concentrated in the largest village, Señor, located along the highway to Valladolid. From 1970 to 2000, the population of Señor increased by a factor of 2.5, from 939 to 2,362 people (INEGI 2000, Secretaría de Industria y Comercio 1971). Nine other permanently inhabited settlements had populations of less than 200 people in 2000 (Figure 4.1a), since 1970 most of these settlements either remained stable or declined in population. In addition, a number of *ranchos* which are only temporarily inhabited are scattered around the *ejido* and are used as a base for agricultural or animal husbandry activities. The locations and names of a total of 79 *ranchos* and abandoned villages were recorded during the field study (Figure 4.1a).

Physical environment

Geologically, Quintana Roo is part of a limestone platform which constitutes the Yucatan peninsula (Figure 2.1). The karstic environment is characterized by thin, limestone-derived soils (mostly lithosols and rendzinas in X-Maben), and a system of underground drainage systems and sinkholes (Flores and Espejel Carvajal 1994). In X-

Maben, average annual temperatures are approximately 26°C, while average annual precipitation ranges from 1200-1500 mm/year (Instituto de Geografía 1990), with a marked dry season occurring from January to April.

The vegetation in X-Maben is generally described as medium semi-deciduous tropical forest (*selva mediana subperrenifolia*) in the Mexican classification system, with a maximum stature of approximately 15 m. Approximately 25% of the foliage is shed in the dry season, and forests are dominated by the canopy species *Brosimum alicastrum* Swartz and *Manilkara zapota* (L.) Van Royen (Flores and Espejel Carvajal 1994, Pennington and Sarukhán 1998). Several inundated vegetation types are found in small extensions, on gley soils particularly in the eastern part of the *ejido*. In the local Maya classification of forest types, three main types of upland vegetation are recognized: **yáax k'áax**, **k'an lu'um k'áax** and **laaj kaj**. These are identified mostly by their species composition, although they also differ in stature and phenology (Table 4.1).

Land-use and economic history

The principal and most longstanding land-use practice in the Maya Zone of Quintana Roo is a traditional system of shifting cultivation (or swidden-fallow agriculture) known as the “milpa”, which is based on a polyculture of maize, beans and squash. Fields are typically felled from various ages of secondary to mature forests, burned, and cropped for 1-2 years, and then left to fallow. Milpa has a high cultural and symbolic value for the Maya communities (Re Cruz 1996, Villa Rojas 1992), and nearly all households in X-Maben still participate in this activity. Most families also produce small livestock and a variety of edible, medicinal plants in homegardens, while hunting, as well as the gathering of a variety of wild plant resources are practised in milpa, fallows and forests.

Since the early 20th century, one of the main sources of cash income for Maya communities in Quintana Roo has been the sale of *chicle*, the latex of one of the dominant forest species, *Manilkara zapota*, which is used as the basis of natural chewing gum. The international *chicle* market underwent a boom in the 1920s-1940s during which time Quintana Roo was the principal producer. Since then, the market has

declined; however some Maya households in X-Maben still participate to some degree in chicle tapping.

Since the early 1970s, construction of roads and greater integration into national life have opened up new economic opportunities, including small-scale commercial activities, wage labour, and sale of handicrafts, and honey (Hostettler 1996, Sullivan 1987). In X-Maben, some households engage in commercial production of horticultural crops such as cilantro, radish and chile and of citrus fruits, especially those with access to plots in the “corredor frutícola” near Señor, an irrigation project started in the early 1990s. Cattle ranching also occurs in the study area but apart from government sponsored project which managed a 1000 ha pasture from about 1968 to 1978, this activity is now practised on a small-scale by a few households. In terms of land-area, cattle ranching and horticultural production are thus not very important in the study area, in contrast to some other regions of the Yucatan peninsula such as southern Quintana Roo where these are major driving forces of land-use change (see Klepeis and Vance 2003).

X-Maben has participated in the PPF since 1986, forming part of a second-level organization called the *Organización de Ejidos Productores Forestales de la Zona Maya* (OEPFZM), which provides technical support. Commercial forestry activities in X-Maben have focused on extraction of precious timbers (mahogany and Spanish cedar) and production of railroad ties derived from tropical hardwoods (Merino Pérez 1997).

Methods

Interviews on land-use regulations

Forest conservation regulations in X-Maben were documented in two ways. First, familiarity with land-use practices was gained through participant observation and informal discussions with various men and women during 12 months (between June 2002 and April 2004) of field work and residence in the main village Señor by the first author (SPD). During this period a conversational fluency in Yucatec Maya was attained and the main elements of land-use practices and regulations were identified. Second, in order to better establish the chronological sequence of land-use agreements, a series of

semi-structured interviews were conducted with 10 of the men who served as presidents of the *ejido* assembly from 1967 to 2004. *Ejido* presidents each serve a 3-year term and preside over all assembly meetings where collective decisions are made. All internal complaints or denouncements about land-use are fielded by the *ejido* president, who also serves as the primary interface between the *ejido* and most government and other external agencies. Interviews with all past *ejido* presidents facilitated the development of a historical perspective of the land-use regulations and interactions with outside organizations.

Interviews were carried out with the help of a local assistant in either Maya or Spanish, though Maya terms were always used for discussing forest types. Each president was asked about land-use regulations and how they were introduced (through internal initiative or via external interventions), milpa practices and community-level projects which existed during his three-year term. In addition, we asked the president to recall all accusations of land-use infractions which he fielded and how they were resolved. A synthesis of the land-use regulations was developed by comparing interviews among the 10 presidents and supplemented with information from informal discussions and observations.

Participatory mapping

A series of participatory mapping exercises were carried out in October and November 2002, in order to identify the location of settlements and ranches, chicle harvesting areas, and forest reserves. Three workshops with 8-10 participants were held in which the approximate locations of these elements were identified on a base map derived from digital orthophotos obtained from the Instituto Nacional de Estadística Geografía e Información (INEGI - Aguascalientes, Mexico). Coordinates for all settlements and ranches were then obtained with a geographical positioning system (GPS) in the field with the help of a person familiar with each site, and approximate dates of occupation were recorded. Due to their remoteness, most chicle harvesting areas were estimated from the base map only.

Land cover maps

To examine changes in forest and agriculture land covers in X-Maben, a time series of land cover maps (including milpa, fallows and forest land covers) were developed based on Landsat satellite images from 1976, 1988, 1997, and 2000 (Table 4.2). In addition, a map of the location of milpas only was developed for 1991 (Table 4.2).

Image processing

All image processing was carried out with the program ENVI v. 3.5 (Research Systems Inc., Boulder, Colorado, USA). The images were all georeferenced with respect to a Landsat7-ETM image from April 21, 2000 with a 30x30 m pixel size², achieving a root mean square of near 0.5 pixels (Table 4.2).

The 1976, 1988, 1997 and 2000 images were classified using a supervised maximum likelihood algorithm. Training sites were identified using an unsupervised classification (ISODATA method in ENVI) of each image, in which spectrally homogeneous groups of pixels could be identified. A separate set of training sites was identified for each image. Interpretation of the land covers/land-uses associated to each of these training sites was made by comparing the unsupervised classification to several data sources. These included: (1) 468 GPS points taken in different vegetation types in X-Maben between June and December 2002; (2) a series of 6 colour aerial photographs taken during the National Forest Inventory of Mexico in November, 2000, covering an area of approximately 4.5 km² each; and (3) nine black and white digital orthophotos (from 1998 and 2000) obtained from INEGI (Aguascalientes, Mexico), which together cover the entire *ejido*. Field interpretation of the land cover associated to each GPS point as well as that of the colour aerial photos were performed with local assistants from X-Maben very knowledgeable of the land-use history of the sites. Detailed information on the history of 26 milpas used as sites for vegetation sampling in Chapter 5 was also employed.

² This last image had been georeferenced using topographic maps in the context of the 2000 National Forest Inventory of Mexico.

Once associated to a given land-cover, the separability of the training sites for each image was tested using the Jeffries-Matusita, and the Transformed Divergence indices. For each image, training sites with very low separability (<1.0) were combined, while those with moderate separability were revised in order to improve their separability. In general, we aimed for a separability >1.9 ; however in some cases separabilities could only be improved to 1.7. The final set of training sites defined for each image was then used in a maximum likelihood supervised classification.

The following land-cover classes were identified for the 1976, 1988, and 1997 images: Open water, wetlands, agricultural fields and open areas, young fallows (2-9 years), secondary forests (10-25 years), burned forests (less than approximately 5 years of having been burned), and mature forests >25 years. For the 1976 and 1997 images, two types of mature forests were identified: (1) more deciduous forests, including **k'an lu'um k'áax**, and (2) more evergreen forests, generally corresponding to **yáax k'áax** in the local classification. It was not possible to distinguish these two forest types for the 1988 image since it was taken at the end of the rainy season when the deciduous trees had not yet shed their leaves. For 2000, the same land cover categories were identified as for 1997 and 1976, with the exception that young fallows ranged from 2-5 y in age, and the older fallows from 6-25. The 1991 image, for which only the cover of milpa/open areas was extracted, was subjected to an unsupervised classification (ISODATA). The spectral classes from the ISODATA corresponding to milpas were identified, and this land class was extracted. Finally, a two-stage "majority analysis" was conducted to first remove unclassified pixels as well as isolated pixels of any land cover class in all images.

Accuracy assessment

During 2 weeks in April, 2004, a ground verification of the most recent image (2000) was conducted. We employed a stratified sampling design based on accessibility to randomly select a total of 27 sites to be verified. In each of the sites, four points were sampled, in the form of a 270 x 270 m square. At each sampling point, we drew a sketch map of the land covers observed in a 180 x 180 m area centred around a single pixel (30x30 m). This design provided land cover information for a total of 108 pixels.

For each land cover, we estimated its condition in 2000. For example, for a site that was a 2-year old fallow in 2004 we would have estimated the age of the vegetation felled in 2002, and subtracted two years to estimate the age in 2000. The vegetation felled was estimated by the size of stumps and of trees spared in the field, and of the surrounding vegetation. Additional notes were taken on the type of substrate and variation in the vegetation cover (e.g. large gaps or patches of less dense or shorter vegetation) for each sampled pixel.

Results were analysed using a fuzzy analysis (Gopal and Woodcock 1994), in order to account for ambiguities in class assignments. This occurred mostly at the threshold between land cover classes, due to uncertainties in estimating the age of sites in the field, which we considered to increase with the age of the site. Therefore, we calculated a probable age range for each land cover, allowing ± 1 y for sites estimated at ≤ 3 y in age, ± 2 y for sites 3-15 y in age, and ± 4 y for sites ≥ 18 y in age. Sites estimated in the field to have been a milpa in 2000, were considered correctly classified if the map classification corresponded to “milpa” or to the age that was estimated to have been felled. In addition, in the case of pixels noted to have more than one land cover class, alternative “correct” answers were also accepted for secondary land cover classes covering $> 30\%$ of the pixel. Finally, where species composition was considered to be intermediate between **k’an lu’um k’aax** (deciduous forests) and **yáax k’áax** (evergreen forests), either of these map classifications was accepted as correct. This fuzzy analysis was compared with a conventional “crisp” analysis (Stehman and Czaplewski 1998), in which the reference category was taken to be the majority land cover estimated for the pixel in the field. For both analyses, formulae for calculating overall accuracies and associated confidence intervals for stratified samples were employed (Stehman 1995). To calculate confidence intervals for user’s and producer’s accuracies, a bootstrap method (Efron 1981) was used, following the script for MATLAB provided by Caswell (2001, p. 318).

The overall accuracy using the fuzzy criteria was 0.81 (s.e.=0.04), while user’s accuracies ranged from 0.71 for milpas to 0.91 for evergreen (**yáax k’áax**) forests (Table 4.3). The results for burned forests and for wetlands are inconclusive due to the small sample size (n=2). Compared to the crisp analysis, the fuzzy analysis improved user’s

accuracies substantially for the classes milpa, young fallow, old fallow, and for **k'an lu'um k'aax** forest (Table 4.3). This indicates that a large proportion of the errors are due to ambiguities at the threshold between classes. Closer examination of the pixels remaining misclassified in the fuzzy analysis (mostly young fallows and secondary forest), suggested that approximately half of these might be due to errors at the boundary between different land classes, while the other half appear to be broader “threshold errors” than accepted in our fuzzy analysis. In combining young fallows with secondary forest, and the two mature forest classes, an overall accuracy of 0.91 (s.e.=0.05) was achieved. In the analyses on land cover change described below we combined classes as much as possible, to minimize the errors described.

Spatial analysis

Analysis of land cover images were carried out in IDRISI version 132.22 (Clark Labs, Worcester, Massachusetts) and Arcview 3.3 (ESRI Inc., Redlands, California, USA).

To examine patterns of agricultural expansion, forest maintenance and forest recuperation, transitions were calculated between agricultural cover and forest cover. In this analysis “agricultural” combines milpa/open areas, young fallow and secondary forest, whereas “forest” includes mature forest and forest burns. Areas under cloud cover, water and inundated areas, as well as urban and built areas were excluded from this analysis.

A chi-square test was used to compare the amount of **yáax k'áax** forests vs. **k'an lu'um k'áax** forests which were converted to “agricultural use” in the 1976-1988 period vs. the 1988-1997 period. The land cover class for 1976 was used to determine if forests later converted pertained to **k'an lu'um k'aax** or **yáax k'áax** forests. The statistic was calculated based on a 500 x 500 m stratified random sample of pixels.

To examine changes in the agricultural landscape, an accessibility index, representing the ease of access from Señor was developed. This was done in order to identify the areas most likely to be used for agriculture by the population of Señor, where most of the *ejido* population resides. To do this, an accessibility surface was created using the cost distance analysis module (COST) in IDRISI. We assumed travel by

bicycle along roads of approximately 12km/h, and travel by foot at a rate of 4 km/h along paths from these major roads. Separate access maps were created for two time periods (1976 and 1988/1997), taking into account the different road networks during these two periods. The maps were divided into access zones, such that zone 1 corresponds to approximately <30 minutes of travel, zone 2 from 30-60 minutes of travel, and zone 3 from approximately 60-90 minutes of travel.

To examine changes in the diversity of land covers, a dominance index was used. Dominance indices are used to express the extent to which an area is evenly distributed among land cover classes (representing low dominance), or dominated by one or a few classes (high dominance). Here we use a dominance index defined as

$$D = \frac{\ln(S) + \sum [p_i * \ln(p_i)]}{\ln(S)}$$

where S is the number of cover types, and p_i is the proportion of a given land cover class (i) (Cardille and Turner 2002). This index has a maximum value of 1 (indicating complete dominance of a land cover class) and a minimum of 0, indicating an even balance among land cover classes.

To analyze changes in the distribution of milpas, the milpa/open area category from 1976, 1991 and 2000 was vectorized in IDRISI and exported to Arcview. In Arcview, each milpa/open area layer was edited to remove all polygons corresponding to villages, other built areas, or pastures. In addition, all polygons less than 1 ha in coverage were eliminated, in order to avoid confusion with tree-fall gaps or other disturbances. These coverages were then imported back into IDRISI. To examine changes in fallow times, milpa coverages from 1991 and 2000 were overlaid with land cover classifications from 1988 and 1997 respectively, thereby obtaining an estimate of the amount of milpa coverage which was derived from different successional stages.

Results

Locally recognized forest conservation regulations

Interviews with the *ejido* presidents and field observations indicated the existence of several kinds of forest conservation regulations in X-Maben which restrict lands

available for agriculture (Table 4.4). These are: (1) restrictions on felling certain forest types for agriculture, with emphasis on the tree composition, and (2) specific forest patches or reserves which are protected from agricultural conversion, independent of their species composition. These include both *ejido* initiatives and programs promoted by non-governmental organizations (NGOs) and the federal government.

Restrictions on forest types

Restrictions on the type of forest allowed to be felled are meant to protect forests with high densities of economically important species. According to the *ejido* presidents, an agreement to protect dense stands of *Manilkara zapota* for chicle collection was made by the *ejido* assembly in the early years of the *ejido* (ca. 1955). *Brosimum alicastrum*, a canopy tree whose leaves are used for forage for horse and cattle, was also reported to be protected, although presidents only recalled denouncements for felling chicle. The first sales of commercial timber in X-Maben were reported to have occurred during the 1970-1973 period, and *ejido* presidents from the early '80s onwards specifically recalled denouncements for felling sites with the two most valuable species – mahogany (*Swietenia macrophylla*) and Spanish cedar (*Cedrela odorata* L.). Areas with high densities of other tropical hardwoods sold by the *ejido* (mainly as railroad ties) were reported to have become of increased concern to the ejidatarios in the 1990s, with one conflict over such an area having been reported in the 1997-2000 period.

A further restriction on forests permitted to be felled for agriculture was reported to have been introduced in 1994 when the PROCAMPO (Programa de Apoyo Directo) program was initiated. This is a federal program providing direct payments to poor farmers with the goal of facilitating transition to neoliberal policy adjustments to the agricultural sector (resulting from the North American Free Trade Agreement) (Klepeis and Vance 2003). According to the local interpretation in X-Maben, the payments available through this program are only for milpas felled from young fallows and secondary forests. Felling of “monte alto” (Spanish for “high forest”) is not allowed, and farmers felling mature forest would risk losing their PROCAMPO payment (worth 1030 pesos per hectare in 2003).

In Maya, “monte alto” translates literally as **nukuch k’áax** and was reported to be synonymous with **yáax k’áax** (evergreen forest). In this view, the “PROCAMPO” regulation does not refer to the more deciduous **k’an lu’um k’áax** which is permitted to fell. In addition, people in X-Maben reported that old fallows known to have been used in living memory for agriculture are also permitted to fell, even if they are **yáax k’áax**. Therefore, locally, it is perceived that farmers risk losing their PROCAMPO support if they fell mature **yáax k’áax**. However, the species protected by earlier *ejido* agreements (*Manilkara zapota*, *Brosimum alicastrum*, *Swietenia macrophylla*) are all associated with **yáax k’áax**. Thus, the local interpretation of the PROCAMPO program is an extension of the logic already in place which accorded more value to **yáax k’áax** forests.

Community reserves/protected areas

Three different types of community reserves exist in X-Maben: (1) customary village reserves, (2) a “permanent forest area”, declared as part of the PPF and (3) reserves resulting from other government interventions.

The village reserves are patches of forest which surround each village. They are referred to in Maya as **jal pach kaaj** (literally “the edge behind the village”), and are important sources of many forest products used for domestic purposes, such as firewood, poles and beams for construction, thatch, etc..

The permanent forest area or PFA is a reserve intended for commercial forest management which was established in *ejidos* throughout Quintana Roo as part of the Plan Piloto Forestal. *Ejido* assemblies were encouraged to prohibit agricultural activities in these areas which would form the basis of a management plan for mahogany with a 25-yr rotation cycle. In X-Maben the PFA is estimated by the OEPFZM to consist of 40,000 ha. However, as discussed by Merino Pérez (2004, p. 158) for other *ejidos* in the area, the PFA has not been delimited on the ground, and has only become a physical reality as rotation blocks have been successively harvested. A sketch map prepared by the OEPFZM of the area showing the 25-year rotation plan for timber harvesting, is shown in Figure 4.1b.

Two reserves in X-Maben exist as a result of additional government programs. The first is referred to as the “COPLAMAR” reserve. This is an area of secondary forest

and fallows that in the 1980s was the focus of a reforestation project (consisting mostly of enrichment plantings of commercial timber species) funded by a government program called COPLAMAR (Hostettler 1996, Sullivan 1987). Subsequently the *ejido* assembly agreed to prohibit felling of the COPLAMAR area, which is now used in much the same way as the **jal pach kaaj**. The second, most recent reserve is an area of approximately 100 ha located at the edge of a large lake in the *ejido*. This was established in 2001 in the context of a government-supported ecotourism project and is the only reserve in which most forms of extraction and hunting are prohibited.

Landscape changes (1976-2000)

Overall land cover changes

Overall statistics on land cover (Figure 4.2) reveal a landscape dominated by mature forest cover, having decreased slightly from 80% in 1976 to 76% in 1997. Other land cover categories which decreased include forest burns, and milpa/open areas. Young fallow and secondary forest increased more than twofold during the 21-year period.

Change statistics (Table 4.5) indicate that 79% of the area under forest cover in 1976 (55,349 ha) remained as forest in 1988 and in 1997. The annual rate of agricultural expansion (transition from “forest” to “agricultural”) increased slightly from the 1976-1988 period to the 1988-1997 period (702ha/1y to 858 ha/y), as did the annual rate of forest recuperation (312 to 407 ha/y). Expressed as a percentage of the original forest cover, this corresponds to a net annual transition of “forest” to “agriculture” of 0.6% in the first time period, and of 0.7% in the second.

Figure 4.3 shows the spatial distribution of transitions across the 21-year period. Visual examination reveals most zones of permanence of the agricultural zone concentrated around the biggest village, Señor. Important areas of agricultural expansion occurred along the road to San Antonio, and around San Antonio, particularly in the 1988-1997 period. Forest recuperation tended to occur in areas far from the larger villages, whereas forest recuperation from 1976-1988 reverting to agricultural use in the 1988-1997 period, occurred primarily within the 1000 ha government-sponsored cattle pasture to the southwest of Señor, which was abandoned in the 1970s.

