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Invasion of Bracken Fern in Southern Mexico: Local Knowledge and Perceptions in Two Indigenous Communities in the Chinantla Region, Oaxaca, Mexico

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INVASION OF BRACKEN FERN IN SOUTHERN MEXICO: LOCAL KNOWLEDGE AND PERCEPTIONS IN TWO INDIGENOUS COMMUNITIES IN THE CHINANTLA REGION, OAXACA, MEXICO

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by

Carolina Berget

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To: Dean Kenneth G. Furton
College of Arts and Sciences

This thesis, written by Carolina Berget, and entitled Invasion of Bracken Fern in Southern Mexico: Local Knowledge and Perceptions in Two Indigenous Communities in the Chinantla Region, Oaxaca, Mexico, having been approved in respect to style and intellectual content, is referred to you for judgment.

We have read this thesis and recommend that it be approved.

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Date of Defense: July 12, 2012

The thesis of Carolina Berget is approved.

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Dean Lakshmi N. Reddi
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Florida International University, 2012

DEDICATION

To nature's resilience and its inherent capacity to return to a state of equilibrium after the occurrence of disturbances and perturbations…….

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ABSTRACT OF THE THESIS

INVASION OF BRACKEN FERN IN SOUTHERN MEXICO: LOCAL KNOWLEDGE AND PERCEPTIONS IN TWO INDIGENOUS COMMUNITIES IN THE CHINANTLA REGION, OAXACA, MEXICO

by

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Miami, Florida

Professor David Bray, Major Professor

The purpose of this thesis was to investigate the local knowledge and perception regarding the invasion of bracken fern in two indigenous communities located in the Chinantla region, southern Mexico. Bracken fern, *Pteridium aquilinum*, has invaded the hillsides that surround the two villages of the study site. The use of structured and informal interviews found that although bracken fern is not perceived as a major problem in the study site, it is of concern to the farmers living there, since the majority of the soils in the invaded lands are not of sufficient quality to cultivate corn. However, yucca and pineapple crops can be grown in the invaded areas, and the cultivation of these control bracken's invasion. Farmers know that restoration of these areas is possible, but they perceive that it is a time consuming and labor demanding process. Suggested management of invaded areas includes firewood/timber extraction, agroforestry and refuge sites for wildlife, especially for two mammals' species currently under threatened status by the IUCN.

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INTRODUCTION

Much of the research on biological invasions has focused on the ecological consequences and effects on ecosystem services and structure, environmental productivity, biodiversity, among other factors directly related to ecosystem's function (Schneider 2004). Less focus has been provided in addressing the biological invasion's dynamics involved in the coupled human-environment systems, in which the "biological nature of plant invasions is explicitly linked to social, economic, and cultural causes of land transformation" as Schneider (2004) explains. More often than not, invasive species have been considered as an environmental issue and in consequence have not received much attention as a major threat to local livelihoods, particularly to agriculture and thus food security in developing countries (GISP 2008).

This thesis investigates the local knowledge and perception regarding bracken fern invasion in two indigenous communities located in the Chinantla region of Oaxaca state in southern Mexico. Mexican agrarian reform laws growing out of the Revolution of 1910, created an ample rural sector of self-governing communities, under the *comunidades* and *ejidos* systems with varying levels of democracy among them (Bray et al. 2003). The *comunidades* are pre-existing indigenous communities that have been given legal tenure of communal land and resources which they have traditionally inhabited and used, whereas *ejidos* are agrarian units of peasants (*campesinos*) who were collectively granted a parcel of land and access to resources for which they did not have prior legal claim (Martin et al. 2010, Nieratka 2011).