A significant difference ($X^2=16.2$, d.f.=1, $p<0.001$) was found between the 1976-1988 period and the 1988-1997 in the amount of **yáax k'áax** (more evergreen forests) and **k'an lu'um k'áax** (more deciduous forests) which were converted to agricultural land-covers (milpas and fallows < 25 y). In the first time period, 57% of agricultural expansion was due to conversion of the more evergreen **yáax k'áax** to agricultural land-covers, whereas only 38% of this forest type was converted in the 1988-1997 period.

Changes in the agricultural landscape

We examined changes in the agricultural landscape by analyzing land covers in three accessibility zones, representing < 30 (zone 1), 30-60 (zone 2) and 60-90 (zone 3) minutes of estimated travel time from Señor. These three zones comprise most of the areas used for agriculture by people in Señor, as well as several of the other villages. The accessibility maps reveal an increase in accessibility from 1976 to 1988 due to the construction of a new road linking Chan Chen Comandante to San Antonio in the early 80s, with zone 1 increasing in size by 19%, zone 2 by 26% and zone 3 by 40%. In the second period, access remained largely unchanged.

Figure 4.4 shows changes in the proportion of the three access zones in four land covers: milpa, fallow, secondary forest, and mature forest (including forest burns). These data show a much more drastic picture of change in the landscape, as opposed to the data for the entire *ejido*. In the most accessible zone for example, forest cover declined from 38% in 1976 to 25% in 1988 and to only 10% in 1997. In the intermediate and far zones, mature forest cover declined from 64% to 24%, and from 86% to 63%. These decreases in forest cover were matched by an increase in the proportion of young fallows in all zones, across both time periods. On the other hand, secondary forest increased continuously in the third accessibility zone, but only in the first time period (1976-1988) in for the two most accessible zones.

In 1976, the three accessibility zones differed substantially in the degree of dominance, with zone 3 being dominated ($D=0.6$) by forest, and zone 1 having a nearly even distribution among the four land cover classes ($D=0.03$) (Figure 4.5). However, by 1997, the dominance in zone 1 had increased, with young fallows being the dominant class ($D=0.24$). On the other hand, dominance in zone 3 had decreased to nearly the

same level as zone 1 ($D=0.29$), having higher proportions of young fallow and secondary forest, although still having mature forest as the most important class.

Finally, examination of the land-cover data (Figure 4.6) reveals that certain forest patches have been conserved despite being accessible, suggesting that the community regulations in X-Maben have resulted in active conservation. The 10% of forest left within the first accessibility zone for example, includes the village reserves around Señor and Chan Chen Comandante, as well as the area corresponding to the COPLAMAR reforestation project. In this latter case, the area consists of mature forest in 2000 that regenerated from secondary forest. In the second accessibility zone, patches of conserved forest include two areas of **yáax k'áax** forest, used for chicle harvesting and logging. In one case the area is within the area designated by OEPFZM as PFA, in the other it is not.

Changes in milpa distribution and fallow times

The map of milpas from 1976, 1991 and 2000 (Figure 4.7) reveals a similar distribution across the three years. In 1976, milpas are more isolated from one another and in a few areas in the north and northeast of the *ejido*, extend beyond the distribution of milpas in subsequent years. New areas of milpa activity in 1991 and 2000 are evident along the road to San Antonio, and around San Antonio. In general, the distribution of milpas within the area corresponding to the permanent forest area (Figure 4.1b) is largely unchanged with milpas being clustered around a few settlements and ranchos. However, in a few cases in the central-southern part of the *ejido*, some ranchos were abandoned, and milpa activity has ceased.

Results on fallow times reveal a similar proportion in milpa area being derived from young fallow, secondary forest and mature forest in the two periods (Table 4.6), although the total area under “milpa” in 2000 is nearly half of that in 1991. In addition, a larger proportion of milpa in 1991 is derived from “milpa and open areas” in 1988 (12.5%) as opposed to the 1997-2000 period (2.7%).

In examining the distribution of these different fallow times among the three accessibility zones, greater differences are encountered between the two periods. In the first two access zones, a decrease in the proportion of milpas being felled from mature

forest with a concomitant increase in those felled from young fallows and secondary forest is observed (Figure 4.8). This trend parallels changes in the accessibility of mature forest in these two zones. On the other hand, in the third zone, there is an increase in the proportion of milpa from mature forest (51% in 1991 to 61% in 2000).

Discussion

The case study of X-Maben reveals relatively high rates of forest retention. The net annual rate of forest loss of 0.6-0.7% is lower than that for other inhabited landscapes in Mexico (ranging from 1-4%), and is only slightly higher than annual rates of forest loss (0.3-0.4%) reported for regions having protected areas at their core (Bray et al. 2004). At the same time, the approach adopted here reveals that this trend of forest conservation is shaped by a variety of community rules and regulations, and has also been accompanied by significant land-use/land cover changes in the agricultural landscape. These two points and their implications for community conservation in Quintana Roo and elsewhere are discussed in the sections that follow.

Interaction of internal and external rules and regulations

The motivations of local people to maintain forest patches have not often been studied (Browder 1996), nor have community institutions been considered much in land-use/land cover research. Here, the joint analysis of conservation regulations with the quantitative analysis of land-use/land cover change reveals that the patterns of forest conservation in X-Maben reflect a variety of land-use regulations resulting both from internal *ejido* initiatives as well as interaction with external organizations.

Internal ejido regulations

The internal conservation regulations have mostly been motivated by a desire to protect certain forest products, especially chicle which historically has played an important role in the local economy since the 1920s. The long-standing importance of chicle in influencing land-use practices is evident in both our spatial analysis, as well as in our data on the land-use regulations. For example, the *ejido* agreement prohibiting felling dense stands of chicle was reported to have been made in the 1950s, and

denouncements in the *ejido* assembly and *ejido* sanctions against people felling chicle and mahogany stands were reported for periods between 1970 and 1984. The spatial data indicates the conservation of even some accessible forest patches with important chicle stands. Furthermore – and perhaps more importantly – our spatial data reveals that a large portion of the area with stable mature forest corresponds to chicle harvesting areas. These results suggest the active protection of chicle and other valuable commercial species prior to the initiation of the PPF in the mid-1980s.

The **jal pach kaaj** (or village reserves) are the second main internal conservation regulation we documented. These are protected mostly due to their value for subsistence activities, such as collection of firewood and other forest products, and also to protect nearby milpas from free-roaming domestic animals (especially pigs). The **jal pach kaaj** is a common pattern of land-use in Maya communities in Quintana Roo (field obs., Beck and Cruz Cáceres 2001). Although the **jal pach kaaj** represent small areas, they are significant in that together with the COPLAMAR reforestation area (discussed below), they are now the only patches existing in the most accessible areas of the *ejido*. Despite this, Señor's **jal pach kaaj** has been gradually reduced (from 246 ha in 1976 to 88 ha in 2000) due to expansion of the village, as well as encroachment of the surrounding agricultural area.

External interventions

External interventions which have influenced forest conservation practices in Señor include the Plan Piloto Forestal, PROCAMPO, and several reforestation projects. However, in all three cases, these programs have interacted with local perceptions and institutions which have influenced their interpretation and implementation.

Plan Piloto Forestal

The main conservation impact of the Plan Piloto Forestal is generally considered to be the establishment of the permanent forest areas (PFAs), which in the case of X-Maben represents more than 50% of the *ejido* territory. According to Bray et al. (2004), the PFAs “effectively created a fixed ‘internal agricultural frontier’ in each *ejido*, forcing slash and burn agriculture to operate within more confined areas” whereas before then

“farmers in Central Quintana Roo were free to roam throughout the *ejido* in search of good soils, while leaving stands of chicozapote”. However, our findings indicate that the area declared as the PFA in X-Maben largely corresponds to chicle harvesting areas, and as discussed above, active community agreements and institutions aimed at conserving chicle areas existed prior to the initiation of the PPF in 1986. Furthermore, interviews with OEPFZM staff in 1989 (Murphy 1990, p. 154) indicate that the area defined as the PFA largely corresponded to regions traditionally protected for chicle harvesting. Our data also indicates a relatively constant distribution of milpa activities since the 1970s suggesting that the establishment of the PFA did not represent a change in land-use pattern. Indeed, limited milpa activities still continue within the PFA in areas near rich **laaj kaj** soils, and near old ranches. In this sense, it is likely that the history of chicle extraction and corresponding institutions protecting chicle stands facilitated the implementation of the PFA, which essentially built on a pre-existing land-use pattern. Thus, rather than introducing a new pattern of land-use, we suggest that the main influence of the PPF has probably been to have provided economic benefits from a wider range of forest products (especially precious timbers and tropical hardwoods), thereby increasing incentives for the maintenance of forest cover in a large part of the *ejido*, which previously was mostly protected for chicle.

PROCAMPO

The PROCAMPO program which – at least according to the local perception – provides support only for milpas not felled from “monte alto” (and specifically **yáax k’áax** or evergreen forests) is a second example of interaction of an external program with local perceptions and institutions. Interestingly, official documents of the PROCAMPO program do not indicate any such requirement (e.g. SAGARPA 1995). Rather, PROCAMPO payments, which are made on a per hectare basis, are supposed to be restricted to land under permanent cultivation only. This condition is intended to alleviate pressure on forested lands, as farmers were expected to use the support to intensify production (Klepeis and Vance 2003). However, in X-Maben, where nearly all agricultural production is based on shifting cultivation, this condition appears to have been applied by encouraging farmers to shorten fallow times.

Although we do not have any specific information on how PROCAMPO officials implemented the program locally (for example, did they specifically state that “monte alto” should not be felled or was this an interpretation of the local farmers?), what is clear is that for the local farmers “monte alto” refers to a particular locally-recognized forest type, namely the more evergreen **yáax k’áax**, associated with valuable tree species. On the other hand, **k’an lu’um k’áax** can still be felled. Our land-cover data demonstrates that this distinction has allowed continued agricultural expansion on mature forests, which occurred significantly more on **k’an lu’um k’áax** forests in the 1988-1997 period, as compared to the 1976-1988 period. Therefore, recognition of the local forest classification and associated values is important for understanding the land-use/land cover dynamic, and how external programs are interpreted at a local level. However, this has rarely been taken into account in land-use/land cover research.

According to many men in the village, the introduction of the PROCAMPO program is when it “really” became prohibited to fell “monte alto”, and most expressed that current regulations protecting the evergreen **yáax k’áax** forests are now more strict than regulations in the past that only pertained to chicle. In X-Maben PROCAMPO therefore appears to have reinforced community institutions which protect this forest type. This is an interesting contrast with Klepeis and Vance’s (2003) findings for colonist communities in southern Quintana Roo which indicate that the PROCAMPO program led to increased deforestation as households dedicated more land to cattle pasture and commercial crop production (especially chile). While here we have not examined PROCAMPO’s effect on land-use decision at the household level, our findings suggest that this program may have been implemented and/or interpreted differently in these two regions, highlighting the need to evaluate variation in the impact of government programs in different cultural and socio-economic contexts.

Reforestation projects

The first formal reforestation project in X-Maben (COPLAMAR) led to the regeneration of a 100 ha patch of secondary forests to mature forest in the 1988-1997 period. This is significant in that it shows that the *ejido* agreement to protect this area was maintained well after the end of the COPLAMAR project in the 1980s. In recent

years, government and NGOs in Quintana Roo have promoted additional reforestation efforts of commercial timber species in abandoned fallows. The COPLAMAR experience suggests that this might lead to regeneration of a greater number of forest patches within the agricultural areas.

Changes in the agricultural landscape

The second main finding of our study is that the high rates of forest conservation in X-Maben have been matched by important changes in the agricultural landscape. The areas most accessible to the majority of the population have shifted from being a diverse mosaic of young to old successional stages in 1976, to a much more homogeneous landscape dominated by younger fallows and shorter fallow periods in 1997/2000. Although our finding that the proportion of area of milpa derived from mature forest has not changed in 2000 as compared to 1991 suggests continued availability of mature forests for agriculture (mainly the deciduous **k'an lu'um k'áax** and old fallows), the distance to these sites has increased, and most of the more accessible areas of mature forests available for agriculture (principally along the road to San Antonio) have been felled.

Restrictions on lands available for agriculture and forest conservation have certainly contributed to these landscape changes. For example, forests available for agriculture have been reduced by the conservation of certain forest patches in more accessible areas. In addition, productive activities in more distant areas is largely restricted to *ranchos* where old fallows or **k'an lu'um k'aax** are available.

At the same time, it is clear that other factors have also contributed to increased pressure in the accessible areas. Most evident is the settlement pattern which has increasingly become concentrated in the largest village, Señor, while other settlements in the *ejido* were either stable, declined in population, or even abandoned. Since the 1970s Señor has also become much more urbanized, offering services, educational opportunities, and a number of off-farm employment opportunities that are not available in the smaller villages and ranchos. This has prompted migration of many people from the smaller settlements creating greater demographic pressure in areas near Señor. Furthermore, increased allocation of time and labour to non-agricultural activities by

families in Señor means that many families are no longer willing to travel long distances to the milpa (Dalle et al. 2004). These changes, in combination with the restrictions on agricultural land-use resulting from conservation have led to a progressive concentration of young fallows and shorter fallow times in the most accessible areas.

In more general terms, the increased pressure on the agricultural areas brings into question the potential for maintaining a balance between milpa agriculture, forest conservation and commercial forest product extraction. For example, the current trend in landscape change may have a negative impact on the availability of certain plant resources important to the domestic economy, particularly those found in older forest patches and/or milpas with long fallow cycles, both of which have become more scarce in the immediate landscape. Moreover, milpas derived from longer fallow times have reduced weed loads (de Rouw 1995, Fujisaka et al. 2000, Staver 1991), and are often thought to produce better yields, although Mertz (2002) has discussed the need for more systematic tests of this latter assumption. Finally, from an ecological point of view, the reduced presence of mature forests within the agricultural landscape could affect processes such as seed dispersal of mature forest trees or those relying on bird dispersal (Guariguata and Ostertag 2001).

Conclusions

Community-based approaches attempt to achieve forest conservation within productive landscapes which are used and managed by people. Assessments of community-based conservation must therefore consider the complex interaction of people with the forest environment, including other land-uses, as well as the local perceptions and forms of organization which shape management practices.

The case study of X-Maben reveals that increased pressure on the agricultural areas has paralleled high rates for forest retention. Potentially, reduced benefits from agricultural habitats on the long-term could compromise incentives for forest conservation or negatively impact the livelihood of households most dependent on these environments. We suggest that greater attention should be paid to agricultural systems and their relationship to forest conservation programs by both researchers and organizations promoting community-based approaches. In particular, it is necessary to

identify the extent to which, and under what economic, social and cultural conditions, communities are willing to modify their agricultural practices in order to implement community-based conservation. Furthermore, management strategies aimed at integrating forest conservation with other land-uses should be explored.

Our findings also demonstrate that examining local perceptions of forest conservation is essential to evaluating trends in forest management and potential management strategies. For example, in X-Maben enrichment plantings of commercially important timber species have been protected by local regulations; this may represent an effective means to promote regeneration of older forest patches within the agricultural matrix. On the other hand, we found that current community forest conservation practices are focused on one locally recognized forest type, considered rich in valuable forest products. The distinction made between **k'an lu'um k'áax** and **yáax k'áax** forests in terms of forest conservation in Central Quintana Roo has not been previously reported, but may be relevant in other Maya communities in the region. No floristic studies have described these locally recognized forest types, however future research may want to address the significance of the less valued deciduous **k'an lu'um k'áax** for global biodiversity conservation, and the extent to which this forest type is represented within the PFAs or other protected forest patches.

Finally, the local perceptions regarding conservation, historical antecedents and community institutions described for X-Maben vary within the Mayan zone of Quintana Roo, and will certainly be different in other regions where community-based approaches might be promoted. This is an important consideration for the application of the PPF model to other contexts and it emphasizes the need for conservation strategies that build on a thorough knowledge of local institutions.

Table 4.1. Main vegetation types recognized in the local Maya classification in X-Maben.

Vegetation type	Characteristics
Yáax k'áax	Forest rich in a number of economic and useful species such as <i>Swietenia macrophylla</i> King, <i>Manilkara zapota</i> (L.) v. Royen, <i>Sabal yapa</i> C. H. Wright ex Becc., <i>Brosimum alicastrum</i> Swartz. Generally taller than k'an lu'um k'áax , and less deciduous. Translates as “green forest”.
K'an lu'um k'áax	Forest with many spiny plants, deciduous in the dry season, such as <i>Acacia pennatula</i> (Schldt. & Cham.) Benth., <i>Pithecellobium albicans</i> (Kunth.) Benth., <i>Mimosa bahamensis</i> Benth., and <i>Lysiloma latisiliquum</i> (L.) Benth. Translates as “forest of yellow/orange soils”.
Laaj kaj	Vegetation type associated with Mayan ruins. Literally translates as “old village”. High density of the cohune palm (<i>Attalea cohune</i> Mart.), and several other characteristic species, including many vines. Often deep organic black soils.

Table 4.2. Characteristics of satellite images used and results (root mean square, RMS) from the georeferencing operation (1st degree polynomial method with nearest neighbour resampling).

Date	Sensor	Pixel size (m)	No. bands used	RMS	No. points for RMS
February 12, 1976	Landsat 2-MSS	60x60	3	0.536	19
December 16, 1988	Landsat 4-TM	25x25	5	0.501	29
February 16, 1991	Landsat 5-TM	25x25	5	0.478	23
January 31, 1997	Landsat 5-TM	25x25	5	0.518	12
February 9, 2000	Landsat 5-TM	25x25	5	0.489	14

Table 4.3. Producer's accuracy (PA) and user's accuracy (UA) for crisp and fuzzy analysis of accuracy assessment.

Map class	n	<i>"Crisp" analysis</i>		<i>Fuzzy analysis</i>	
		PA	UA	UA*	
Milpa	8	0.222	0.142	0.714	(0.27-1)
Young fallow	23	0.556	0.689	0.83	(0.65-0.96)
Secondary forest	26	0.559	0.483	0.79	(0.61-0.93)
Evergreen forest	29	0.804	0.910	0.91	(0.81-0.98)
Deciduous forest	18	0.783	0.759	0.79	(0.50-0.98)
Wetlands	2	1.000	0.500	0.50	
Burns	2	n/a	0	0	

*Confidence intervals are indicated in parentheses.

Table 4.4. Summary of restrictions on lands available for *milpa* agriculture, according to interviews with *ejido* presidents (1967-2004).

Period	Action	Level
<i>1. Restrictions on Forest Types Permitted for Milpa</i>		
Ca. 1955-1960	Prohibited to fell ya'ax k'áax with high densities (e.g. 15/ha) of <i>chicle</i> trees. Written permit required from <i>ejido</i> president to burn the <i>milpa</i> .	<i>Ejido</i>
1979-1982	Milpas in areas with high densities of Mahogany denounced in <i>ejido</i> assembly.	<i>Ejido</i>
1988-1991	Farmers encouraged by the OEPFZM to fell younger secondary forest for <i>milpa</i> and to use fertilizer.	OEPFZM
1994	PROCAMPO Program. No support provided for milpas felled from "monte alto".	Federal government
1992-2004	<i>Ejido</i> presidents mention a wide variety of commercial timber species as protected.	<i>Ejido</i>
No date determined	Reforestation Program. Agricultural fallows with enrichment plantings of Mahogany, Spanish Cedar not permitted to be felled.	<i>Ejido</i> -OEPFZM Program
<i>2. Reserves/Delimited Areas Excluding Milpa</i>		
No date determined	Village Reserves. Areas of forest around several villages are prohibited to fell for <i>milpa</i> .	Customary/ <i>Ejido</i>
1980s	COPLAMAR reserve. Area of secondary forest enriched with timber and other economic species. Approximately 100 ha.	<i>Ejido</i> – COPLAMAR program
ca. 1986	Permanent forest area (community forestry). Area of 40,000 ha designated for timber management. <i>Milpa</i> prohibited, <i>chicle</i> and other extractive activities allowed.	<i>Ejido</i> -OEPFZM Program
2001	"Laguna Azul" Ecotourism Reserve. Area of 35 ha. <i>Milpa</i> , as well as hunting and timber extraction prohibited.	<i>Ejido</i> -Ecotourism Project

Table 4.5. Land cover change statistics for the periods 1976-1988 and 1988-1997.

Land cover change	1976-1988	1988-1997
<i>Agricultural expansion</i>		
Annual rate of conversion (ha/y)	702	858
Annual % of change relative to forest cover at t_1 *	1.0%	1.3%
<i>Forest recuperation</i>		
Annual rate of conversion (ha/y)	312	407
Annual % of change relative to agricultural cover at t_1	3.3%	2.9%
<i>Net mature forest loss</i>		
Annual % of change relative to forest cover at t_1	0.6%	0.7%
<i>Agricultural permanence</i>		
Hectares	5,737	10,504
% of agricultural cover t_1	60.5%	74.2%
<i>Forest permanence</i>		
Hectares	61,616	57,629
% of forest cover t_1	88.0%	88.2%
<i>Forest permanence 1976-1988-1997</i>		
Hectares	55,349	
% of forest cover t_1	79.0%	

* t_1 refers to the first year in each time period; for example, for the period 1976-1988, t_1 is 1976.

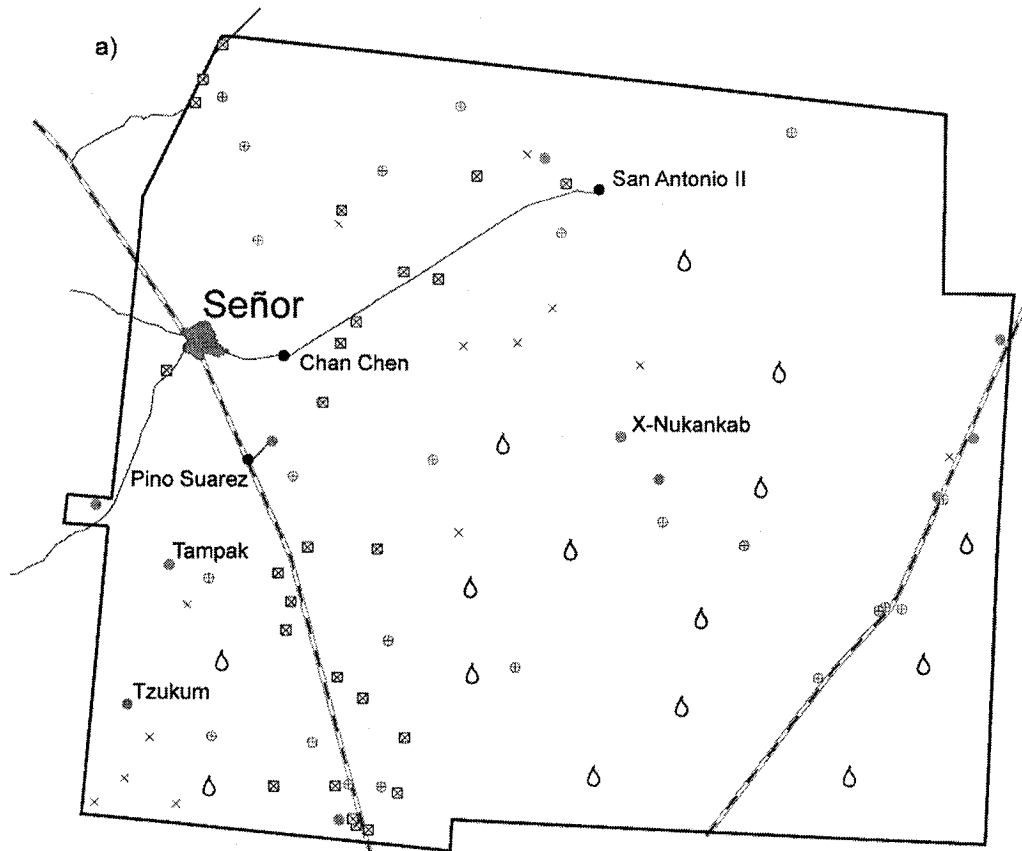
Table 4.6. Area of land classified as milpa in 1991 and 2000 felled from different successional stages, as estimated by land-cover in 1988 and 1997, respectively. This provides an estimate of the fallow lengths employed for milpas in the two time periods.

Land cover classification in t_1^*	Area classified as milpa in			
	$t_2=1991$		$t_2=2000$	
	ha	%*	ha	%**
Milpa/open area	160.1	12.5	19.0	2.7
Young fallow	262.6	20.5	173.3	24.3
Secondary forest	326.9	25.5	199.5	28.0
Mature forest	533.8	41.6	320.8	45.0
Other (clouds, etc)	12.1	---	3.8	---
TOTAL	1295.5		716.4	

* t_1 refers to the first year in each time period; for example, for the period 1988-1991, t_1 is 1988.

**% is with respect to total area of milpa excluding that derived from "other"

Figure 4.1. Maps of (a) Settlement patterns and chicle harvesting areas; and (b) the permanent forest area (indicated by the location of rotation blocks from 25-year timber management plan). The latter was adapted from the "Plano Plan de Corta, *Ejido X-Maben y Anexos*", OEPFZM, 2001.



Settlements

- Señor
- Village (>5 families)
- ⊙ Settlement (<5 families)
- ⊠ Rancho
- ⊕ Abandoned after 1960
- × Abandoned before 1960

Roads and boundaries

- Graded road
- Paved highway
- Ejido limits
- 💧 Chicle harvesting area



3 0 3 6 Kilometers

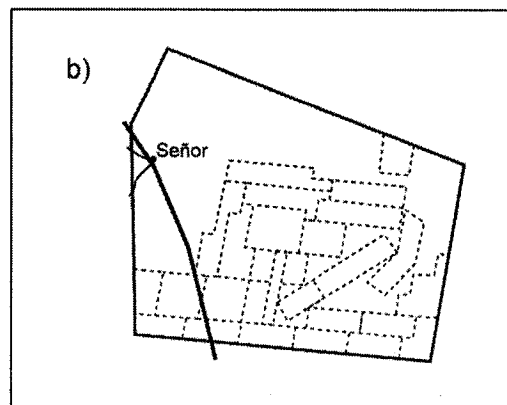


Figure 4.2. Change in proportion of ejido lands under different land covers from 1976 to 1997.

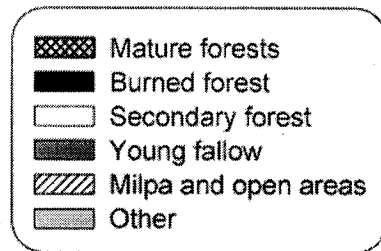
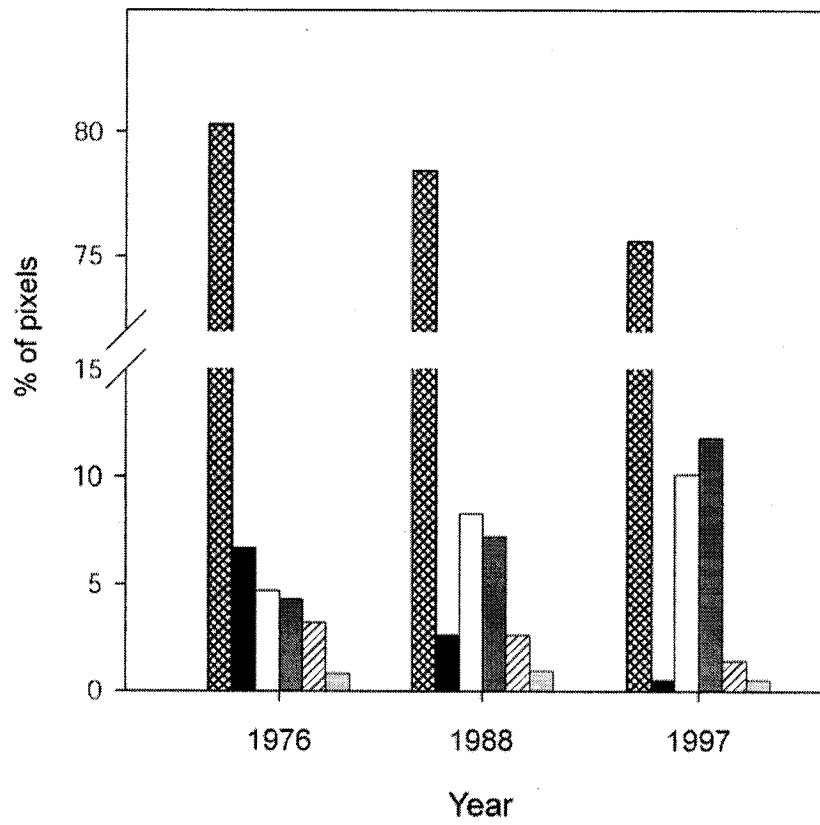
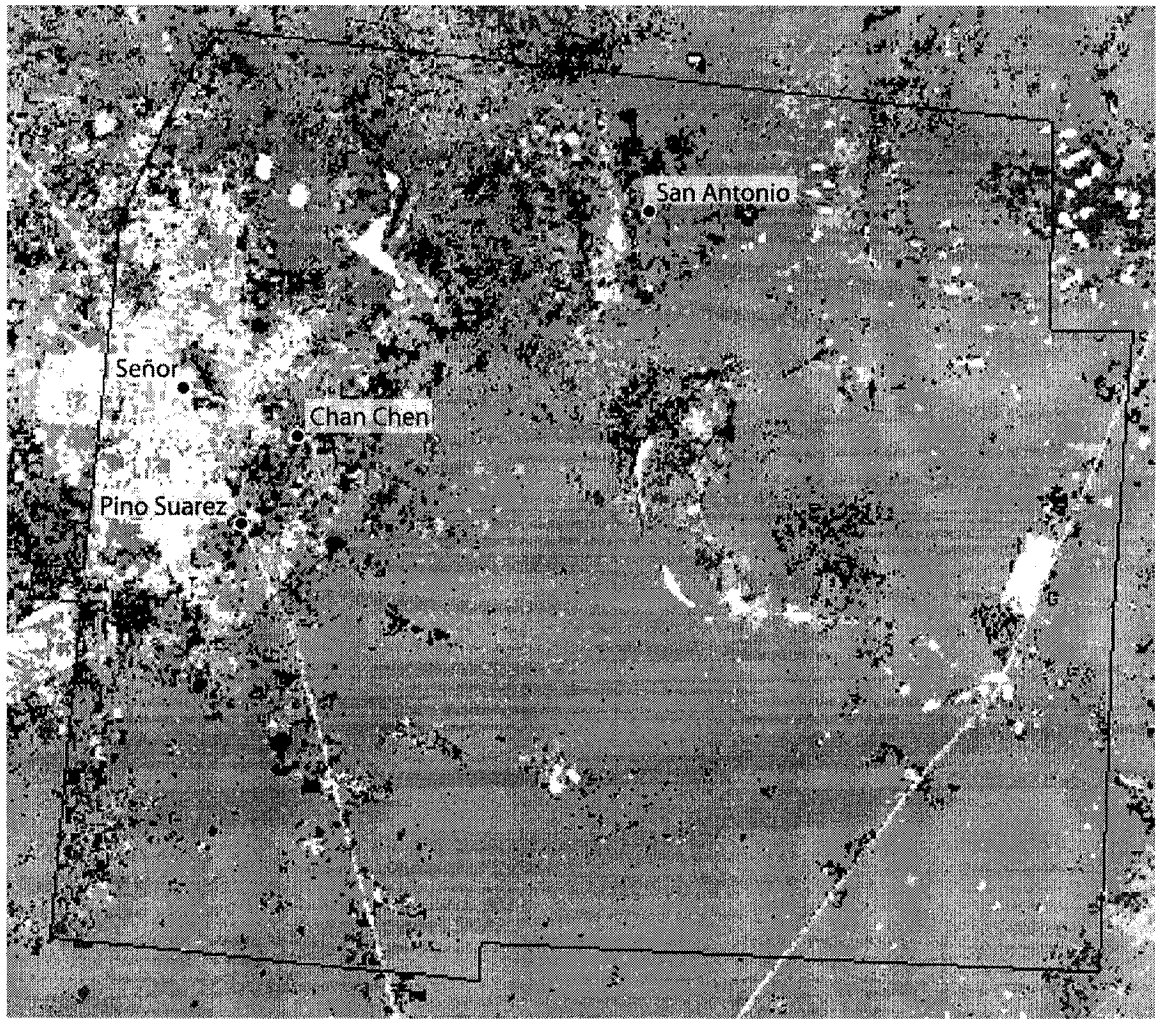


Figure 4.3. Map of land cover transitions 1976-1988-1997. Codes for transitions: A=agricultural, F=mature forest. Please consult Dalle et al. (2006) for the original colour version of this figure.













	1976	1988	1997
 Agricultural permanence 1976-1988-1997	A	A	A
 Forest permanence 1976-1988-1997	F	F	F
 Agricultural expansion 1976-1988	F	A	A
 Agricultural expansion 1988-1997	F	F	A
 Agricultural permanence, Forest regeneration	A	A	F
 Agricultural expansion, Forest regeneration	F	A	F
 Forest regeneration, Forest permanence	A	F	F
 Forest regeneration, Agricultural expansion	A	F	A
 Other transitions			
 Villages			

Figure 4.4. Change from 1976 to 1997 in land cover composition in three access zones.
Zone 1= < 30 minutes travel; zone 2= 30-60 minutes travel; zone 3= 60-90 minutes travel.

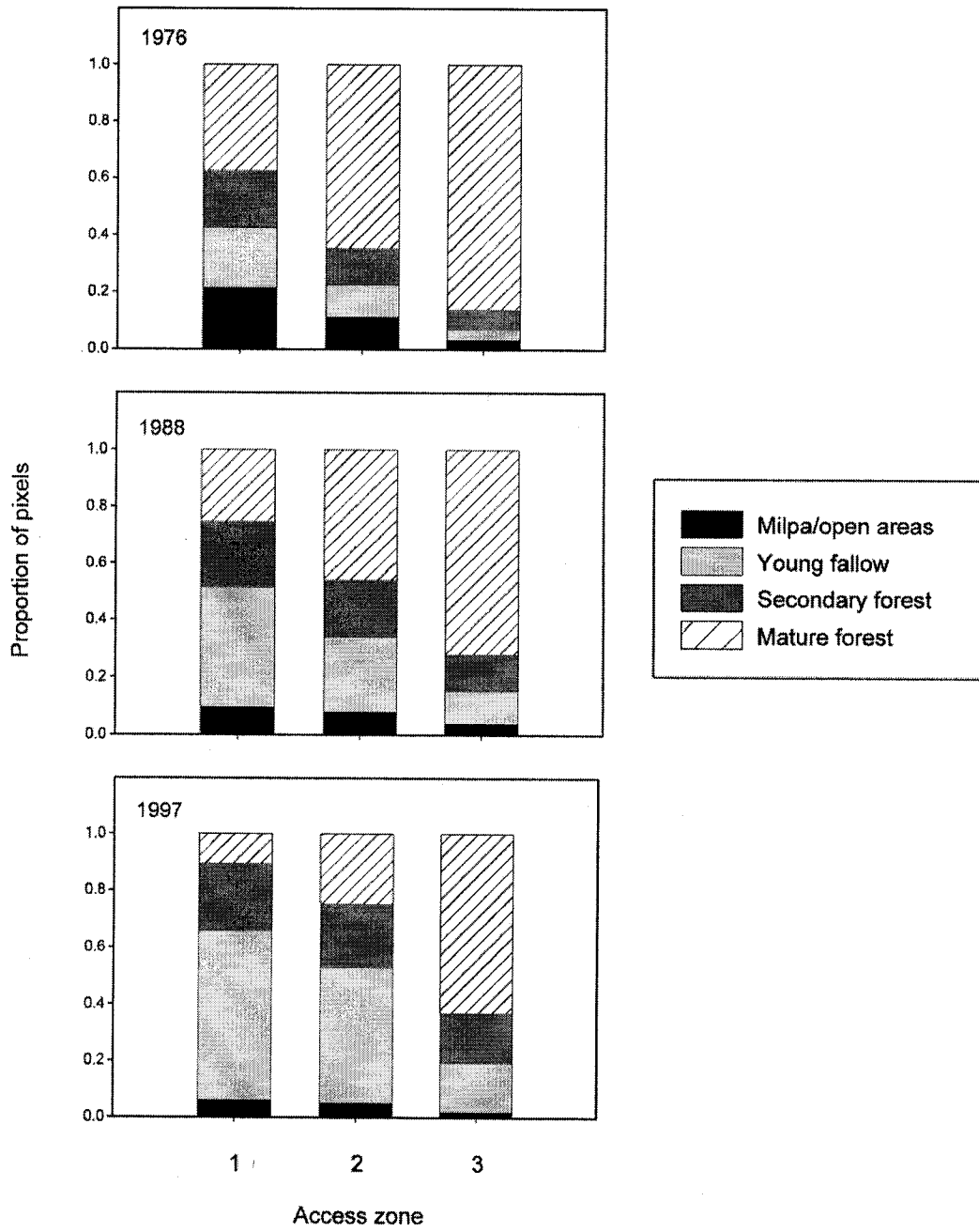


Figure 4.5. Change from 1976 to 1997 in dominance of land cover composition by access zone. Zone 1= < 30 minutes travel; zone 2= 30-60 minutes travel; zone 3= 60-90 minutes travel.

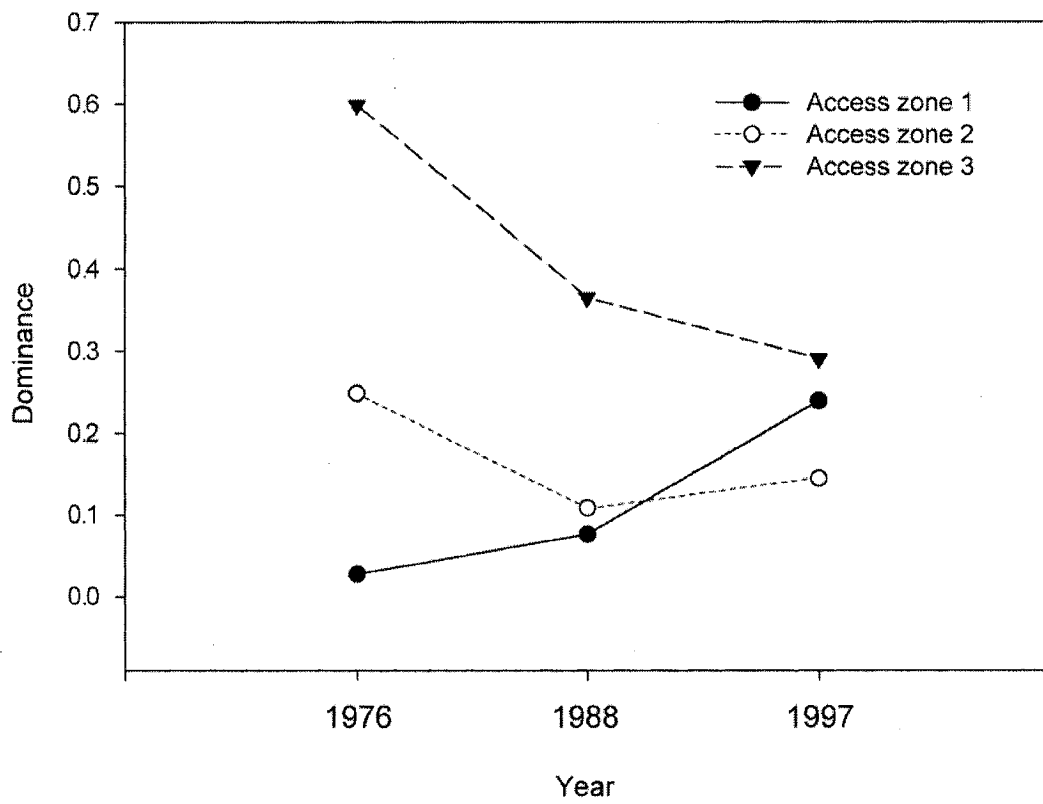
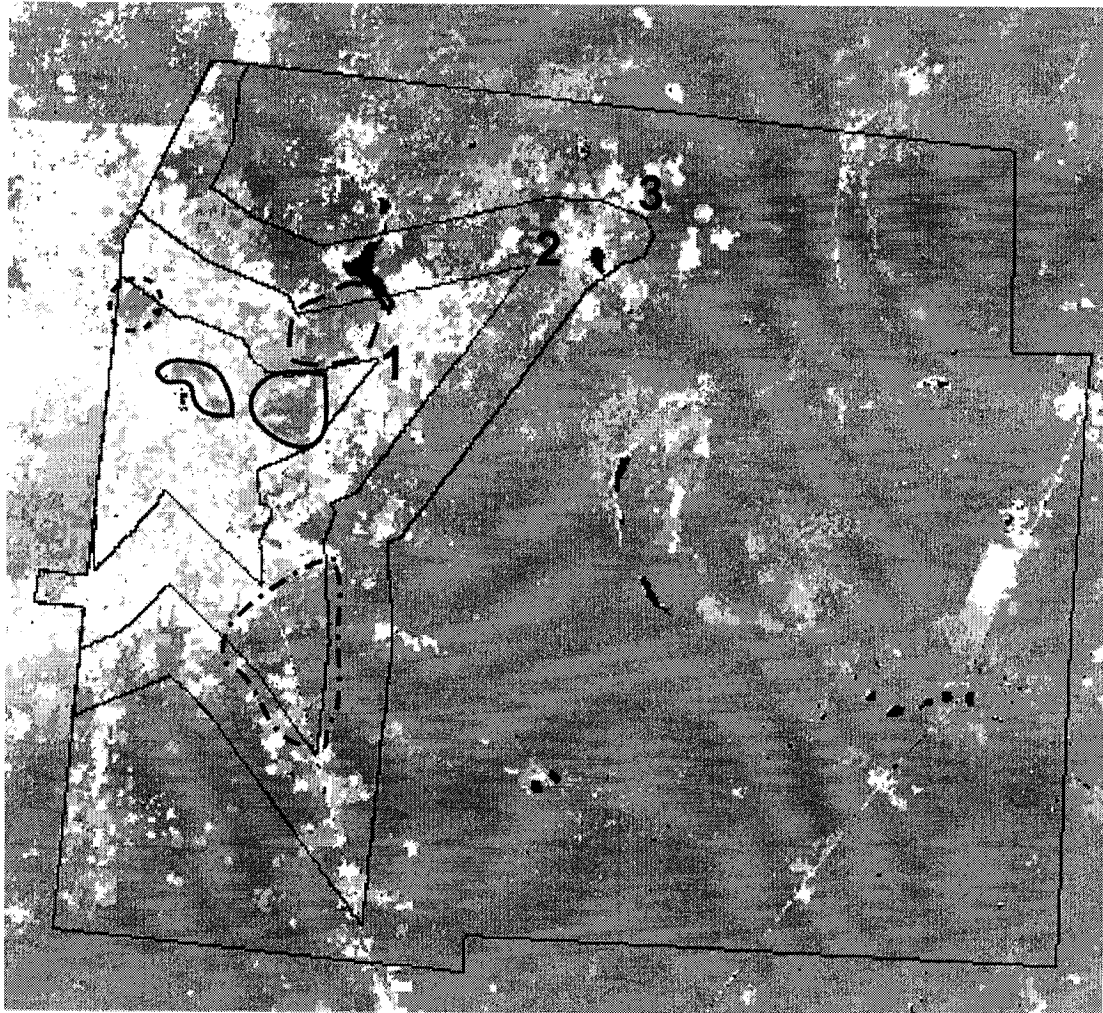










Figure 4.6. Conserved forest patches in relation to accessibility zones. Land covers are from 1997.