In the Sierra Norte of Oaxaca, six *comunidades* joined together to create an organization known as the Regional Natural Resource Committee of the Upper Chinantla (*Comité Regional de Recursos Naturales de la Chinantla*) or CORENCHI (Bray et al. forthcoming). The purpose of CORENCHI is to seek official recognition of traditional conserved territories as the Indigenous/Community Conserved Areas (ICCAs) (Borrini-Feyerabend 2004), or voluntary conservation areas (VCAs) as they are legally known in Mexico, and specifically to get certified by the Mexican Natural Protected Areas Commission (CONANP) (Nieratka 2011). CORENCHI's total area is 34,907 ha, of which 26,770 ha have been certified as ICCAs, the largest single block of certified ICCAs in Mexico (Bray et al. forthcoming).

My study will focus on two of the six CORENCHI communities, Santiago Tlatepusco and San Pedro Tlatepusco, which currently have some areas covered by a combination of three invasive plant species: two fern species and one grass species. Of these three species the most abundant in the invaded areas was identified in the field as bracken fern (*Pteridium aquilinum*). Unfortunately, the other two species (known locally as *helecho* and *camalote*) could not be identified in the field, and since these communities do not allow the extraction of any type of plants or animals, samples could not be taken out for taxonomic identification. From personal observations in the field and from information gathered from informal interviews, there is an apparent association between bracken and the two other invasive species, in which bracken is present simultaneously with the other invasive plants, but where bracken is the most abundant. Therefore, going forward, this thesis will only make reference to bracken fern.

Bracken is a plant species which under a diverse range of environmental conditions has become invasive at a global scale (Schneider 2004). In my study site, subsistence agriculture is practiced using traditional swidden agriculture techniques, and bracken poses concerns for its current occupation of areas which could be used for agriculture, and for its potential expansion to agricultural areas in the future. The crop-fallow cycles associated with the swidden agriculture system creates favorable conditions for bracken invasion, as it is known that bracken establishes in disturbed areas dominated by fires, deforestation and agricultural activities (Schneider 2006). The subject of this thesis was discussed with different stakeholders in the two study communities and this topic was suggested as an issue of community interest (E. Duran pers. com.).

OBJECTIVES

The aim of my thesis is to investigate and understand the local knowledge and perception regarding the invasive bracken fern (*Pteridium aquilinum*) and its impact on land use, in the San Pedro Tlatepusco and Santiago Tlatepusco indigenous communities, located in the Chinantla region of Sierra Norte, Oaxaca.

Specific objectives of my study are as follows:

1) To characterize the households as agricultural productive units and the main agricultural systems of the study site.
2) To document local knowledge and perceptions of bracken fern and motivations to control it.
3) To describe existing local techniques to control bracken fern.
4) To characterize bracken fern's impact on land use in the studied territory.

5) To investigate local perceptions on Voluntary Conserved Areas (VCAs) and the degree to which the VCAs and bracken fern combined may be impacting the availability of agricultural land.

Relevant research questions include:

- How do households carry out agricultural production and what are the labor demands?
- What do inhabitants know and what do they think about bracken fern? What are the motivations to control bracken fern?
- What are the traditional land use practices/methods utilized by the local communities to control the invasion of bracken fern? How do issues with nuisance animals diminish local efforts to recuperate bracken invaded lands?
- What is the impact of bracken fern on land use in the studied territory?
- What are the local perceptions on current conservation programs and bracken fern? To what extent does the combination of the VCAs and bracken fern create pressures on land availability?

COUPLED HUMAN-ECOLOGICAL SYSTEMS

The coupled human-ecological system refers to the integration of these two systems, in which people interact with natural components (Liu et al. 2007). Traditionally, the social and ecological sciences have been studied separately, and there has been a lack of progress in examining the complexity of the human-nature interactions associated with the coupled systems (Liu et al. 2007). This complexity is rooted in the many factors, processes, and feedbacks operating within the coupled human-ecological