Land covers

-  Open areas, milpa, young fallow
-  Secondary forest
-  Mature forest
-  Other land covers

Conserved forest patches

-  Village reserves (jaal pach kaaj)
-  COPLAMAR reforestation project
-  Permanent forest area/chicle
-  Chicle area

Accessibility zones  **1**

Figure 4.7. Distribution of milpas before (1976) and after (1991, 2000) the initiation of the Plan Piloto Forestal in 1986.

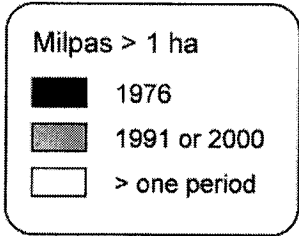
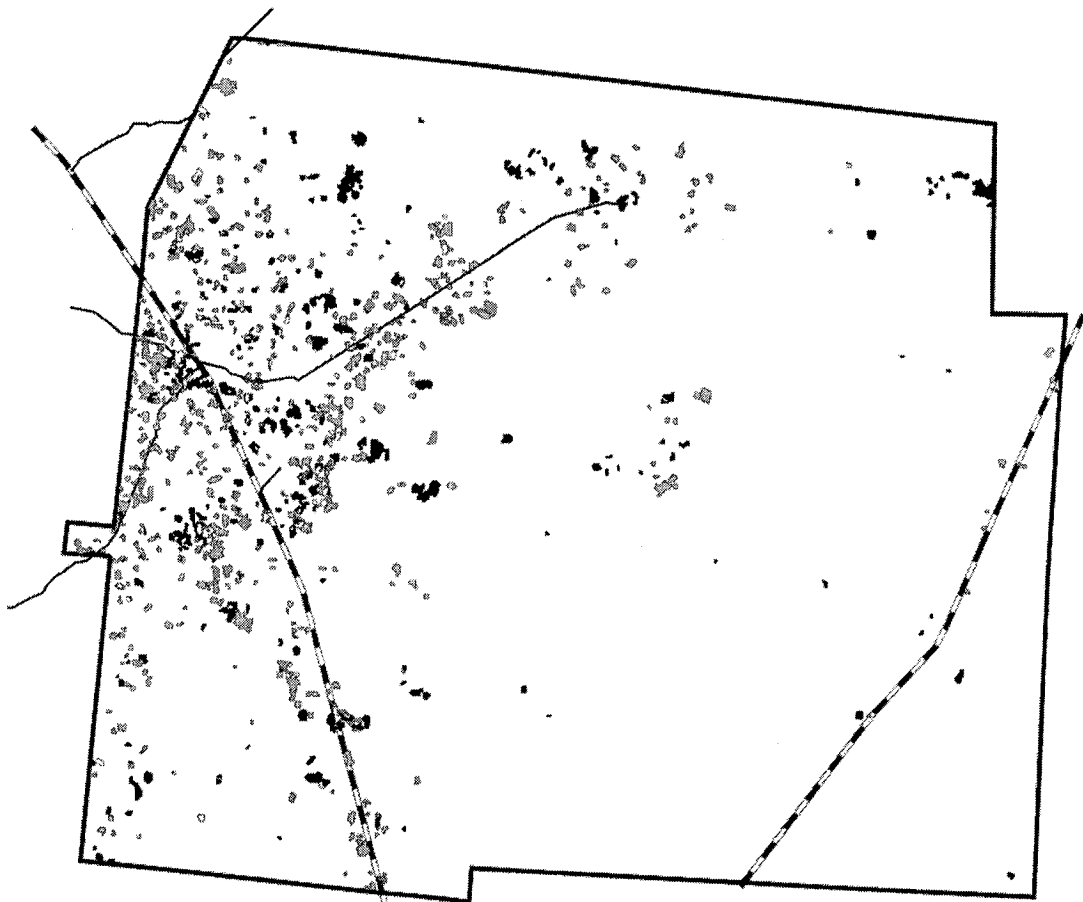
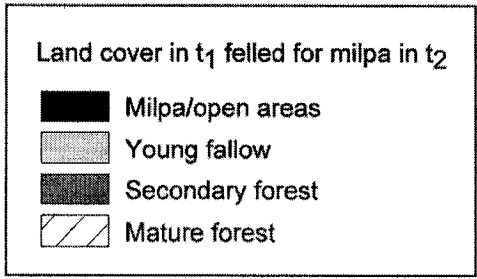
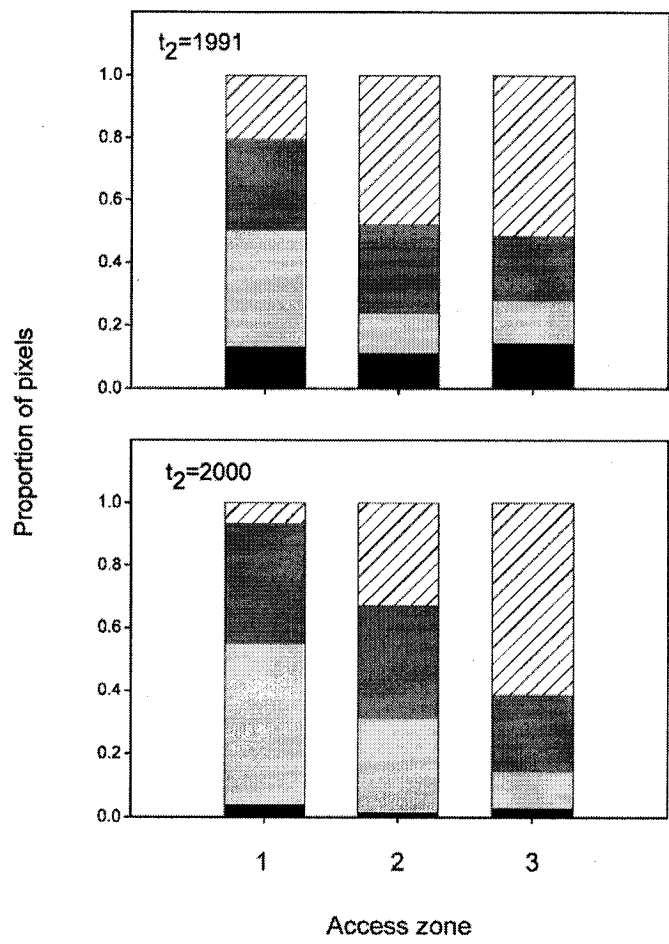


Figure 4.8. Proportion of milpa area in 1991 and 2000 felled from different ages of fallow/forest, by access zone (t_1 = 1988 and 1997, for 1991 and 2000 respectively). Access zone 1= < 30 minutes travel; zone 2= 30-60 minutes travel; zone 3= 60-90 minutes travel.



PREFACE TO CHAPTER 5

In Chapter 4, I found that high rates of forest conservation in X-Maben have been matched by comparatively drastic changes in the agricultural landscape. The areas most accessible to the majority of the population have shifted from being a diverse mosaic of young to old successional stages to a much more homogeneous landscape dominated by younger fallows and shorter fallow periods.

Here, I examine the extent to which a particular aspect of these changes in the agricultural landscape – shorter fallow times – affect the availability of two plant resources in agricultural fields. The resources examined are forage and firewood, which are considered of particular value to women, in their role in the domestic economy (Chapter 3). In the context of this thesis, the findings elucidate some of the implications of the land-use/land cover changes occurring in the agricultural area (Chapter 4).

By discussing some of the ecological processes potentially driving changes in resource availability in shorter fallow cycles, this manuscript also contributes more broadly to the literature on succession processes in shifting cultivation systems, which has rarely examined the effect of past fallow cycles.

CHAPTER 5

Changes in fallow times affect the availability of non-crop plant resources and secondary succession in a shifting cultivation system

Sarah Paule Dalle and Sylvie de Blois

Introduction

Shifting cultivation systems are an important form of agricultural production in the tropics and historically were important in many temperate regions (Kellman and Tackaberry 1997, p. 210). Many different systems exist and can employ different means of land preparation (burning or mulching), cropping patterns, and fallow management (active or not) (Brookfield and Padoch 1994, Conklin 1961, Kass and Somarriba 1999, Ramakrishnan 1992). However, production systems referred to as shifting cultivation are usually identified by the temporary cultivation of fields followed by a longer fallow period (Conklin 1961), and generally require few external inputs of energy (Kellman and Tackaberry 1997, p. 210).

The fallow period has been recognized as a crucial part of the system, serving to restore soil nutrients (Kleinman et al. 1995, Szott et al. 1999) and to reduce the weed load (de Rouw 1995, Misra et al. 1992, Staver 1991). Furthermore, maintenance of a fallow period increases diversity in the landscape, by producing a mosaic of differently-aged fields, fallows and forests (Finegan and Nasi 2004, Metzger 2003).

Although these low-input systems are often thought to be less productive than more intensive systems at least in terms of per hectare crop yields, it is increasingly recognized that a number of non-crop resources are harvested both from fields as well as from the diverse mosaic of fallows and secondary forests created by shifting cultivation (Alcorn 1981, Colfer et al. 1997, Frei et al. 2000, Levy Thatcher and Hernandez Xolocotzi 1992, Schmidt-Vogt 1997). In fact, it has been argued that medicinal, edible and other non-crop plants can be seen as part of a diversified agricultural production system (Bye 1981, Mazhar and Buckles 2000); in some cases such non-crop resources represent a substantial part of the produce harvested (e.g. Vieyra-Odilon and Vibrans 2001).

In many regions, a reduction in the fallow period has been reported (Cairns and Garrity 1999, Finegan and Nasi 2004). Reduced fallow periods are often associated with declining yields, although as reviewed by Mertz (2002), the results of many studies reporting on crop yields in relation to fallow time are limited due to lack of replicates or failure to examine potentially confounding edaphic or management factors.

Information on the effect of changing fallow times on the availability of non-crop resources, and on succession processes in general, is even more scarce. Indeed, while some studies have mentioned the loss of some non-crop plant resources due to changes in management practices such as herbicide use (Mazhar and Buckles 2000, Vazquez-Garcia et al. 2004), the role of more frequent fallow cycles has not been investigated.

Ecological studies on succession processes in shifting cultivation systems have established that shortening the fallow period often leads to an increase in the density and biomass of herbaceous vegetation (Saxena and Ramakrishnan 1984), with a concomitant decrease in woody species in the early stages of succession (de Rouw 1995, Fujisaka et al. 2000, Illsley Granich 1984, Staver 1991). However, beyond examining broad life forms, few studies have examined the fates of specific species and a more detailed understanding of succession processes in short versus long-fallow systems is lacking.

In this paper, we examine the impact of reduced fallow times on the availability of two non-crop plant resources – forage and firewood – which are collected in shifting cultivation fields by Maya communities of the Yucatan peninsula, Mexico. Firewood is cut from trees and stumps which are spared at the time of felling. The aboveground parts of these are usually killed in the burn, after which time the dry wood can be collected. Forage is gathered from the weed vegetation which regenerates spontaneously in the fields. For small livestock (mainly pigs, turkeys, chicken), forage is collected and brought back to animals in the homegarden. Large animals such as horses, cattle, and sheep may be taken to old fields and grazed or else forage may be cut and brought to the animals.

Using a data set of 26 fields of the same age (~1.5 y) but differing in the length and frequency of past fallow cycles, we examine the impact of fallow history on the regeneration of 17 forage and 5 firewood species, as well as on the amount of standing firewood (in the form of stumps and spared trees). Our findings show that some of these

plant resources are strongly affected by the fallow management history. We discuss some of the ecological and management factors which may influence the availability of these resources and consider the implications of these changes for local livelihoods, and for the maintenance of effective fallows in the shifting cultivation system.

Study area

Research was conducted in the Ejido X-Maben, in the state of Quintana Roo, Mexico. The population is nearly entirely Yucatec Maya, and in 2000 was estimated at 2,849 people (INEGI 2000), 83% of whom live in the largest village, Señor.

The vegetation in X-Maben is generally described as medium semi-deciduous tropical forest (*selva mediana subperrenifolia*) in the Mexican classification system, with a maximum stature of approximately 15 m, shedding approximately 25% of its foliage in the dry season (Flores and Espejel Carvajal 1994, Pennington and Sarukhán 1998). The landscape is karstic, and is characterized by thin limestone-derived soils (mostly lithosols and rendzinas), and a system of underground drainage systems, caverns and sinkholes (Flores and Espejel Carvajal 1994). Average annual temperatures are approximately 26°C, while average annual precipitation ranges from 1200-1500 mm/year (Instituto de Geografía 1990), with a marked dry season occurring from January to April.

Shifting cultivation (referred to locally as “milpa” in Spanish or **kool** in Maya) is practiced by nearly all households in X-Maben (Murphy 1990, Chapter 6). The main crops are maize, beans and squash, the seeds of which are planted together. Other crops, such as various types of tubers, watermelon, and other squashes and gourds can be interplanted among these main crops. Vegetation is typically cleared during the dry season using an axe and/or machete, although for older vegetation clearing may begin earlier. The burn is generally carried out in April or May, while planting occurs following the first rains, generally in May or June. Use of inorganic fertilizers, manually applied at the base of each corn plant, is widespread. Weeding is performed by hand, usually not more than once in the growing season; use of chemical herbicides is rare. Fallow periods practiced in X-Maben vary widely, with shorter fallow periods being more common in the areas close to the main village, Señor (Chapter 4).

Methods

Field work for this study was conducted between November 2002 and October 2003, during which time the first author resided in the main village Señor. All stages of the project (including species and site selection and the vegetation sampling) were conducted with close collaboration of a full-time assistant (W. Pat Canche, a man from the village with a secondary school education, and experience in milpa agriculture), while several other local assistants aided at different stages of the research.

Study species

Eighteen forage species were selected for study, based on their importance as a resource and also to represent a range in life-forms and reproductive strategies (Table 5.1). Each species' use and its relative importance as a resource were identified in a set of focus groups held with men and women in Señor (see Chapter 3 for more details). Of the 17 species, nearly all are used as forage for horse, sheep and cattle, while five are used for pigs or fowl. The preferred species for this latter purpose is wild *Carica papaya* L.

To examine the amount of firewood left standing as trees and stumps in fields, a list of firewood species and their quality was developed using interviews and focus groups (see Chapter 3). A total of twenty-five firewood species considered as high or good quality were identified (Table 5.2). Of these, the regeneration of five of the preferred firewood species (*Caesalpinia gaumeri* Greenm., *Coccoloba spicata* Lundell, *Lysiloma latisiliquum* (L.) Benth., *Nectandra coriacea* (Lundell) Kostermans, *Piscidia piscipula* (L.) Sarg.) was examined along with the forage species. This was done to better evaluate the response of re-sprouting tree species to fallow history, since these were not well represented among the forage species.

Site selection

A total of 26 sites were selected to represent a gradient of short to long fallow times. All sites were milpas that had been cultivated in the 2002 agricultural cycle (e.g. burned in April-May 2002) for the first time after a fallow period of at least 5 years. Most milpas had not been cropped again in the 2003 cycle; in cases where a portion of the milpa had been cropped a second time, only the un-cropped areas were sampled. A

second criteria guiding site selection was that the history of each site, in terms of the number of milpa cycles, and the age of vegetation felled, needed to be relatively well known (see following section).

The sites included milpas that had been felled from two forest types recognized by the local Maya population. These generally differ in their degree of deciduousness, presumably responding to variations in edaphic conditions in the study area. The first is called **k'an lu'um k'áax** (KL) and is more deciduous, while the second, **yáax k'áax** (YK) is more evergreen. In both cases they are identified by local Maya farmers by their species composition. In early successional state, KL is identified by the prevalence of trees such as *Acacia pennatula* (Schldt. & Cham.) Benth., *Pithecellobium albicans* (Kunth.) Benth., and *Lysiloma latisiliquum* (L.) Benth, while *Nectandra coriacea* (Lundell) Kostermans is considered indicative of the more evergreen YK. Similar forest types are distinguished by Maya in other parts of the Yucatan peninsula (Iillsley Granich 1980). Because of the potential relationship between these forest types and other variables in our study, we stratified our sampling by selecting 10 milpas in the deciduous KL and 16 in the more evergreen YK. In both cases these represented a gradient of short to long fallow histories, however YK tends to be more intensively used, and we have more short-fallow milpas of this forest type in our data set.

Fallow cycle histories

Site histories were identified through interviews with the owners of each milpa. For some sites, this involved talking with several people since more than one farmer had been known to work the site. Our interviews were generally conducted with the member of the household who had the prime responsibility for selecting and felling the site, although in some cases other family members were consulted. All informants were men.

In each case farmers were asked to estimate the age of vegetation felled and the number and length of previous cycles. In most cases we were able to obtain histories dating back to 1960. We attempted to verify the estimated dates of the successive cycles by referring to key events that most people in the area remember. These included events such as hurricanes, floods, the paving of access roads, and several government programs for agricultural credit. Thus, when asking farmers to recall information on previous

cycles, we asked whether they had worked the site before or after a given event. In other cases, we verified dates of specific events mentioned in the interview (such as a marriage or land-use conflict) by consulting relevant certificates or other independent sources. Referral to such events helped to confirm estimated lengths of cycles. Furthermore, when several farmers were interviewed regarding a given site, histories could be verified by examining consistency in the information reported.

For the 26 sites, the length of the last fallow cycle ranged from an estimated 5 years to approximately 40 years, and the number of cycles since 1960 ranged from 1 to 5. In a few cases, non-milpa disturbances or land-uses were reported to have occurred. These included a government-sponsored cattle pasture which operated between 1966 and 1979, and some wild fires. In the case of the cattle pasture, we sampled several milpas which represented a full gradient of short to long fallow times, and thus assumed that any influence of this history on our data would be spread out among fallow periods. Wild fires were reported to have occurred in 4 sites. We considered these to constitute a “cycle” equivalent to milpa, assuming that many of the trees died and a process of secondary succession was initiated.

Vegetation sampling

Sampling occurred from August to October 2003. All milpas were approximately 1.5 y old with respect to the date of the last burn. A systematic sampling design was employed in which each milpa was sampled using a grid of 2 meter radius circular plots spaced evenly at 15 meter intervals across the entire milpa. This produced approximately 36 sampling plots per hectare; for our 26 sites the mean number of sampling plots was 56, with a range of 21 to 151. Site-level estimates of relative frequency of the forage species and densities of spared trees were later calculated based on the total number of occurrences or abundances divided by the number of sampling plots per site.

The vegetation sampling was carried out by a team of four people, consisting of the first author (SPD), the main assistant, W. Pat Canche, and two additional assistants from X-Maben who had extensive knowledge of the local vegetation. W. Pat Canche

was trained to record the field data, while the other two helped identify plant species according to their Maya names and to measure the variables to be recorded.

In each circular plot we recorded the presence/absence of the 17 forage and 5 firewood focal species, and the Maya name of all spared trees, spared stumps > 70 cm in height. Trees or stumps which had already been cut for firewood were also recorded. The basal diameter of these harvested stumps or trees, as well as that of standing stumps was measured, whereas the diameter at breast height was recorded for spared trees. The Maya name and height of the tallest stem in each 2 m circular plot, and the percent of each plot occupied by plant cover (including the focal species) were estimated visually using a 7 point scale (<10%, 10-25%, 25-40%, 40-60%, 60-75%, 75-90%, >90%).

In addition to vegetation data, we also collected information on other ecological variables that could be related to fallow history and the observed vegetation patterns. Our field observations indicated that substrate could be important for understanding the distribution of the species, so we characterized the substrate in each 2 m circular plot. By “substrate” we refer to the conformation of the soils and limestone outcrops that characterize the karstic landscape (Weisbach et al. 2002). These outcrops are extremely variable and differentially weathered such that they can form soil-filled depressions of different extents and depth, be flat outcrops covered by only a thin layer of soil, or be broken up into boulders or smaller rocks, with soil accumulating in the crevices. These different conditions influence regeneration niches and cultivation potential (Illsley Granich 1984, Illsley Granich and Hernandez Xolocotzi 1980), and help to explain differences in vegetation communities (Sanchez Sanchez and Islebe 2002, White and Hood 2004). To characterize these edaphic conditions, we employed the local Maya soil classification (see Figure 5.1) to identify five types of substrate. As described in Figure 5.1, these five substrate types roughly correspond to two major soil types found in the region (lithosols and rendzinas). We used the Maya classification since it was a more efficient way to quickly assess the extremely fine-scaled variation occurring within each of these major soil types, as compared to more conventional scientific methods that would require intensive field measurements. For each circular plot, we estimated the percentage represented by each of these categories. Site-level estimates of the relative

cover of each substrate type were calculated by summing the percentage of sampled area associated to each type and dividing by the number of plots.