systems, which are simultaneously affected by social and biophysical processes and flows within and across the boundaries of the systems (Turner et al. 2003). The two indigenous communities studied in my thesis represent an interesting case study of the coupled human-ecological system, since these communities are immersed in large tracts of conserved forests where they have practiced traditional shifting agriculture for hundreds of years. For perhaps a millennia they have managed to meet their agricultural production needs while conserving the forests. Bracken fern is a species that occurs naturally as an understory plant in the forest ecosystems of my study site, and it does not become invasive until favorable conditions for its establishment are met, specifically full exposure to sunlight and presence of fire which helps disseminate the fern's spores. For unknown reasons bracken has invaded some areas of the territories of my two study communities. And although, bracken is not currently a major problem, the recent creation of the VCAs, combined with the areas taken out of production by bracken, has the potential of becoming an important negative component of the coupled human-ecological system of my study site, since the combination of the two may be creating new pressures on availability of agricultural land, as it will be discussed later.

BRACKEN FERN

Pteridium (Dennstaediaceae) is an isolated and well circumscribed, cosmopolitan genus comprised of several species of large, coarse ferns (Marrs & Watt 2006). Bracken (*Pteridium aquilinum* (L.) Kuhn) is an extremely successful plant (Marrs et al. 2000) and considered to be one of the world's most powerful weeds (Webster & Steeves 1958). Current observations, archeology and documentary records and the palynological record

of the British flora and vegetation collectively show *Pteridium* as a "camp-follower of man" which expanded as a result of the removal of factors limiting it, or the creation of opportunities for expansion (Marrs & Watt 2006).

According to Marrs & Watt (2006), humans learned to use *Pteridium* for a range of purposes and its harvest must have at least restricted its spread and at most reduced its cover and intensity. The uses of *Pteridium* since ancient times have included the following: rhizomes as food source, and for preparation of glues and the brewing of beer; the fronds for packing fruit in baskets and for protection of gardens against the winter frost; dye production; thatch for houses, cordage and as fuel for domestic heating; for animal and human bedding since Roman and Viking times; as a fertilizer; for soap and glass-making; as a medicine for at least 21 different uses; and finally there is a traditional belief that it can confer the power of invisibility (Marrs & Watt 2006).

However, as humans have stopped using *Pteridium* as a resource in recent times, it is now regarded as a weed. More recent expansion of *Pteridium* has been attributed to land-use change (Marrs & Watt 2006). For example in Europe, in County Mayo, Ireland, expansion occurred after a period of woodland clearance in the late 18th century, with a peak in cropping with oats and potatoes in the mid-1800's, followed by a decline and a change to marginal pasturing with subsequent *Pteridium* increase (Little & Collins 1995).

Originally, a woodland plant and a component of open forest communities long before the human evolution and development of agriculture, its range has expanded markedly as a result of human's activities and it has managed to maintain high productivity outside the woodland habitat, probably as a result of being able to restrict its

water loss more effectively than other ferns (Pakeman & Marrs 1992). According to Marrs et al. (2000), there are many reasons why bracken is so successful, these include:

1. a very large rhizome system containing large carbohydrate and nutrient reserves, and many buds capable of producing new fronds,
2. high productivity, which produces a frond canopy that projects deep shade,
3. large accumulations of litter which prevent other species from colonizing,
4. a range of toxic chemicals within its tissues which can prevent it being eaten or decaying, and possibly acting to prevent the establishment of other species through allelopathy (phenomenon in which produced biochemicals inhibit the growth of nearby plants).

Pteridium can survive in a range of light flux densities from heavy shade to full sunlight, and as a woodland understory species, *Pteridium* is suppressed presumably through a combination of reduced light and moisture, but it thrives when fully exposed to daylight (Harmer et al. 2005). Therefore, the presence or absence of *Pteridium*, its vigor, density, cover and height are all influenced by light and consequently increases in woodland gaps (Marrs & Watt 2006, Harmer et al. 2005).