Finally, since landscape context (or the surrounding vegetation) can influence colonization patterns (Martinez-Garza and Gonzalez-Montagut 1999, Purata 1986), at each site we drew a sketch map indicating the type of vegetation bordering the milpa (milpa or young fallow < 10 years, secondary forest 10-25 years or mature forest > 25 y). We estimated the amount of mature forest in the surrounding landscape by extracting the number of pixels classified as mature forest (> ~25y) within a 500 m radius from a classified LANDSAT image from February 2000 (Chapter 4). Voucher specimens for all firewood and forage species included in this study were collected and identified and deposited at MEXU in Mexico City.

Data Analysis

Calculation of indices of intensity of fallow history and rockiness

In all our analyses, we represented the fallow history of each site by an index which combined two measures: (1) the length of the last fallow period and (2) the number of cycles since 1960. These two variables are highly correlated (Spearman $R = -0.782$, $p < 0.0001$) thereby making it difficult to statistically separate their effects; as a result we felt it was more adequate to combine the two in a single variable. The duration of the last fallow period was expressed as a semi-quantitative variable with the following ordered categories: 1 = <8 y, 2 = 12-23 y, 3 = >35 y, while the number of cycles ranged from 1 to 5. The index was defined as the first axis of a principal component analysis (PCA) based on these two variables. It ranged from negative scores for those sites with longer, less frequent cycles to positive scores for those with shorter and more frequent cycles. This index is referred to herein as “fallow intensity”.

The data on substrate types for all plots in a site were summarized by using a quantitative variable representing the degree of rockiness. To do so, we calculated a PCA on the relative cover of each of the five substrate types. The first PCA axis (defined as the variable “rockiness”) represented a gradient from sites with a low proportion to those with a high proportion of rocky substrate types (Figure 5.1).

Relationships between fallow intensity, site characteristics, and standing firewood

For spared firewood stumps and trees the total basal area for each site was calculated including only the 25 good quality firewood species shown in Table 5.2. In cases where the tree or stump had already been cut (presumably for firewood) it was assumed that it had been a spared tree if the basal diameter was >6 cm, the average minimum diameter of spared trees (Table 5.4); otherwise it was considered to have been a stump. Note that for analyses on firewood, data from one short-fallow site could not be used, thus the sample size is 25.

Pearson correlations of fallow intensity with firewood (density, minimum and average stump/tree size, and basal area) and with other site characteristics (surrounding vegetation, density of vegetation, rockiness) were conducted on rank-transformed data (equivalent to a Spearman R), since some variables were highly skewed and could not be normalized.

Relative influence of fallow intensity, rockiness, and forest type on the frequency of forage and firewood species

We examined the relative influence of three explanatory variables - fallow intensity, rockiness, and forest type (deciduous KL or evergreen YK) on the frequency of the 22 forage and firewood species. This was done using redundancy analysis (RDA), a form of canonical analysis which produces an ordination of a multivariate data set (the species frequencies in this case) constrained by a linear combination of explanatory variables (Legendre and Legendre 1998, p. 579).

Two sets of analyses were carried out. First, we examined an RDA of the species frequencies vs. all three explanatory variables. Second, we controlled for the effect of forest type (assigning this as a co-variable), and examined the relative importance of fallow intensity and rockiness in explaining the species frequencies, using partial canonical analysis (Legendre and Legendre 1998, pp 769–779). This method allows a partitioning of the variation of the species data into three fractions: (1) that explained by fallow intensity alone, (2) that explained by rockiness alone, and (3) that explained jointly by fallow intensity and rockiness. This allowed us to test whether a significant independent effect could be attributed to fallow intensity.

We used RDA rather than canonical correspondence analysis, since RDA has the advantage of not assigning differential weights to sites according to the number of species present (Legendre and Gallagher 2001). However, RDA is generally not appropriate for analysing species data especially when unimodal species-environment relationships are present. Therefore, we applied the “distance between species profiles” transformation developed by Legendre and Gallagher (2001) to the species data, thereby making them amenable to analysis by RDA. Of the 5 transformations proposed by Legendre and Gallagher (2001) this one was selected since it produced the RDA with the strongest species-environment relationship. RDAs were conducted with the program CANOCO for Windows v. 4.5.

Results

Relationship between fallow intensity, site characteristics, and standing firewood

Fallow intensity was correlated with a number of other site characteristics (Table 5.3). In particular, shorter, more frequent fallow cycles were associated with less surrounding mature forest, denser vegetation cover in the milpa and reduced rockiness in the soils. Increased fallow intensity also showed a significant correlation with the maximum and average dbh of spared trees, but not with the density or minimum dbh of spared trees. Examining the correlations between rockiness and fallow intensity by forest type indicates that the relationship is stronger for the 10 more deciduous KL sites ($R = -0.483$) than for the 16 more evergreen YK sites ($R = -0.286$).

Overall, 41 folk species were recorded as spared trees, and 100 as spared stumps. Of the 25 species considered as preferred firewood in this study, 20 occurred as spared trees and all were encountered as stumps. Thus, the preferred firewood species represented nearly 50% of all species encountered as spared trees, but only 25% of those found as spared stumps. The species most frequently spared as both trees and stumps were *Piscidia piscicula*, *Coccoloba spicata*, *Lysiloma latisiliquum* and *Lonchocarpus rugosus*, with *P. piscicula* being the most common spared tree (80% of sites), and *C. spicata* the most frequent spared stump (100% of sites). Whereas 13 firewood species were encountered in more than 50% of sites as stumps, only three were found as spared

trees at this frequency. Thus, spared firewood stumps were generally represented by more species than were spared trees.

The amount of preferred firewood species left as spared trees and stumps varied substantially among sites. Overall, the total basal area of stumps ranged from 0.7 to 9.9 m²/ha, whereas spared trees ranged from 0.15 to 7.8 m²/ha (Table 5.4). With increasing fallow intensity, the maximum and mean diameters as well as the basal area of both spared stumps and trees of preferred firewood decreased significantly; however, there was no significant relationship between fallow intensity and density of either stumps or trees (Table 5.4, Figure 5.2b, e). Thus, decreases in basal area with fallow intensity were due to the smaller size of trees and stumps in sites felled from younger vegetation, rather than differences in density. Visual inspection of scatterplots of firewood basal area vs. fallow intensity indicated similar trends between the two forest types (KL or YK).

Relative influence of fallow intensity, rockiness, and forest type on the frequency of forage and firewood species

Overall, the 17 forage and 5 firewood species were widely distributed, with only five being present in less than 80% of sites (*Cecropia peltata*, *Viguiera dentata*, *Phytolacca icosandra*, *Centrosema schotti*, and *Melanthera aspera*, ranging from 69%–50% of sites). However, the species varied greatly in their relative frequencies among sites, with the maximum relative frequency ranging between 11% for *Phytolacca icosandra* and 96% for *Panicum* sp. (Figure 5.3). While most species had minimum relative frequencies near zero, three (*Trema micrantha*, *Coccoloba spicata*, and *Piscidia piscicula*) occurred in at least 10–20% of sampling plots at any given site.

The RDA of the relative frequency of the 22 species vs. fallow intensity, rockiness and forest type was significant (F=8.603, p=0.001). The forward selection procedure indicated that forest type (YK vs KL) explained the most variance in the species data (30%), followed by fallow intensity (28%) and rockiness (9%). Together, these three variables explained 54% of the variance in the species data.

Figure 5.4 shows the correlation biplot resulting from this analysis. Examination of the biplot reveals three species being most strongly related to less intense, long fallow cycles: *Carica papaya*, *Trema micrantha*, and *Phytolacca icosandra*, while those more

strongly associated to sites with short fallow cycles were the shrubs *Viguiera dentata*, *Melanthera aspera*, and *Desmodium incanum*. Furthermore, sites with short fallow cycles (high fallow intensity) tended to be less rocky and had more evergreen YK sites, whereas sites with histories of longer fallow cycles were rockier and more associated to the deciduous KL vegetation. Thus, some of the species negatively associated with intense fallow cycles (especially *Passiflora pedata*, *Cecropia peltata* and *Lysiloma latisiliquum*) are more frequent in the more deciduous KL sites, while others are more frequent in rockier sites (e.g. *Vitex gaumeri* and *Acalypha indica*). Similar relationships are evident among the species more associated with short fallow cycles.

In the partial canonical analysis we found that, overall, 34.7% of the species variation is explained by fallow intensity and rockiness, after controlling for forest type. Of this explained variation, 61.5% is attributable to fallow intensity alone, 20.1% jointly to fallow intensity and rockiness, and 18.4% to rockiness alone. Figure 5.5 shows the amount of the variation explained by each of the three fractions for each species; these are presented in order of their association to the gradient in fallow intensity. In general, the overall relationship between species frequencies and fallow intensity is similar to that found in the full RDA (Figure 5.4), with the same groups of species associated to short and long fallow cycles. By comparing the length of the species vectors in Figure 5.4 (proportional to the amount of variation explained) with the amount of variation explained in the partial canonical analysis (Figure 5.5), it is evident that some species have a much smaller proportion of their variation explained after controlling for forest type (e.g. *Cecropia peltata*, *Phytolacca icosandra*, and *Passiflora pedata*). In other instances a large proportion of the variation explained is due to a joint effect of fallow intensity and rockiness (e.g. *Viguiera dentata*, *Acalypha indica* and *Phytolacca icosandra*). Nonetheless, for many species, between 20 and 40% of variation in their relative frequencies is attributable to an independent effect of fallow intensity.

Discussion

Our results show significant trends in the availability of forage and firewood resources according to the past fallow history. Responses were different for the two

resources, with some forage plants being positively and others negatively associated to shorter cycles, whereas firewood shows an overall decrease with shorter fallow cycles. Furthermore, because the two resources are derived from different components of the shifting cultivation system – forage from new shoots of the “weed” community, firewood from remnants of the original vegetation, – the processes which govern their availability in relation to the fallow period differ. Here we discuss some of the ecological and management factors which may influence the availability of these resources and consider the implications of these changes for local livelihoods, and for the maintenance of effective fallows in the shifting cultivation system.

Regeneration of forage and firewood plants

The regeneration of the 17 forage and 5 firewood plants showed both positive and negative responses to fallow intensity. In general, the species most associated to shorter fallow cycles were short-lived shrubs and herbs; trees depending on establishment from seed (including short-lived pioneer trees) were most common among the species most associated to long fallow cycles, while resprouting trees (mostly used for firewood) tended to be neutral to fallow time (Table 5.5).

Previous studies have reported that reductions in the fallow period lead to an increase in density of herbaceous weeds (Saxena and Ramakrishnan 1984), with a concomitant decrease in woody species in the early stages of succession (de Rouw 1995, Fujisaka et al. 2000, Illsley Granich 1984, Staver 1991). The dominance of herbs and other short-lived, early successional species in short-fallow cycles can be explained by the accumulation of viable propagules of such species in the seed bank of young fallows (Quintana-Ascencio et al. 1996, Rico-Gray and Garcia-Franco 1992, Staver 1991, Young et al. 1987). In other instances, species with fire-resistant underground organs may be able to resprout from these in short-fallow cycles if they still persist or have viable root stocks in young fallows that are felled. Moreover, the less intense burns of short fallow milpas (Saxena and Ramakrishnan 1984) likely increase the survival rate of soil seeds and root stocks. In our study, it seems that the species most strongly associated to short fallows might combine both of these strategies – for example, *Viguiera dentata* has abundant seed production, is pyrophillic (Lawrence et al. 2004) and can resprout from

underground parts, while *Desmodium incanum* resprouts from its woody stem (field obs), and has adhesive seeds that are extremely effectively dispersed by humans and animals. These traits are likely to be advantageous as the intensity and frequency of disturbances increase.

In contrast to the short-lived species dominating in short-fallow cycles, longer lived trees with a propensity to resprout tended to be neutral to fallow history (e.g. *Pouteria campechiana*, *Nectandra coriacea*, *Piscidia piscicula*, *Coccoloba spicata*). Some studies have suggested that coppicing species could become more common in repeated fallow cycles (Lawrence 2004, Lawrence et al. 2005). With the exception of *Caesalpinia gaumeri* which showed a weak positive association to short-fallow milpas, we did not find evidence for this; however, this might be due to the fact that we examined relative frequency rather than stem density. While multiple coppicing events could be expected to increase stem density, colonization of new sites through seed dispersal or lateral root suckers (e.g. Nygeres 1989) would be necessary for these species to increase their relative frequency.

Species most strongly associated to long fallow milpas were trees depending primarily on establishment from seed. These included the long-lived *Lysiloma latisiliquum*, as well as short-lived pioneers such as wild *Carica papaya*, *Trema micrantha* and to a lesser degree *Cecropia peltata*. In addition, six of the eight species showing an association with long-fallow milpas have fleshy fruits dispersed by birds and other animals. There are several hypotheses which may explain these trends. One possibility is that these species compete poorly with more aggressive short-fallow species (e.g. as suggested by Purata 1986), and the conditions of higher plant density in short-fallow milpas. This could especially be the case if these species regenerate primarily from recently dispersed seeds which would have to compete with already established short-fallow species and coppicing trees. For example, *Cecropia* spp. have been shown to have low longevity in the seed bank and to be highly dependent on continued seed rain for regeneration in forest gaps (Alvarez-Buylla and Martinez-Ramos 1990, Dalling et al. 1998). Germination of this, and other photoblastic, early successional species, could be inhibited due to shading from more quickly established competitors.

Another hypothesis is that some of the long-fallow species might face dispersal limitation in short-fallow milpas which have smaller remnant trees and less nearby mature forest. Remnant trees that serve as perches for birds have been found to promote the dispersal of woody and especially bird-dispersed species in pastures (Guevara et al. 1986, Uhl et al. 1982) and shifting cultivation fields (Carriere et al. 2002a, 2002b), while the dispersal and establishment of such species is also increased with greater proximity to mature forest (Martinez-Garza and Gonzalez-Montagut 1999, Purata 1986). Although these studies have often emphasized the dispersal and establishment of late successional forest trees, early successional species might also depend on the same dispersers. Indeed, Lawrence (2004) reported a decline in the number of early successional tree species occurring in 9-12 y fallows with increasing distance from the forest. Thus, dispersal limitation may explain at least in part the decline of species such as *Carica papaya*, *Trema micrantha*, *Cecropia peltata*, *Passiflora pedata* and *Phytolacca icosandra* in short-fallow milpas.

Finally, changes in nutrient status with fallow period may be an additional factor influencing the species' distributions. For example, in Borneo, Lawrence et al. (2005) report P, N and C stocks to increase with repeated shifting cultivation cycles, and this to partly explain the abundance of certain tree species. In Yucatan, Ceccon et al. (2003, 2004) found recruitment of tree seedlings to be affected by N and P fertilization. However, how nutrient status varies with changing fallow times and variations in fertilizer application is not clear.

Firewood: ecology and management of remnant vegetation

The significant decrease in the basal area of spared trees and stumps in milpas with shorter, more frequent fallow cycles is related to the smaller diameter of trees in such milpas. While the younger age of the vegetation felled is the most evident explanation for the smaller tree sizes, it is also possible that the more frequent fallow cycles short fallow milpas may have reduced tree growth rates, thereby contributing to smaller tree sizes (e.g. Lawrence et al. 2004).

Variation in management practices also likely influenced the amount of firewood available. For example, density of spared stumps and trees, while not related to fallow

history, was extremely variable. While it is possible that this might be a consequence of variations in density in the original vegetation (e.g. Read and Lawrence 2003 report extremely variable densities for a given stand age), it is probably due at least in part to differences in sparing practices. Indeed, the sites with the highest density of both spared trees and stumps (seen as outliers in Figure 5.2 b,e with spared tree density of 954 and 555 stems per hectare, and stump densities of more than 2000) were a milpa which had been felled specifically with the goal of extracting firewood to sell in the village, and a very accessible milpa located on the outskirts of the village which had been heavily harvested for firewood. In both cases, this led to slightly higher basal areas especially for spared trees compared to other sites with similar fallow history. However, in short fallow cycles, the ability to increase the amount of firewood is limited by the smaller size of trees of younger fallows.

Because the age of the initial vegetation is likely the main factor limiting availability of firewood, all firewood species can be expected to respond similarly to shorter fallow cycles. In some cases, species whose regeneration is reduced in shorter fallow cycles (such as *Lysiloma latisiliquum*) could be expected to decline more rapidly with repeated cycles, assuming that the trend observed in the first 1.5 y is maintained at later stages of succession. Availability of individual species will also depend on variations in species composition in the original vegetation, and sparing practices. However, overall firewood as a resource appears to be greatly reduced in short-fallow milpas.

Implications of shorter fallow times for use of non-crop plant resources

The shortening of fallow periods in shifting cultivation has been reported as a widespread phenomenon in many parts of the tropics. In our study area this appears to be true in the most accessible areas of the landscape where milpas derived from young fallows have become more common than those derived from mature forest (Chapter 4).

Shorter fallow periods are often associated with declining crop yields. Our findings indicate that the availability of some non-crop resources can also be negatively affected. In regions where such resources contribute significantly to household

economies, trends in shortening of fallow times could potentially have implications for local livelihoods.

Of the resources examined, the reduction in firewood is perhaps the most critical since nearly all households in our study area depend on firewood to meet their fuel needs, and milpa is the primary source of firewood for nearly half of households in the main village Señor (Chapter 6). It is important to note that differences in the actual volume of firewood available at these sites are probably greater than basal area suggests, since older sites would not only have trees with larger basal area but also of greater height. To better understand the livelihood implications of shortened fallow times for firewood availability more detailed assessments of harvestable volumes produced in relation to local needs are required.

In the case of forage, the scarcity of some resources may be buffered by the number of species available for a given purpose. For example, a large number of species can be used for horses, sheep and cattle and these showed mixed responses to fallow times, implying that if certain species became scarce in the landscape, others could likely serve as substitutes. Similarly, two of the forage species used for small domestic livestock such as pigs and turkeys, were positively associated to short-fallow milpas, while the preferred species (wild *Carica papaya*) showed a strong negative response. Due to the smaller number of species available for this purpose, the scarcity of this preferred species in short-fallow milpas, may be of more concern.

For both resources, households may respond to changes in resource availability in a number of ways. For example, alternative sources may be sought (e.g. forage from homegarden, or through exchange with kin or neighbours), household needs might be modified (e.g. purchase firewood) or alternatively the potential availability of resources in certain types of milpas might influence agricultural decisions about what kind of vegetation to fell. Moreover, responses are likely to vary among households (Adhikari et al. 2004, Coomes et al. 2004). Further examination of local patterns of resource use within the context of differential household economic strategies is necessary to fully understand the livelihood implications of the changing availability of resources in the landscape.

Maintenance of effective fallows in the shifting cultivation system

A second implication of our results is that the near absence of short-lived pioneer trees such as wild *Carica papaya* and *Trema micrantha* in short-fallow milpas may reduce the effectiveness of the fallow in re-establishing soil nutrients and ensuring rapid succession in shifting cultivation systems. First, pioneer trees' high production of leaf litter is important for nutrient cycling in early stages of succession (Gomez-Pompa and Vazquez-Yanes 1981, Vazquez-Yanes 1998), and some fallow species are thought to be efficient in mobilizing soil nutrients due to extensive root exploration (Lawrence and Schlesinger 2001). As a consequence, their loss in the system could reduce the nutrient cycling of the fallow vegetation. Secondly, due to their fast growth and monopodial architecture, pioneer trees contribute to a rapid development of a secondary forest vegetation by producing a canopy that quickly shades out light loving species (Gomez-Pompa and Vazquez-Yanes 1981). De Rouw (1995) has suggested that in the absence of other pioneers, coppicing tree stumps and root suckers can provide cover, albeit more patchy. However, this change in canopy species composition can influence the successional pathway. For example, Mesquita et al. (2001) found that the understory of secondary forests dominated by a *Cecropia* canopy had greater basal area, larger trees, and greater species richness than those dominated by re-sprouting *Vismia* spp., possibly due to the denser monolayer canopy of the latter. In short-fallow milpas in our study, the tallest individuals were generally resprouting trees, such as *Coccoloba spicata* and *Piscidia piscicula*. The resprouts of such trees are dense and vertically oriented (field obs.) as opposed to the spreading crowns provided by pioneer species such as *Trema micrantha* or *Carica papaya*. Changes in the species composition of the initial canopy could therefore possibly result in an altered successional pathway, and less rapid forest recovery.

A few reports from other regions of loss of pioneer trees in short-fallow cycles (de Rouw 1995, Fujisaka et al. 2000) suggest that this might be a widespread occurrence. Further study of the mechanisms impeding establishment of pioneer tree species in short-fallow cycles could be useful for developing management strategies to improve the productivity of these systems.

Table 5.1. Forage species included in this study, with their uses and importance ranking according to focus groups with men and women.