Bracken fern is a typical representative of serial stages following the clearing of forests and its competitive strength benefits considerably from any kind of forest clearing and in particular from the use of fire (Hartig & Beck 2003). Everywhere from the tropics to the temperate zone, bracken turns arable land that has been obtained from forests by the use of fire into land that cannot be used by humans (Hartig & Beck 2003). As a result bracken is regarded as a weed species, causing problems for a wide range of land management options (Marrs et al. 2000).

Pteridium is often a secondary invader of abandoned farmland and its patchiness is obvious at the landscape level scale, and is related primarily to variability in terrain, type of grazing animals and land-use history (Watt 1976). Some cases in southern Mexico have shown that bracken can invade areas where traditional swidden agriculture is practiced. These case studies will be presented later on in this Chapter. According to Lawrence et al. (2004), this pan-tropical invasive species has three devastating effects: 1) it retards the re-colonization of woody species, 2) it seems to enhance the propagation of wild fires, and 3) in large stands, farmers abandon invaded plots, expanding the area taken into swidden cycles and encouraging deforestation. This species highlights a positive feedback in the coupled human-ecological systems: certain types and size of land management (including swidden agriculture), involving the use of fire generate bracken and the presence of the fern reinforces fire.

I was able to observe the effects mentioned by Lawrence et al. (2004) in my study site, as I observed that bracken fern has invaded the hillsides that surround the villages, and that the invaded areas are mainly composed of the invasive species, with little presence of other type of plants. Farmers reported being concerned about the use of fire in the invaded areas given that bracken is highly flammable. In addition, I observed that although there are areas covered by the fern, some farmers have tried to manage some invaded sites through the cultivation of yucca and pineapple.

BRACKEN FERN CONTROL

Reversal of bracken succession is possible given appropriate management (Marrs et al. 2000). However because of its outstanding competitive strength, bracken impedes

reforestation efforts (Humphrey & Swaine 1997). It is difficult to eradicate, and the resulting plant community may not be desired. Paths through time may be complicated by a range of processes in complex interactions – such as management, site characteristics, soils, and climate, and all of these may change through time (Marrs et al. 2000).

The literature reports several methods of bracken fern control, which includes mechanical control (e.g. cutting, crushing, and stock treading), burning, herbicide application (Pakeman et al. 2000) and inhibition by other vegetation (Marrs & Watt 2006). The two most common approaches to bracken removal are the application of asulam (herbicide) and cutting (Pakeman et al. 2000). The following is a description of some of these methods:

- Cutting. The method of cutting bracken with machinery or by hand is widespread where farming systems required an intensive use of labor, or where concern about herbicide use on non-target species prevents the use of chemical control (Pakeman et al. 2001). With this method the fronds are cut before and up to the point of maximum frond expansion, and the objective is to assure a maximum removal of nutrients and carbohydrates from the rhizome reserves (Pakeman et al. 2001). When using this method it is recommended to cut the fronds before there is a translocation of the large amounts of assimilated nutrients from the fronds to the rhizomes (Williams & Foley 1976). In order for cutting to be effective, it has to be done from one to three times annually and it needs to be repeated for at least three years (Braid 1959). The advantage of cutting is that it breaks up deep *Pteridium* litter and helps natural regeneration (Marrs & Lowday 1992). The disadvantage of this method is that is time consuming and labor intensive.