Maya name	Scientific name	Family	Code ¹	Voucher no. ²	Ranking ³		Animals fed ⁴					
					♂	♀	P	Ch	T	H	Sh	C
Púut ch'iich'	<i>Carica papaya</i> L.	Caricaceae	CARI	362	1	1	1	1	1	1	1	
Ya'ax kanal	<i>Psychotria nervosa</i> Swartz	Rubiaceae	PSYC	263, 279, 296	1	2	1			1	1	1
K'an chim	<i>Panicum</i> sp.	Poaceae	PANI	272	1	2		1		1	1	1
Ya'axnik	<i>Vitex gaumeri</i> Greenm.	Verbenaceae	VITE	266	1	2				1	1	1
Ch'ilitu'ux	<i>Acalypha unibracteata</i> Muell. Arg.	Euphorbiaceae	ACAL	330	1	3	1			1	1	1
X-K'o'och	<i>Cecropia peltata</i> L.	Cecropiaceae	CECR	267, 276	1	3				1	1	1
Yo'och oop' tsiimin	<i>Petrea volubilis</i> L.	Verbenaceae	PETR	252	1	3				1	1	1
Jobom k'áak'	<i>Euphorbia heterophylla</i> L.	Euphorbiaceae	EUPH	264	1	.				1	1	1
Paak' um paak'	<i>Desmodium incanum</i> D.C.	Fabaceae	DESM	282	1	.				1	1	1

¹ This code (first four letters of the genus name) is used to indicate species in Figures 5.3 to 5.5

² S. Dalle collection numbers

³ Rankings represent the perceived importance of each species relative to other forage plants; rank 1 is the most important, rank 3 the least.

⁴ Animals are P=pigs, Ch=chickens, T=turkeys, H=horses, Sh=sheep, C=cattle

Table 5.1. continued

Maya name	Scientific name	Family	Code ¹	Voucher no. ²	Ranking ³		Animals fed ⁴						
					♂	♀	P	Ch	T	H	Sh	C	
Tah	<i>Viguiera dentata</i> (Cav.) Spreng. var. <i>heliantoides</i> (HBK.) Blake	Asteraceae	VIGU	333	1	.					1	1	1
Toplanxix	<i>Melanthera aspera</i> (Jacq.) Small	Asteraceae	MELA	265	1	.					1	1	1
K'aniste'	<i>Pouteria campechiana</i> (HBK.) Baehni	Sapotaceae	POUT	269	1	.					1	1	1
Xeret'	<i>Centrosema schotti</i> K. Schum.	Fabaceae	CENT	310	1	.					1	1	1
Chak kanal	<i>Hamelia patens</i> Jacq.	Rubiaceae	HAME	245, 297	1	.						1	1
Toon toon tsimin	<i>Passiflora pedata</i> L.	Passifloraceae	PASS	309	1	.					1		
Telkox	<i>Phytolacca icosandra</i> L.	Phytolaccaceae	PHYT	311	3	3				1			
Paux	<i>Trema micrantha</i> (L.) Blume	Ulmaceae	TREM	242	3	.					1	1	1

Table 5.2. Species ranked as good and high quality firewood resources, included in this study.

Maya name	Species name	Family	Code ¹	Voucher ²
Kitamche'	<i>Caesalpinia gaumeri</i> Greenm.	Fabaceae	CAES	352
Boob	<i>Coccoloba spicata</i> Lundell	Polygonaceae	COCC	MEC 129
Tsalam	<i>Lysiloma latisiliquum</i> (L.) Benth.	Fabaceae	LYSI	270
X-Jochok	<i>Nectandra coriacea</i> (Lundell) Kostermans	Lauraceae	NECT	290
Ja'abin	<i>Piscidia piscipula</i> (L.) Sarg.	Fabaceae	PISC	MEC 255
Ja'as che'	<i>Alseis yucatanensis</i> Standley	Rubiaceae		MEC 322, 353
Chak ni' che'	<i>Ardisia revoluta</i> HBK	Myrsinaceae		MEC 54
Tsu'urontok	<i>Bauhinia divaricata</i> L.	Fabaceae		MEC 50, 55, 69, 135
Ch'fich' boob	<i>Coccoloba cozumelensis</i> Hemsl.	Polygonaceae		MEC 280, 355
Pe'eresk'uuch	<i>Croton arboreus</i> Millsp.	Euphorbiaceae		251, 256
Kokche'	<i>Croton icche</i> Lundell	Euphorbiaceae		307
Chi' kéej	<i>Crysophyllum mexicanum</i> T.S. Brandege ex. Standley	Sapotaceae		MEC 59
Ts'its'il ya'	<i>Dipholis salicifolia</i> (L.) A.DC.	Sapotaceae		MEC 140, 271
Sakloobche'	<i>Eugenia</i> sp.	Myrtaceae		MEC 83
Sak ya'ap	<i>Gliricidea sepium</i> (Jacq.) Steud.	Fabaceae		347
Taasta'ab	<i>Guettarda combsii</i> Urban	Fabaceae		292
P'ii	<i>Gymnanthus lucida</i> Swartz	Euphorbiaceae		363
Ts'its'il che'	<i>Gymnopodium floribundum</i> Rolfe	Polygonaceae		MEC 201
K'anasin	<i>Lonchocarpus rugosus</i> Benth.	Fabaceae		MEC 105
K'askáat	<i>Luehea speciosa</i> Willd.	Tiliaceae		MEC 86, 117, 168
Pichi' che'	<i>Psidium sartorianum</i> (Bergius) Niedenis	Myrtaceae		293
K'atal óox	<i>Swartzia cubensis</i> (Britton & P. Wilson) Standley	Fabaceae		350
K'anchunup	<i>Thouinia paucidentata</i> Radlk.	Sapindaceae		288
Sabakche'	Unidentified	Rubiaceae		284
K'an jóol	<i>Abutilon gaumeri</i> Standley	Malvaceae		MEC 68

¹ This code (first four letters of the genus name) is used to indicate species in Figures 5.3 to 5.5.

² All vouchers are S. Dalle's collection numbers, except those labeled MEC. The latter were collected during a concurrent study in Ejido X-Maben by Maria Eugenia Correa (Correa Cano 2004).

Table 5.3. Spearman rank correlations of fallow intensity with other site characteristics (n=25)

Variable	Spearman rank R
<i>Surrounding vegetation</i>	
% of milpa perimeter with mature forest	-0.616 **
Amount of mature forest in 500 m radius	-0.555 **
<i>Spared trees (all species)</i>	
Density	0.021 ns
Minimum dbh of spared trees	0.007 ns
Maximum dbh of spared trees	-0.835 ***
Average dbh of spared trees	-0.782 ***
<i>Density of vegetation</i>	
% plots with vegetation cover >90%	0.528 *
<i>Substrate</i>	
Rockiness	-0.485 *

*p<0.05, **p<0.001, ***p<0.0001, ns=not significant

Table 5.4. Descriptive statistics for diameter, density and basal area of spared firewood trees and stumps, and Spearman rank correlations with fallow intensity

Variable	Mean¹	Range	Spearman rank R
<i>Stumps</i>			
Minimum diameter (cm)	3.1	3-4	0.266 ns
Maximum diameter (cm)	15.4	6.1-33	-0.812***
Mean diameter (cm)	6.6	4.4-11.7	-0.761***
Density (stems/ha)	1212	300-2307	0.063 ns
Basal area (m ² /ha)	4.4	0.7-9.9	-0.770***
<i>Trees</i>			
Minimum diameter (cm)	6.0	2.2-11	-0.059 ns
Maximum diameter (cm)	19.7	4.5-42	-0.832 ***
Mean diameter (cm)	11.1	3.1-19.8	-0.801 ***
Density (stems/ha)	237	43.5-954	0.072 ns
Basal area (m ² /ha)	2.4	0.15-7.8	-0.611 *

¹Mean of estimates for each site (n=25)

*p<0.05, **p<0.001, ***p<0.0001, ns=not significant

Table 5.5. Summary of species' responses to fallow history, and associated characteristics

Species	Life form	Presence in mature forest ¹	% plots where occurred as resprout ²	Dispersal by animals ³
Long fallow cycles				
<i>Carica papaya</i>	Pioneer tree	–	0	*
<i>Trema micrantha</i>	Pioneer tree	–	2.5	*
<i>Vitex gaumeri</i>	Tree	+	91.3	*
<i>Lysiloma latisiliquum</i>	Tree	+	10.3	
<i>Acalypha unibracteata</i>	Shrub	–		
<i>Phytolacca icosandra</i>	Forb	–		*
<i>Cecropia peltata</i>	Pioneer tree	–	6.2	*
<i>Passiflora pedata</i>	Vine	–		*
Neutral response				
<i>Pouteria campechiana</i>	Tree	+	96.7	*
<i>Nectandra coriacea</i>	Tree	+	93.9	*
<i>Piscidia piscipula</i>	Tree	+	82.6	
<i>Coccoloba spicata</i>	Tree	+	90.0	
Short fallow cycles				
<i>Centrosema schotti</i>	Vine	–		
<i>Petrea volubilis</i>	Woody vine	+		
<i>Caesalpinia gaumeri</i>	Tree	+	94.1	
<i>Panicum</i> sp.	Grass	–		
<i>Psychotria nervosa</i>	Shrub	–		*
<i>Hamelia patens</i>	Shrub	–		*
<i>Euphorbia heterophylla</i>	Forb	–		
<i>Desmodium incanum</i>	Shrub	–		
<i>Melanthera aspera</i>	Shrub	–		
<i>Viguiera dentata</i>	Shrub	–		

¹ Based on a floristic inventory of different successional stages carried out in X-Maben (Correa Cano 2004) and field observations; + present, – absent in mature forest.

² For trees only; based on data from this study.

³ Species for which endozoochory is reported in the literature or assumed based on fruit type (fleshy fruits).

Figure 5.1. Schematic representation of Maya substrate types used to describe variation in edaphic conditions in this study. Grey fill indicates zones of soil accumulation. Local names are A=**kon kon lu'um**, B=**laja** or **tsek'el**, C=**wool wool tunich**, D= **ch'iich lu'um**, E=**k'ankab**. Types A-C tend to have high organic content, whereas types D and E tend to be redder in colour (corresponding roughly to lithosols and rendzinas respectively, Weisbach et al. 2002). The inset shows the relative position of each substrate type along the PCA axis which we defined as our rockiness index (ranging from sites with a high proportion of plots with less rocky types D and E, to those with a high proportion of plots with rockier types A and B).

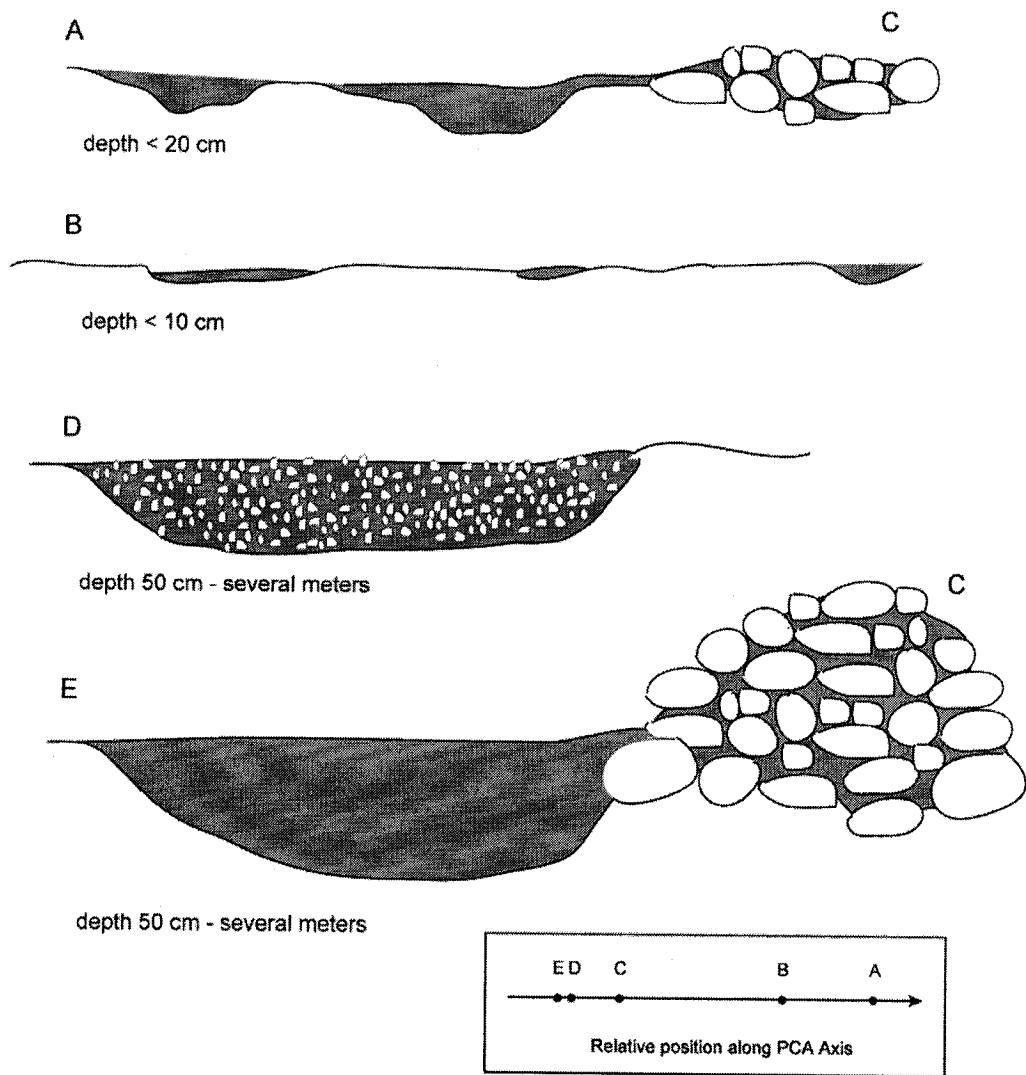


Figure 5.2. Scatterplots of average diameter, density and basal area against fallow intensity for spared stump (a-c) and spared trees (d-f). Data based on the 25 firewood species only.

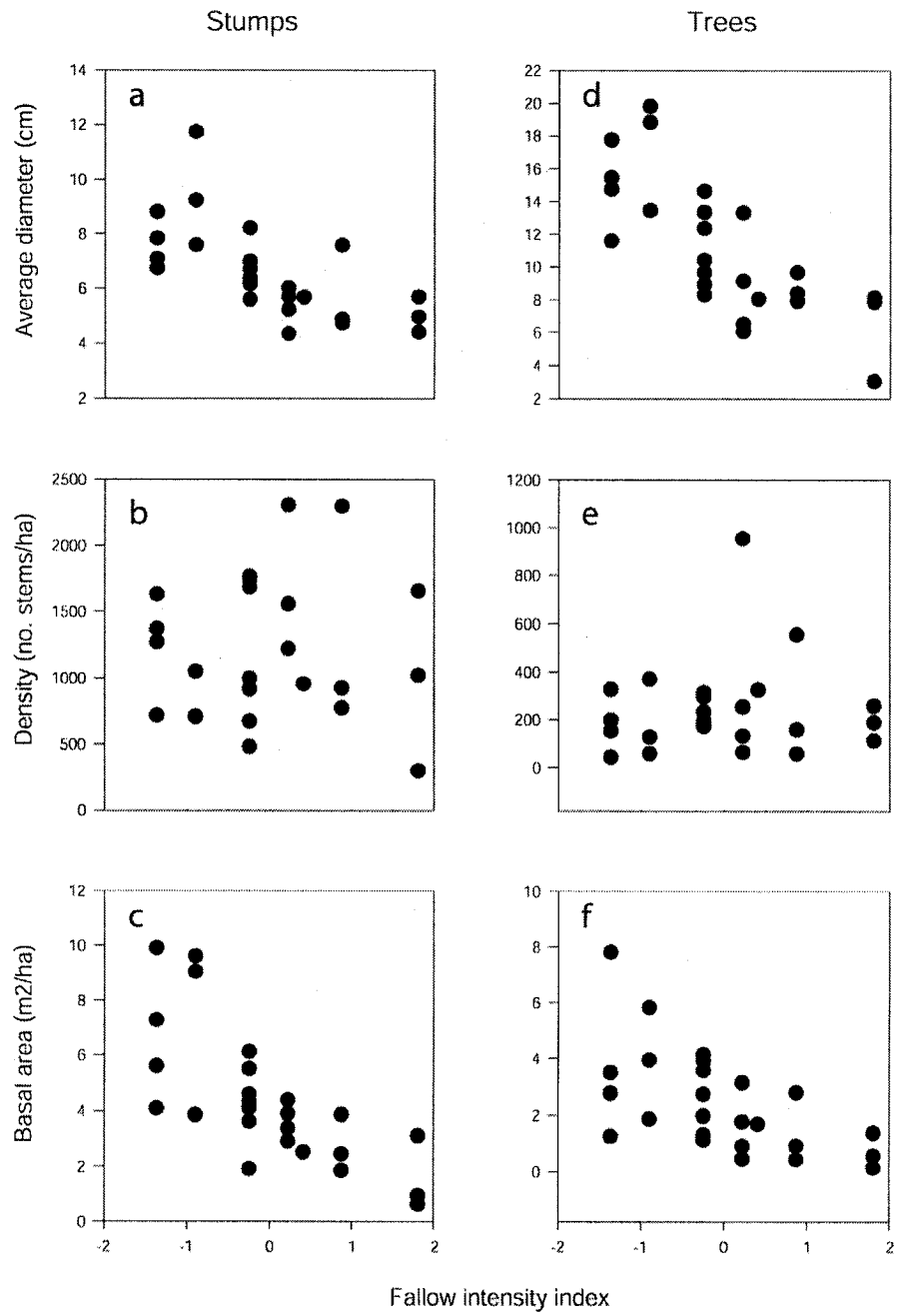


Figure 5.3. Range in relative frequency of 17 forage and 5 firewood species. Circles indicate the minimum and maximum relative frequencies observed for each species. Note that sites where species were absent were excluded. Species codes are the first 4 letters of the genus name (see Tables 5.1 and 5.2).

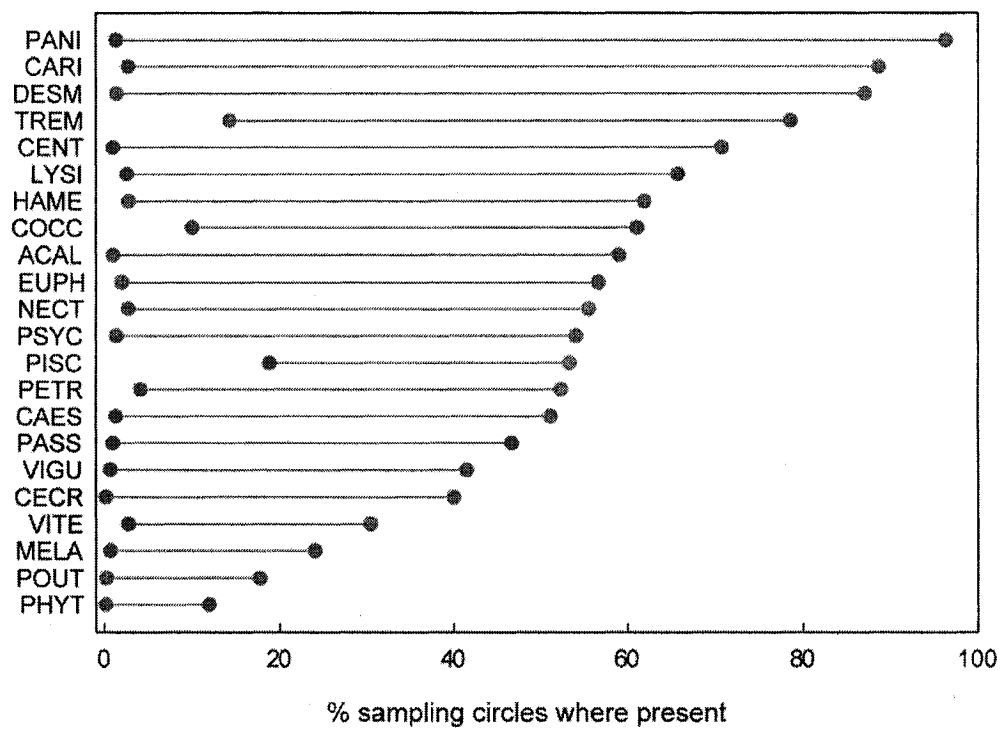


Figure 5.4. Correlation biplot from RDA of the relative frequency of 17 forage and 5 firewood species constrained by forest type (deciduous KL and evergreen YK), fallow intensity and rockiness. In this biplot, correlations between species and the quantitative explanatory variables (fallow intensity and degree of rockiness) are represented by the angle between their vectors, such that the smaller the angle, the stronger the association. The relationship of forest type with species or other quantitative variables can be inferred by projecting its centroid on the vector at a right angle; projections at more extreme ends of the vector indicate a stronger relationship between the variables. The length of a species' vector indicates the amount of its variation explained by the ordination. Species codes are the first 4 letters of the genus name (see Tables 5.1 and 5.2).