- Crushing. Is a variant of cutting and is a more recent mechanical method. Crushing does less damage to the litter layer than cutting and therefore it may be less effective than cutting. Crushing is utilized as an alternative to the use of cutters on difficult terrains which can damage the cutter and it consists on crushing bracken using rollers. (Pakeman et al. 2005, Marrs & Watt 2006). Similarly to cutting, this method is not suitable for eradicating bracken and it is necessary to follow-up by other methods (Marrs & Watt 2006).
- Stock treading: This technique is utilized to crush bracken and disturb litter (Pakeman et al. 2005). The livestock encourages frost penetration to the rhizomes and the regeneration of vegetation by damaging the rhizome buds and the developing fronds which are either near the surface or just emerging, and by disturbing and breaking-up the litter (Marrs & Watt 2006).
- Burning. This is a land management technique used to remove litter where it is particular deep (Pakeman et al. 2005). Burning can be utilized to facilitate the success of crop cultivation and plant seeding. There are several disadvantages on burning dead litter without follow-up, such as increase in frond production, fire risk and negative (but temporal) effects on the value of the landscape (Marrs & Watt 2006).
- Glyphosate. This herbicide is non-selective, and will kill any grass or other herbaceous plants present (Marrs & Wall 2006). Because of its non-selective nature, Marrs & Watt (2006) recommend that this herbicide should be sprayed only in deep litter bracken areas, with little underlying vegetation.
- Asulam. Asulam (N-(4-*Aminobenzoylsulfonyl)-carbamic acid-methylester*) is an herbicide used in many parts of the world to control bracken fern. It is marketed by

Bayer CropScience, specifically for the control of bracken and docks *(Rumex sp*.) (Bayer CropScience 2005). Asulam is incorporated via leaves and transported to the roots, weakening the plant at least transitorily by inhibition of cell division (Williams & Fraser 1979). The three methods used to apply it are by helicopter, by ground-based vehicles or by hand-operated sprayers (Rhone-Poulenc n.d).

- Inhibition by other vegetation: Manipulating plant succession by planting trees within bracken stands, is an approach that will inevitably reduce bracken cover and replace it with other vegetation (Marrs & Watt 2006). But this method presents the disadvantage of bracken being able to expand again if trees are removed by felling, given that bracken most probably will not be completely eradicated, and it will remain a component of the field layer (Marrs & Watt 2006).

According to Marrs & Watt (2006) usually a two stage control process is required, using different combinations of the above mentioned methods. Where *Pteridium* is dense, there needs to be an initial control stage, and thereafter there will almost certainly need to a second phase of follow-up control, possibly integrated with a restoration phase to re-establish semi-natural vegetation. Once a suitable vegetation type has been established, a maintenance phase is needed to ensure that the required vegetation is maintained and the *Pteridium* is kept at a low level. Where *Pteridium* is present at low densities at the beginning, control can be less intensive, but management of the surrounding vegetation is needed to keep it in good condition and prevent expansion (Marrs & Watt 2006). Where a *Pteridium* front is invading other communities, expansion can be kept in check by cutting, herbicide use (Pakeman et al. 2002) or by the development of competitive vegetation (Watt 1955).

Stewart et al. (2008), carried out a meta-analysis study of bracken fern control in a multiple sites in the United Kingdom, and tested five different control treatments in the different sites. The treatments were the following: 1) cut once per year, 2) cut twice per year, 3) a single cut in year one followed by herbicide (asulam) spraying in year two ('cut and spray'), 4) asulam in year one only ('spray'), and 5) asulam in year one followed by a single cut in year two ('spray and cut'). The results from the inter-site comparison of all treatments found that the effectiveness of bracken control varies between sites. The comparisons also revealed that in general cutting twice within a year (treatment number two) was usually the most effective treatment to control bracken fern. The authors of this meta-analysis emphasize on the need for management experiments to be repeated in different places to elaborate evidence-based management decisions, due to the fact that many times, management conclusions are drawn from limited numbers of sites.

In many occasions, these methods fail because of the vigor of the rhizome system of this fern, which as explained earlier, forms a dense network at several depths of the soil (Hartig & Beck 2003). Therefore, at least part of the plant is effectively protected from fire, from damage by mechanical weeding (Lowday 1987), and from most herbicides with the potential exception of asulam (Marrs & Watt 2006). Currently, there is not a complete understanding of why bracken is so variable (possibly the site variation is caused by differences in climatic regime, substrate, and past and current management practices), and why in some places is difficult to control, whereas in other places is less difficult, therefore there is a need for further work to explain these differences (Stewart et al. 2008).

BRACKEN FERN IN SOUTHERN MEXICO

The ecology and control of bracken fern in the tropics has special characteristics, and here I will examine it in the specific case of three case studies of bracken in southern Mexico, the area of research of my thesis.

CASE STUDY ONE: LACANDON MAYA OF CHIAPAS STATE

The ecology and control of bracken fern in the tropics has special characteristics, and here I will examine it in the specific case of southern Mexico, the area of research of my thesis. Douterlungne et al. (2008) analyzed local knowledge on restoration of degraded tropical forest clearings dominated by bracken fern in the Lacandon Maya of Chiapas, southern Mexico. The Lacandon Maya have traditionally relied on a long fallow rotational slashing and burning farming system (*milpa*) of the original vegetation, in order to provide clearings in which crops (such as maize) can grow within tropical forests. Their reliance on the long-term maintenance of a functioning ecosystem has provided the Lacandon people with sophisticated knowledge of forest dynamics.

Although successional processes usually lead to rapid restoration of abandoned fields, bracken fern can block natural succession. The Lacandon are aware of this and use the fast-growing tree pioneer species, Balsa (*Ochroma pyramidale*) to accelerate succession toward mature forest. The Lacandon Maya's low-input restoration techniques involve broadcasting large numbers of small Balsa seeds and applying traditional weeding techniques. Cutting bracken is labor intensive, but is the most effective means to ensure Balsa survival and growth. However, since Balsa establishment is very rapid, only four months of bracken weeding are required. According to the authors, the Lacandon

technique is simple, cost effective and compatible with natural processes. The results of this study validated the effectiveness of the Lacandon method for directing succession and confirmed the general potential of Balsa as a facilitator in the restoration of degraded tropical forest areas.

CASE STUDY TWO: SOUTHERN YUCATAN IN CAMPECHE STATE

Schneider (2004, 2006, 2008), Schneider & Geoghegan (2006), and Schneider & Fernando (2010) have carried out the most comprehensive study of bracken fern invasion in Mexico, in the case of the Southern Yucatan in Campeche State. Her research on the problematic bracken fern has focused on understanding the land dynamics through an examination of coupled human-environment systems by joining biophysical, socioeconomic, and geographic information systems (GIS) evidence. She shows that during the past 20 years there has been a fourfold increase in the area covered by bracken fern in this region, where most of the agriculture is subsistence farming (*milpa*), and practiced on an extensive basis, using traditional slash-and-burn techniques of temporary cultivation and continuous rotation through forest fallow.

Bracken fern poses exceptional difficulties for farmers in the region, because the fact that once a plot is invaded, some farmers permanently remove the plot from rotation. Previously, land was not abandoned in this system, as after a sufficient fallow period, soil fertility would recover, bracken did not establish and the land would be returned to agricultural use. Therefore, both the fern invasion and its associated land abandonment are new phenomena that disrupt traditional crop-fallow cycle dynamics. As fern invasion and its associated land abandonment are such new phenomena, there has been no official

region-wide policy response to the invasion, so farmers have been attempting to devise management strategies individually. Schneider's research has not focused on studying these bracken management strategies. Rather, her studies have mainly focused on explaining the relations of land use and the current distribution of bracken fern in the Calakmul region, and on investigating the factors that affect the decision of a subsistence farmer to either continue cultivating an invaded agricultural plot or permanently abandon the plot and cultivating elsewhere.

Schneider's analyses suggest that bracken fern invasion in the Yucatan region is negatively correlated with land availability. Bracken density is low in land-sparse *ejidos* characterized by intensive cultivation and high land pressures. On the contrary, bracken's density is high in land-surplus *ejidos* characterized by less intensive cultivation and low land pressures. Repetitive burning of the areas dominated by bracken also favors its retention. Socioeconomic and spatial information gathered in Schneider's studies, suggest that farmers' willingness to combat bracken invasion is related to the land, labor, and capital conditions of the individual households. She suggests that in land-surplus conditions, the high labor and other costs involved in controlling bracken fern has led to a common response: leave the invaded land, and cultivate the non-invaded land. In contrast, in land-sparse conditions, the common response to bracken invasion has been to control bracken the moment it begins to invade the plots.