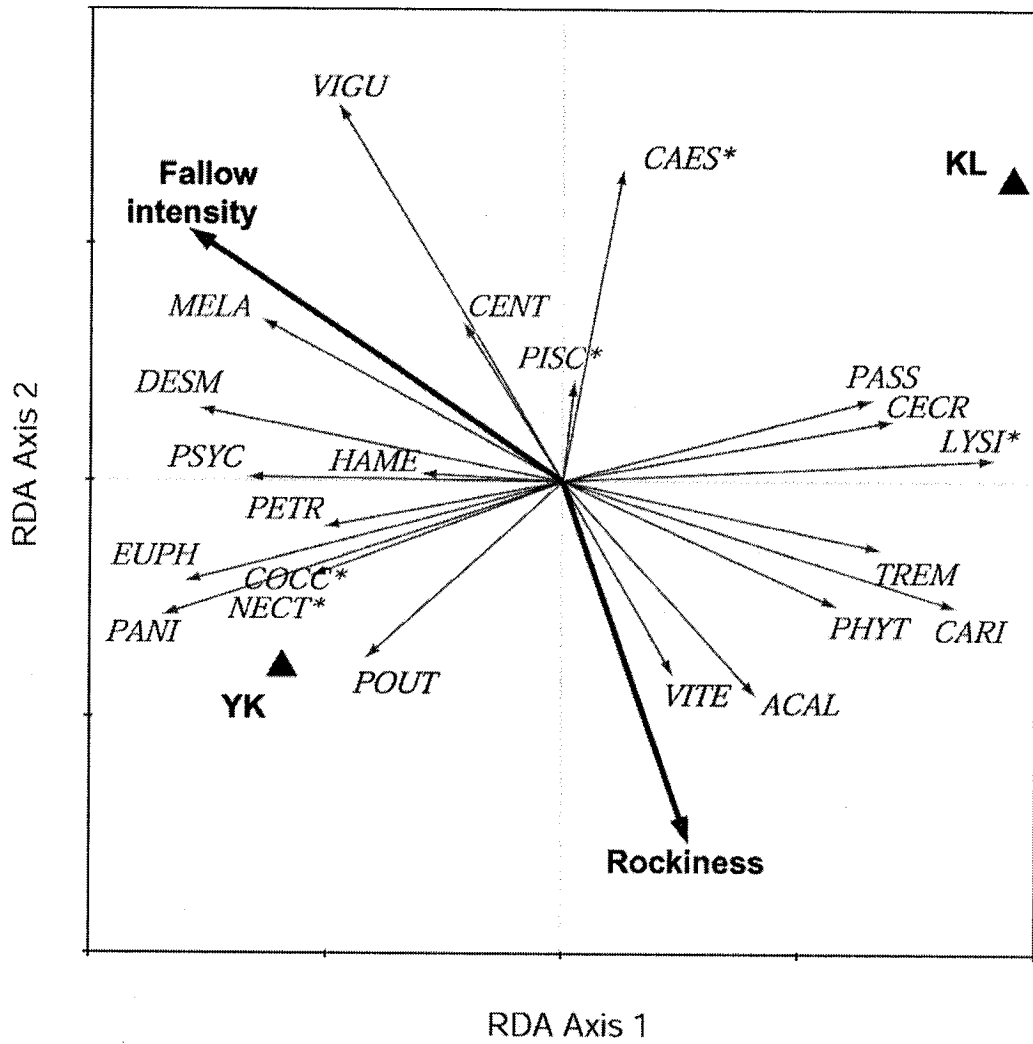
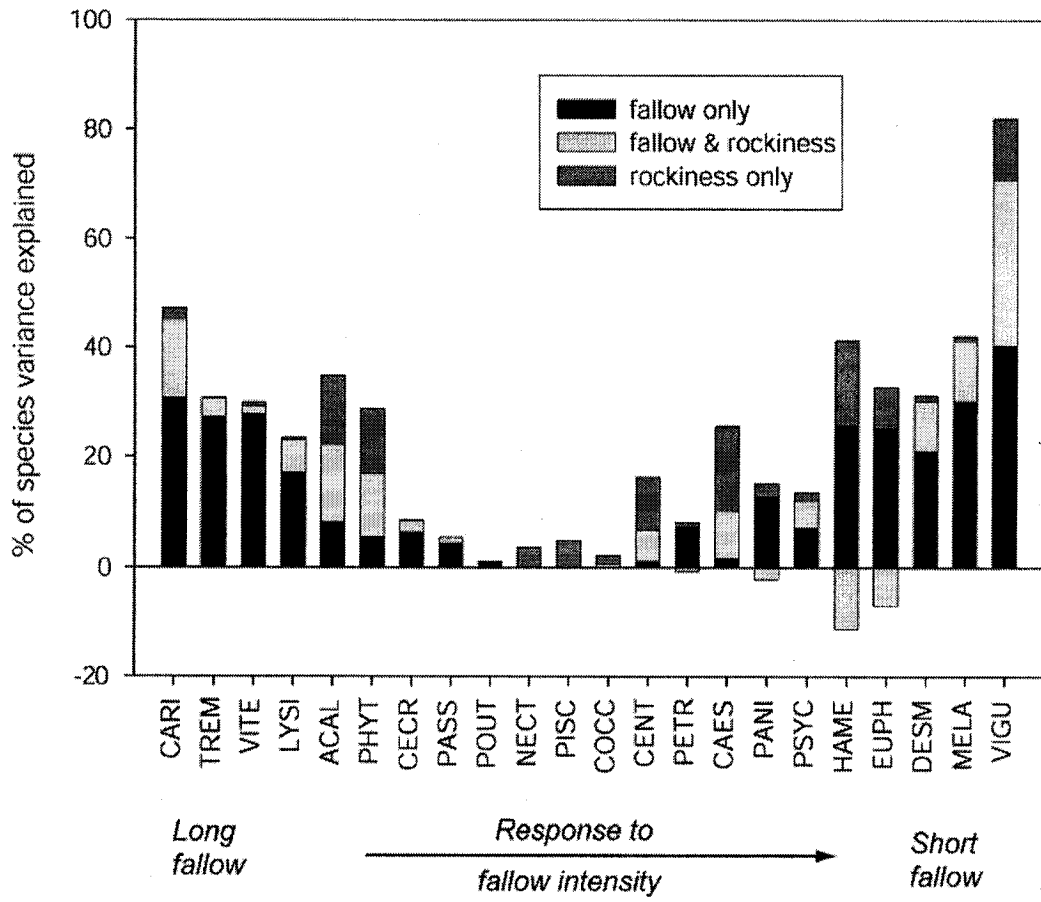


Figure 5.5. Percentage of species variation explained by three fractions: fallow intensity only (black), joint effect of fallow intensity and rockiness (light grey), and rockiness only (dark grey), after controlling for forest type. Species are arranged according to their response to the first two fractions. Negative values for the joint fallow-rockiness fraction occur in some cases because this fraction is calculated by subtraction rather than directly estimated (Legendre and Legendre 1998, p. 532). Species codes are the first 4 letters of the genus name (see Tables 5.1 and 5.2).



CHAPTER 6

Patterns of firewood use in a changing landscape: preliminary insights into household resource-use strategies

Introduction

In Chapters 4 and 5, I established that changes have occurred in the agricultural landscape of X-Maben. Chapter 4 showed that despite conserving large areas of forest cover, the most accessible areas used for agriculture have shifted from being a diverse mosaic of young to old successional stages in 1976, to a much more homogeneous landscape dominated by younger forests and shorter fallow periods in 2000. Furthermore, the results presented in Chapter 5 reveal that the short fallow milpas provide less firewood, and are poorer in certain forage species. Together, these findings suggest that access to plant resources in X-Maben has changed over the past 20 years, with those associated to older forest patches and to long-fallow milpas now being scarcer in the most accessible areas.

An important question that has not been sufficiently addressed in the ethnobotanical literature is how people's resource-use strategies respond to ecological change. Here I present data from a household survey and other field observations to describe current patterns of firewood use in X-Maben, and examine how these are related to the landscape changes described in this thesis. The findings presented provide some initial insights into the dynamics of resource use in this changing landscape.

Methods

In January 2004, a survey of 41 households was conducted in the largest village, Señor. Households were selected using a stratified random sampling design. The stratification was achieved by dividing a map of Señor into 13 strata, thus ensuring an even spatial distribution across the village. This was done since many of the well-established and better-off households are located in the centre of the village, whereas on the outskirts the families tend to be recent arrivals to the village and have more ready access to the surrounding village reserve (**jal pach kaaj**). A proportional sample of households was selected from each block. On the map, a "household" was defined as a

house-lot (demarcated by a stone enclosure, as is typical in the region). However, as discussed by Hostettler (1996, p. 231-232), households in the region can be nuclear or extended; in the latter case they may be dispersed among different dwellings. Therefore, at the time of the interview I determined the composition of the household, using as the main criteria those members who pooled resources and “ate out of the same pot”.

The questionnaire was a combination of structured and some open-ended questions, focusing on the following themes: (1) composition of the household, (2) economic activities, (3) domestic animals and use of forage plants, (4) milpa practices in 2003, and (5) sources of firewood. Here, data is presented from the last two sections only.

The questionnaire was tested with approximately four households before being applied. Interviews were carried out with the aid of a local assistant and were carried out in Maya and/or Spanish. In general, we visited each household twice in order to speak with both the senior man and woman. Typically we obtained information on milpa practices and firewood collection with the men, whereas women provided information on the composition of the household, domestic animals and use of forage plants.

Some data presented in this chapter is also supplemented with information collected in interviews with the owners of the milpas surveyed in Chapter 5, as well as observations made during the course of 12 months of residence in Señor.

Results

For the 2003 agricultural cycle, 90% of households (n=37) had milpas. Figure 6.1 shows the fallow times employed by 41 households in Señor. These figures pertain to the newly felled milpa in 2003 (**chak ben kool**), and do not refer to milpas from previous years (e.g. from 2002) cropped for an additional year, unless this was the only milpa planted. The results show that 75% of the households felled sites less than 20 y old, and that nearly 40% were less than 10 y old. The remaining 25% felled old secondary forest sites or deciduous **k'an lu'um k'áax** sites.

All households surveyed reported the use of firewood as a source of fuel. Only two households owned a gas stove, but even these relied on firewood for some of their cooking. Traditional underground ovens are used to cook for many rituals, village *fiestas*

and other special occasions and rely on large amounts of firewood. Firewood (mostly from *Piscidia piscicula* or **Ja'abin**) is also used in the cooler months of December and January by placing hot coals on the floor under the hammock to warm each person during the night. There is an internal market for firewood as some households buy their firewood (see below), as do some small enterprises in the village such as the bakery and the *polleria* which sells roasted chicken. Firewood is sometimes an important source of income for some of the most economically marginalized families.

In each interview, household members were asked where they had obtained their firewood in the last year (2003) and were asked to rank the extent they had used each source. Table 6.1 shows the principal sources of firewood reported by households in Señor. These data indicate that the family's current milpa was the most frequently cited principal source (38%) followed by forest (29%), which in most cases refers to one of the nearby village reserves. Other milpa-related habitats that were used were 1-yr old fallows, other people's milpas, and a new horticultural plot which had been used as milpa the previous year and in which firewood species had been spared. The remaining households either mostly bought their firewood from other people within the village, or collected it in secondary forests or forest burns (sometimes at the edge of the milpa).

Data on the last load followed a similar pattern, although fewer households obtained their last load from the milpa and more purchased it (Table 6.2). Of the households which collected (rather than purchased) their last load (n=33), 31.7% transported it by foot then by bicycle, 26.8% by foot only, 14.6% by bicycle only and 7.3% by truck (usually rented). The distance transported by walking varied between 200 m and 3 km, whereas the distance transported by bike ranged from 500 m to 6 km. In the three cases a truck was used to visit distant forest patches; the distances traveled were 6, 12, and 18 km. While I refer to bikes here in general, cargo tricycles are frequently used for transporting firewood and other loads.

Given the variability in sources used for firewood, I examined whether the availability of firewood in the family's milpa influenced whether the milpa was used or not as the main source. Based on the findings in Chapter 5, I expected that milpas derived from older forests should be more frequently used as a source of firewood, since these have more firewood. However, the relationship between the principal source of

firewood (family's milpa vs. other sources) and the age felled for the main milpa was not significant (Mann Whitney $W=243$, $p=0.19$), although as is evident in Figure 6.2, there is a trend for short-fallow rather than long fallow milpas to have been used as a principal firewood source. Field observations suggested that the ease of access to the family's milpa could be more important than the amount of firewood available in the milpa. To test this, I created an accessibility index consisting of a weighted sum of the distance traveled by foot, by bike or tricycle, and/or by motorized vehicle to get to each household's milpa, in which a higher weight was assigned to the distance traveled by foot, and a lower weight to that traveled in bus or truck. As expected, a significant relationship was found between the ease of access to a milpa, and the use of the milpa as the main source of firewood (Mann Whitney $W= 182$, $p=0.001$).

Discussion

Households in Señor obtain their firewood from a variety of different sources, with the milpa and the nearby conserved forest patches being the most important. The use of a diversity of sources is consistent with another study of firewood use by Maya households in the state of Yucatan (Sánchez González 1993), although in that study the main sources used were secondary forests, milpa and the homegarden, which over one year provided 57, 30 and 14% respectively of the volume of firewood collected by the five families studied.

Ecological studies in ethnobotany frequently assess the productivity or availability of resources in different land-uses or forest types, and it is sometimes assumed that use of a given habitat should be related to the availability of the resource. In Chapter 5, I found that long-fallow milpas have higher amounts of standing firewood, and expected that this might encourage their use as a source of firewood. In contrast, here I found that accessibility was a key factor determining use of milpa as a main source of firewood, and these tended to be short rather than long-fallow milpas. In fact, in interviews some people mentioned that the ease in accessing firewood (along with other harvests) was one reason for choosing to fell young fallows. While resources difficult to transport, such as firewood, are more likely to be influenced by accessibility, this

emphasizes the importance of considering the structure of the landscape in understanding patterns of resource use.

One consequence of these findings is that the accessible areas with the least amount of firewood (short-cycle milpas) are the ones experiencing the highest harvesting pressure. This was corroborated by data from the survey of 1.5-year old milpas (Chapter 5) in which the most accessible milpas we studied had a very high proportion of stumps that had been cut for firewood. Because of this, conflicts have arisen in Señor over access to firewood in closeby milpas. Owners of such sites often prohibit others from cutting firewood in their milpas (I was told of one case where a woman “caught” in another milpa by the owner had to leave the load she had already cut). However, this protectionism appears to be contingent on the potential for overharvesting by outsiders. For example, my field assistants often opportunistically cut firewood in other milpas where we were working, claiming that there was no problem because as they said “*está lejos*” (it’s far).

For families with no or only distant milpas, forest patches – including mature, secondary and burned forests – provide alternative sources of firewood. The conservation of nearby forest patches such as the village reserves (**jal pach kaaj**) and COPLAMAR reforestation project (Chapter 4) thus appears to enable those families who are able and/or willing to fell distant sites (often long fallow-milpas). In this sense, the little diversity remaining in the accessible landscape (Chapter 4) appears to facilitate the maintenance of diverse land-use strategies among households in Señor. However, the drastic reduction in forest cover in the areas surrounding Señor (Chapter 4) and reportedly more degraded state of the remaining forest patches means that these are probably less important as a source of firewood than they might have been in the past. In interviews, many people claimed to have made more frequent use in the past of the **jal pach kaaj** and other forests (including forest burns) to meet their firewood needs.

Use of bicycles, tricycles and trucks have certainly eased some of the problems of this increasingly degraded resource base by increasing access to distant locations (Table 6.3). Today, nearly all households in Señor have access at least to a bicycle or tricycle, and this enables access to areas at least 3-6 km away. Trucks tend to be contracted in order to extract several months’ worth of firewood, especially in more distant forests.

However, such options may be more limited for certain segments of the population with less access to cash income (to contract trucks or purchase firewood) or less mobility (e.g. women or older people who do not ride bicycles). Finally, access to an internal firewood market may be another way in which increased scarcity of firewood can be dealt with. Nonetheless, my observations suggest that this is more related to economic activities and labour limitations, with purchasing of firewood being relied upon at times when much household labour is dedicated to cash-generating activities.

Conclusion

This preliminary portrayal of firewood use in X-Maben reveals that accessibility is an important factor influencing household patterns of firewood use, and likely accentuates the consequences of reduced firewood availability in what is now a less diverse and intensively-used agricultural landscape. At the same time, the landscape diversity which has been conserved, as well as means to increase access to more distant firewood sources, seems to provide households a certain amount of flexibility in dealing with this increasingly degraded resource base. The ability of different households and segments of the population to access these alternatives may vary, and should be the focus of additional research.

Table 6.1. Percentage of households reporting different sources of firewood as their principal source, and the source of the last load obtained. Standard errors are given in parentheses.

Source	Principal source 2003	Last load
Family's milpa (2003)	38.1 (7.4)	
Other milpa-related environments*	11.9 (5.0)	
TOTAL (All milpa-related habitats)	50.0 (7.7)	36.5 (7.5)
Secondary forest, burned forests, edge of milpa	9.5 (4.5)	12.2 (5.1)
Forest (village reserves)	28.6 (7.0)	31.7 (7.3)
Purchased	11.9 (5.0)	19.5 (6.2)

*1-yr fallow, other people's milpas, horticultural plot

Table 6.2. Distance (in meters) traveled to transport last load of firewood (n=33)

	Foot and bicycle		Foot only	Bicycle only	Truck
	<i>Foot</i>	<i>Bike</i>			
	<i>portion</i>	<i>portion</i>			
Min	200	500	300	500	---
Max	2000	6000	3000	6000	---
Mean	685	2538	1055	3083	---
Standard error	173	422	242	712	---
N		13	11	6	3
%		39.4	33.3	18.2	9.1

Figure 6.1. Number (bars) and cumulative percentage (line) of households reporting different fallow times for their main milpa in the 2003 agricultural cycle. The cumulative percentage refers only to households with milpa (n=37).

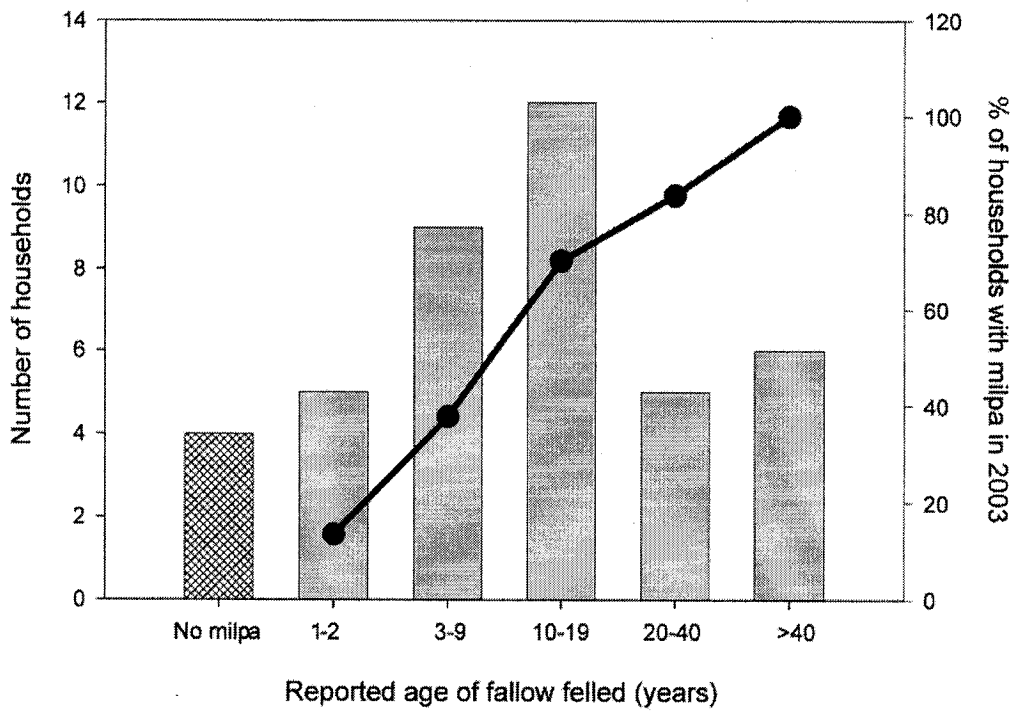
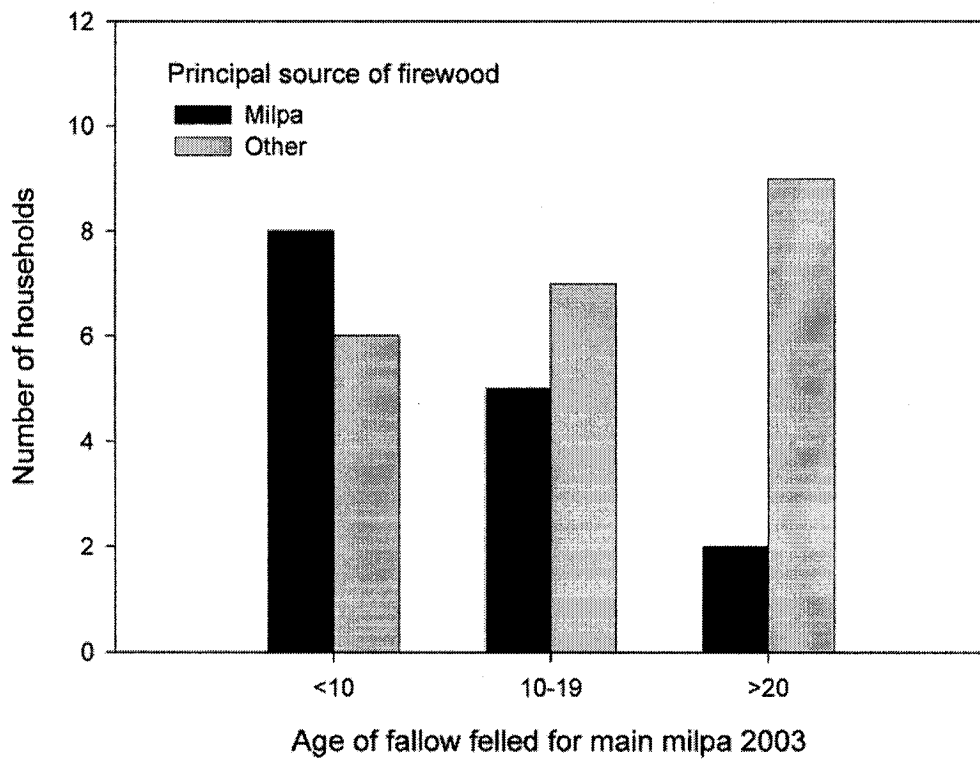


Figure 6.2. Bar graph showing trend for short-fallow milpas being more frequently used as a principal source of firewood. Note that this relationship is not statistically significant (Mann Whitney $W=243$, $p=0.19$).