Apparently, bracken fern became a more persistent problem with the massive appearance of widespread swidden agriculture in the Yucatan lowland tropics associated to the colonization process. Thus, Yucatan colonists do not have the traditional knowledge to combat bracken, as opposed to the Lacandon Maya's who have practiced

swidden agriculture for millennia, and have developed traditional ecological knowledge to control bracken invasion.

CASE STUDY THREE: SAN JUAN LALANA IN THE CHINANTLA ALTA REGION IN OAXACA STATE

Edouard et al. (2004) studied the bracken fern problem in the indigenous municipality of San Juan Lalana, located in the Chinantla region of Oaxaca, near the study site of my thesis. San Juan Lalana's landscape presents high levels of deforestation, but there are still vegetation patches composed of secondary vegetation and young fallows, in which subsistence agriculture (mainly *milpa*) is practiced. There are also some patches of mature forests and old fallows, in which shade-coffee is produced, and wood, firewood and non-timber forest products are extracted. In the last few decades there has been expansion of degraded areas mainly because of the burning of oak forest to clear lands for the introduction of coffee and livestock. The expansion of these degraded lands has provided appropriate conditions for the establishment of bracken fern. Community members considered the bracken fern problematic and created in 1998 an agroforestry model to restore the invaded areas. The model is based on local experiments that included the following techniques:

- Introduction of grasses suitable for livestock consumption. The method has proven effective in the study area to eradicate bracken. But the livestock practice is not a productive viable option in this area.
- Introduction of mucuna bean (*Mucuna spp*.) as a cover crop. The technique has reduced bracken abundance in the parcels were it has been applied in the study area.

- Establishment of a variety of crops and forestry species in the invaded parcels. The technique generates short and mid-term household income and initiates a restoration process that utilizes tree and shrub shade species (to inhibit bracken propagation) with cash-crops and subsistence species (e.g. timber species, fruit trees, legumes, etc.).
- Pineapple cultivation. The plant has developed very well in the degraded areas and has had a good fruit production. The pineapple fruit is used for household consumption, and its local and regional market demand has converted it on an important cash-crop. Thus, the majority of the producers have recently intensified pineapple production in the invaded parcels, because it is a secure source of income.

Community members have recognized that restoring bracken invaded lands is a challenging task, which is time consuming, labor demanding and it requires dedication. The prior practiced method in smaller parcels was to pull up the rhizomes. But this method proved not to be appropriate for larger parcels given its labor-intensive nature. Because of the shortage in labor in the area, and with the objective of eradicating bracken while the crops grow, the producers started to cut the bracken shoots, to abate the photosynthetic activity and the rhizome development. The technique was proven successful in the sense that it reduced the labor and it lessened the vigor of bracken.

The authors concluded that the bracken control experimentation model in San Juan Lalana demonstrated that options to recuperate bracken invaded lands to productive parcels are possible, and that agroforestry systems that combine crops that can be harvested over the mid and long-term are the best ones to control the fern invasion.