CHAPTER 7

Discussion and conclusions

This thesis has examined the dynamics of land-use change and wild plant resources in the Maya ejido of X-Maben in Quintana Roo, Mexico. The overall goals of the thesis were twofold. First, due to the nearly 20 years of experience of community forestry, the regional interest in conservation of the so-called “Maya forest”, and concern for promoting sustainable livelihoods among the resident communities, I aimed to gain a better understanding of the implications of forest conservation for the management and use of wild plant resources, an aspect of peasant livelihoods which is often overlooked by development planners (Mazhar and Buckles 2000, Pinedo-Vazquez et al. 1992). Second, on a theoretical level my goal was to consider the significance of employing a landscape perspective for examining dynamics of plant use and resource management in ethnobotany. Below I provide a summary of the findings and contributions of each chapter presented in the thesis, followed by a discussion of the significance of the case study for each of these two overall goals.

Chapter Summaries

In Chapter 3, I explored gender differences in the perception and knowledge of plant resources obtained from milpas, fallows/secondary forests and mature forests. Within the context of the thesis, my aim was to identify plant resources considered important by inhabitants of X-Maben. This information was used to select resources to study further in terms of their response to land-use changes (Chapters 5 and 6). Because women’s concerns and priorities regarding natural resources are often overlooked in both research and development projects, I specifically examined gender differences. The findings indicated that perceptions regarding the importance of plant resources reported by the men and women’s focus groups were markedly different: men attributed highest importance to commercial forest products such as valuable timbers, chicle, and railroad ties, while those resources most highly valued by women were used frequently in the domestic realm, and were derived from both agricultural and forest environments. Furthermore, the results suggest that while men appear to have a broad ecological and

associated ethnobotanical knowledge, often mentioning large numbers of species, women's knowledge may better indicate those resources most commonly used in the household. In the ethnobotanical literature, analysis of gender has been limited for the most part to quantifying the number of uses known by men and women. While this study is clearly exploratory, being based on a limited sample size (1 focus group for men and women each, of between 5 and 10 participants), it represents a significant contribution by pointing out more qualitative differences in the type of knowledge and perceptions held by men and women which could be further investigated in future studies and community development initiatives

While Chapter 3 set the stage by identifying wild plant resources valued by the Maya population in X-Maben, Chapter 4 delves into analyzing the spatial and temporal dynamics of change in the land-covers from which these resources are obtained, and examining the rules and regulations motivating the overall trend of forest conservation on the ejido. The results indicated a high degree of forest conservation on community lands with net rates of forest loss of 0.6-0.7% per year. However the most accessible parts of the landscape underwent important changes, which shifted from being a diverse mosaic of young to old successional stages in 1976, to a much more homogeneous landscape dominated by younger forests and shorter fallow periods in 2000. Data collected on the local land-use rules and regulations indicated a long history of local conservation initiatives, starting around the time of the ejido grant in the 1950s with the protection of dense chicle stands and eventually being expanded to include other commercial forest products associated with a more evergreen forest community (**yáax k'áax**) recognized by the local Maya population. In addition a number of locally declared forest reserves were reported. The progressive restriction on felling the more evergreen forest type was borne out in the spatial data, which showed a decrease in the amount of this forest type felled in the 1988-1997 time period, as opposed to 1976-1988. Furthermore, I demonstrated that the area defined in the mid 1980s as the permanent forest area (PFA) in the context of the Plan Piloto Forestal mostly corresponds to the more distant traditional chicle harvesting grounds, whereas forest patches conserved in the most accessible parts of the ejido include customary village reserves, a reforestation project, and other chicle stands outside of the PPF. These findings provide considerable

insight into some of the forces influencing forest conservation in X-Maben, and more generally provide evidence that local land-use regulations have resulted in active conservation. Furthermore, the results draw attention to the fact that high rates of forest conservation can be accompanied by increased pressure on other land-uses, and suggests that the potential for conflict in these situations should be monitored.

In Chapter 5, I examined the effect of one of the landscape changes found to have occurred in the more accessible areas of X-Maben – shorter fallow times – on the availability of two plant resources obtained in the milpa and particularly valued by women: forage and firewood. Based on a survey of 26 fields of the same age (~1.5 y) but differing in the length and frequency of past fallow cycles, I show that fallow history is a significant factor explaining the highly variable frequency of 17 forage species, with some responding positively and others negatively to shorter fallow periods. Furthermore, standing firewood in the form of spared stumps and spared trees is shown to decrease significantly in short fallow cycles. This manuscript represents an original contribution to the literature on shifting cultivation systems in two ways. First, although it is frequently believed (albeit not well tested) that crop yields decline as a consequence of shortened fallow times, few studies have focused on the fate of non-crop plant resources. By showing that these are also affected, the paper raises the question of how such changes may be dealt with by communities that depend on these resources. Second, the paper identifies some of the ecological processes potentially driving resource availability in short-fallow cycles, thereby identifying hypotheses for future research. Representing one of the few studies which investigates the effect of fallow history on succession processes, and more generally adding to the limited studies available for succession in tropical dry environments, this paper contributes in a significant way to the literature on succession in shifting cultivation systems.

Finally, in Chapter 6, I described patterns of firewood collection based on data from a survey of 41 households in Señor. The data show that households obtain firewood from a variety of sources, with the milpa and nearby forest patches being the most important. I found that accessibility is a significant factor affecting patterns of firewood collection, with the consequence that the areas with the least amount of firewood available (short-fallow milpas and reduced forest cover, as demonstrated in

Chapters 4 and 5) are those which experience the highest collection pressure. Transportation of firewood with tricycles and especially trucks has probably alleviated this problem to a certain degree by increasing access to firewood in more distant areas of the ejido, however these are not equally available to all segments of the population. These findings indicate that the land-use/land cover changes in the immediate landscape have led to an increasingly degraded resource base and could have significance for local livelihoods.

Emerging Themes

While each of the chapters described above provides a unique contribution to the specific theme addressed (gendered knowledge, land-use dynamics, succession processes, resource use), taken as a whole the case study presented in this thesis provides significant insights into the dynamics of resource use and management in the landscape, and for the development of community forestry programs. These are discussed in the sections that follow.

Indigenous territories as dynamic and heterogeneous scenes of land and resource use

This thesis has provided substantial evidence of change and heterogeneity in several aspects of land and resource use on this indigenous territory. For example, the agricultural landscape in X-Maben has become much less diverse in terms of land cover, now being dominated by young secondary vegetation and short fallow periods (Chapter 4), resulting in reduced availability of firewood and some forage species (Chapters 5 and 6). In addition, I also found that land-use regulations changed progressively over a 40 year period, responding to shifting perceptions on what is worth conserving (Chapter 4), while patterns of firewood collection appear to be changing with less reliance on nearby forest and greater use of various vehicles and access to an internal firewood market (Chapter 6). Furthermore, use of the landscape was found to vary spatially, with both agricultural activities and firewood collection being more intense in the more accessible areas (Chapters 4 and 6). Together, these findings are testament to a complex process of change and adaptation, which exemplifies that indigenous territories and patterns of resource-use can indeed be quite dynamic.

In large part, this dynamic view of resource use emerges from what I have termed here a “landscape approach” to ethnobotany. Typically, ecological studies in ethnobotany have focused on specific resources or productive units, and more emphasis has been given to examining the influence of harvesting practices (see Ticktin 2004 for a review) than of land-use dynamics on wild plant resources. On the other hand, studies of wild plant use have only begun to examine how different components of the landscape are used and managed to meet household needs. This thesis is original in that it considers the use and value of resources from several landscape units (milpas, fallows and forests) and their dynamics over time and in space. Figure 7.1 summarizes some of the interactions between land-use practices at different scales and wild plant use dynamics which were revealed by this approach. In this view, the spatial and temporal dynamics of the landscape are a result of conservation rules and regulations developed at the ejido scale, and of household-level decisions regarding milpa practices. The resulting landscape determines the distribution and abundance of resources, which in turn influences patterns of wild plant use. In this sense, the availability and use of non-crop plant resources is seen as functioning within a broader context of land-use. However, the case study also provides evidence of feedbacks between wild plant use and land-use practices. For example, I found that the value attributed by men to commercial forest products (Chapter 3) was an important motivation for the development of conservation rules (Chapter 4), while access to firewood was reported as a factor encouraging the use of short fallow cycles (Chapter 6). Although not examined in this thesis, wild plant-use can also feedback on resource availability, for example through harvesting practices (Ticktin 2004), transplanting or other management practices oriented at individual plants (Alcorn 1981, Casas et al. 1996). Finally, wild plant use, conservation rules, and milpa practices are all influenced by a number of social, cultural, economic and political factors (Figure 7.1).

This landscape view of resource use contextualizes management practices by considering the influence of various (and sometimes competing) factors. For example, it has sometimes been observed that the diversified economic and resource use activities of many indigenous communities results in a land-use system which often maintains or promotes diversity in the landscape (e.g. Toledo et al. 2003, Turner et al. 2003). Thus, in

X-Maben, access to various domestic and commercial forest products, as well as a need to maintain a buffer around the village to deter domestic animals from entering surrounding milpas, has motivated the conservation of the **jal pach kaaj** and other accessible forest patches (Chapter 4). Yet seemingly contrary to this, changing demographic, economic and social circumstances have led to a homogenization of the shifting cultivation landscape (Chapter 4). This example illustrates how resource and land management are the result of diverse and interacting processes, and demonstrates the value of the integrated view of resource use which emerges from the landscape approach adopted in this thesis.

Implications for community forestry and biodiversity conservation

As demonstrated in Chapter 4, and coinciding with available regional-level studies (Bray et al. 2004, Duran et al. 2005), X-Maben and other similar ejidos in central Quintana Roo have been successful in conserving forest cover. A second major contribution arising from this thesis are several insights which help to better understand the dynamics of forest conservation in X-Maben. More generally, these have relevance for community forestry and other initiatives which aim to promote the conservation of community-controlled forests while contributing to the improvement of local livelihoods.

One of the most important contributions of this study is its attention to dynamics in the agricultural areas within the context of community forestry and conservation. Indeed, while a growing literature focuses on evaluations of such programs, few have considered how agriculture or other important land-uses have evolved in these circumstances. The findings from this thesis revealed rather drastic reductions in older forest patches (Chapter 4) and effects on the availability of resources such as firewood (Chapter 5), in an otherwise highly conserved forested landscape. While these trends are certainly not due only to forest conservation, this increased pressure on the agricultural areas could conceivably compromise incentives for conservation on the long term or present difficulties for those sectors of society less able to deal with these ecological changes.

Based on these findings, a general recommendation for community forestry initiatives would be to consider the requirements of diverse land-uses which contribute to

local livelihoods. As findings from Chapter 3 emphasize, consultation with diverse sectors of the community, including women, is important to identify these varied needs. In X-Maben firewood needs could be better met by the conservation of more proximate forest patches; findings from Chapter 4 indicate that the planting of commercial forest species in fallows currently being practised in the region might be one way in which this could be achieved.

Another important insight comes from evidence which suggests substantial initiative and self-determination on the part of the Maya communities in managing their lands. As discussed in Chapter 4, outside programs and interventions have certainly influenced land-use practices and dynamics, however these interact with endogenous processes (e.g. existing social institutions, cultural perceptions, established patterns of land use, demographic trends etc.). These findings imply that the role of such internal factors in contributing to the success of a program in one area should be carefully considered in adapting the same model to other contexts (Chapter 4).

It is also evident from this study that encouragement of certain land-uses and management practices to promote one component of biodiversity may represent a trade-off for others. For example, commercial forestry and other “enterprise” strategies for conservation (Salafsky et al. 2001) aim to encourage forest conservation by increasing cash income derived from forest products. In X-Maben I found that value attributed to commercial forest products by men (Chapter 3) was indeed an important incentive for conservation (Chapter 4). However, the flip side of this is that forest types poor in such valued species (namely the more deciduous **k’an lu’um k’áax**) are less likely to be conserved. Similarly, policies promoting shorter fallow times as a means to reduce pressure on forests can be seen as “trading off” components of biodiversity associated to long-fallow milpas. Although early successional species are often considered of low importance to regional conservation as compared to late successional species (Finegan and Nasi 2004), some, such as wild *Carica papaya* in this study, may be wild crop relatives and may represent important genetic resources.

Importance of analyzing local knowledge, perceptions and values: contributions of an ethnoecological approach to land-use research

While one of the objectives of this thesis was to consider the value of adopting a landscape approach to examining resource dynamics in ethnobotany, in several instances this thesis illustrates that an ethnoecological approach, which considers the interaction of people's belief and knowledge systems with the modes of use and management of natural resources (Toledo 1992), can contribute important insights and methodological tools for landscape-ecological research.

Perhaps the most notable example of this comes from Chapter 4 in which I found that a recognition of the folk classification of forest types was essential for understanding local conservation practices which protect the more highly valued evergreen **yáax k'áax** forest type, while agricultural expansion continues on the more deciduous **k'an lu'um k'áax**. This insight only became obvious once I became familiar with the Maya terms and their application. Indeed, although most researchers, foresters, and other outsiders use the Spanish term *monte alto* (literally "high forest") to designate all mature forests, for the local Maya population this is synonymous to the **yáax k'áax** forest type only. Thus, when researchers ask questions about *monte alto* or outside agencies (such as PROCAMPO) encourage farmers to conserve *monte alto* they are often not aware that for the local Maya this excludes **k'an lu'um k'áax**. While in Chapter 4 I find that this insight is important for understanding the land-use dynamic, more generally it highlights the importance of understanding culturally-defined perceptions in land-use research.

Attention to local ecological knowledge was also fundamental to the way in which I examined the impact of changing fallow times on plant resource availability (Chapter 5). Indeed, the question itself arose through informal conversations with local farmers: early in my fieldwork, when asking about variation in the species composition of early successional vegetation I was told "*ah porque esta milpa es de monte alto*" (oh, because this milpa was felled from mature forest). Further conversations revealed substantial local knowledge about species which regenerate after different fallow times and their uses (several being forage). Yet in the literature I found very few studies examining plant succession in relation to fallow history. Later, stratification of the sample sites according to the locally recognized community types (**yáax k'áax** vs. **k'an**

lu'um k'áax) and characterization of the unusual karstic substrate types using the Maya classification allowed me to statistically remove these confounding factors from the data, thereby isolating the effect of fallow history. For both soils and vegetation, the local Maya classification better reflected fine-scaled variations in the study area and was more practical to implement than available scientific classifications (see Barrera-Bassols and Toledo 2005 for a discussion of this point). Use of local knowledge therefore enabled a more effective characterization of the local environment. It should also be noted that local knowledge was critical for determining the fallow histories of the study sites, and may be one reason that the effect of fallow history has so infrequently been examined in the ecological literature on shifting cultivation.

Finally, local perceptions of wild plant resources, and in particular gender differences in these, were examined in Chapter 3. In the initial conception of this project, this was done to identify important plant resources to study in terms of their response to land-use change (Chapters 5 and 6). The markedly different perceptions of importance between men and women found in Chapter 3 prompted me to focus the research presented in Chapters 5 and 6 on two resources primarily valued by women, forage and firewood. This approach in my research is significant in that it addresses criticisms of bias towards male priorities in both ethnobotanical research and natural resource management (Fortmann and Rocheleau 1984, Howard 2004, Johnson 2004).

In sum, the attention to local knowledge and perceptions significantly improved the quality and significance of this thesis by providing insights into land-use practices, generating novel research questions, improving sampling designs and better representing concerns of the local population.

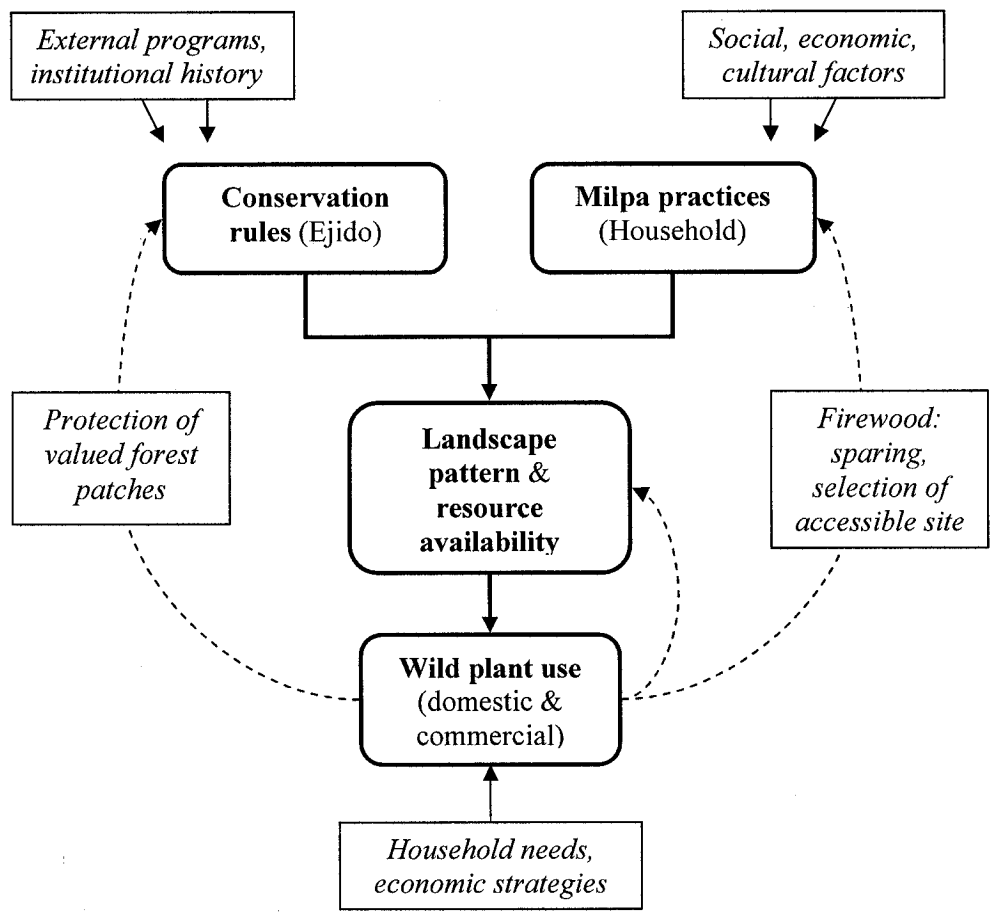
Future directions

This thesis has made important contributions to examining the dynamics of resource use in the landscape, as well as improving understanding of shifting cultivation and forest conservation on community lands. In part, the accomplishments of this thesis are based on an integrative approach which simultaneously examined the dynamics of several land-uses and resources, drawing on concepts and methods from both landscape- and ethno-ecology.

The core of this thesis focused on examining landscape and ecological dynamics related to resource availability and use, while considering the influence of local knowledge, perceptions and institutions on these. However, as shown in Figure 7.1, a number of other social, economic and political factors also influence the landscape and resource use dynamics examined in this thesis. By acknowledging these, the thesis has posed a number of questions that could be pursued in further research. These include the role of women or less powerful sectors in influencing land-use decisions (Chapter 3), and the ways in which differentiated households respond to ecological changes (Chapters 5 and 6). Further research could also address the relative role of conservation programs and demographic or other economic factors in contributing to increased pressure on the agricultural landscape (Chapter 4), while in Chapter 5, I provide a number of alternative hypotheses that could be tested to better understand the responses of different species to changing fallow times. While many of these questions require more detailed disciplinary research, the approach adopted here has proven an effective means for generating relevant research questions within the context of an integrative model of land and resource management.

In conclusion, this thesis has provided a model for ethnoecological landscape research, and in so doing has generated important insights for understanding resource use in tropical landscapes. I encourage continued interaction between disciplinary and integrative approaches with the aim of contributing to more equitable natural resource management on community lands.

Figure 7.1. Schematic representation of the interaction of landscape practices and wild plant use dynamics, based on the case study of Ejido X-Maben presented in this thesis.



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**Certificate of Ethical Acceptability for
Research Involving Humans**

Project Title: Ethnobotanical diversity in changing landscapes in Quintana Roo, Mexico #823-0603

Applicant's Name: T Johns/ Dalle S

Supervisor (if applicable):

Reviewers: Committee

Type of review: Expedited review

Comments: The project was approved without need for correction

DECISION: Approved

**Peter Jones, Chair
Research Ethics Committee
Faculty of Agricultural and Environmental Sciences**

June 30th, 2003

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