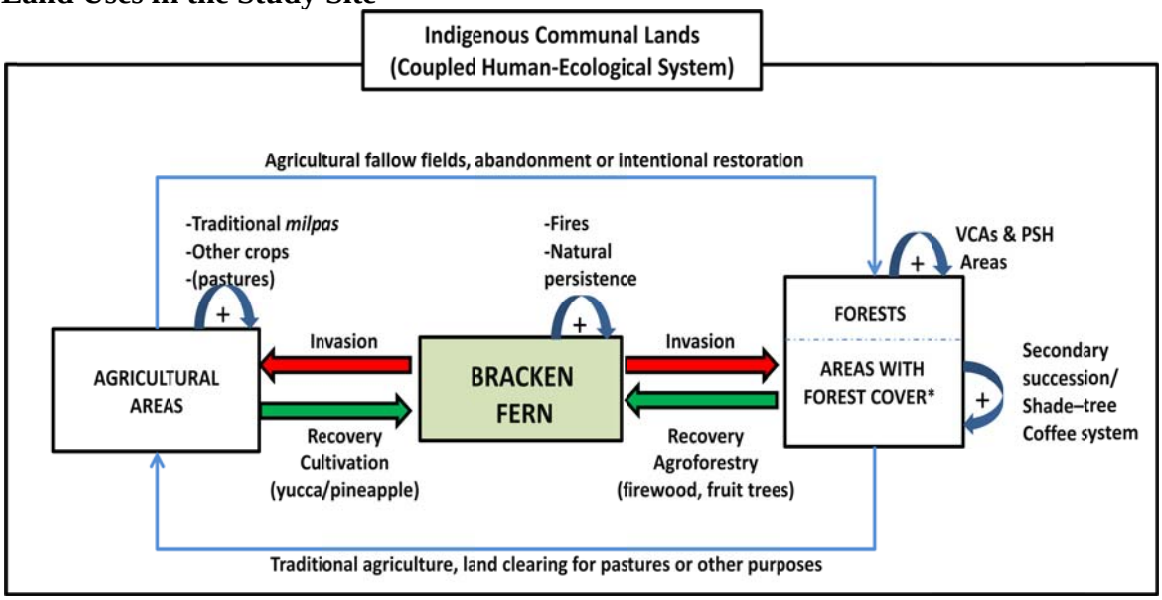
In my thesis, I will examine the phenomenon of bracken invasion in a similar setting to the one examined above. As in the reviewed case studies, my thesis is a distinct

case study of a complex coupled human-environment system which takes place in southern Mexico's mega-diverse forests (Figure 1.1). My study site is characterized by its communal land tenure and by traditional subsistence agriculture (*milpa*) which is practiced using ancestral slash-and-burn agriculture methods. It is a fact that bracken fern is present at low percentages, mainly in the outskirts of the two studied villages, but the circumstances that led to the invasion of bracken are unknown, as it is unknown when the invasion started. Inhabitants of the study site have tried to recuperate the degraded lands by cultivating yucca and pineapple. Bracken control efforts have been diminished by the presence of nuisance animals which eat the yucca and pineapple harvests, discouraging the community members to recuperate the invaded lands. Apparently, the presence of these pest-animals has been exacerbated by the establishment of voluntary conserved areas and their associated strict conservation measures, including a self-imposed hunting ban. After establishment of conserved areas in the study site, land use planning designated certain areas for agricultural purposes. These designated areas are subject to reduced crop-fallow cycles, which along to frequent fires associated with swidden agriculture, can create favorable conditions for bracken's expansion. Bracken is a competitive plant that is known to invade cultivated fields and disturbed areas, posing potential threats to local livelihoods if agricultural production of *milpas* is prevented in the invaded areas.

Bracken fern has been part of the landscape structure of the study site for more than a hundred years, and its fluxes (Figure 1.1) have been related to the land management decisions of local farmers. Management actions tend to: 1) accelerate, 2)

promote, 3) delay and 4) avoid fluxes that are not necessarily positive for certain purposes.

Figure 1.1. Conceptual Model of the Dynamics between Different Land Covers and Land Uses in the Study Site



*****Areas with forest cover not only include old-growth forests, but also second-growth forest second-growth forests and shade-coffee fields.

THESIS ORGANIZATION

The remainder of this document will be organized as follows: **Chapter II** will describe the study area and the methodology that was employed in this research. **Chapter III** will address the results obtained from the methodological tools utilized. Finally **Chapter IV** will discuss the obtained results, and **Chapter V** will summarize and conclude important finding, and also will formulate some practical recommendations for the studied communities.

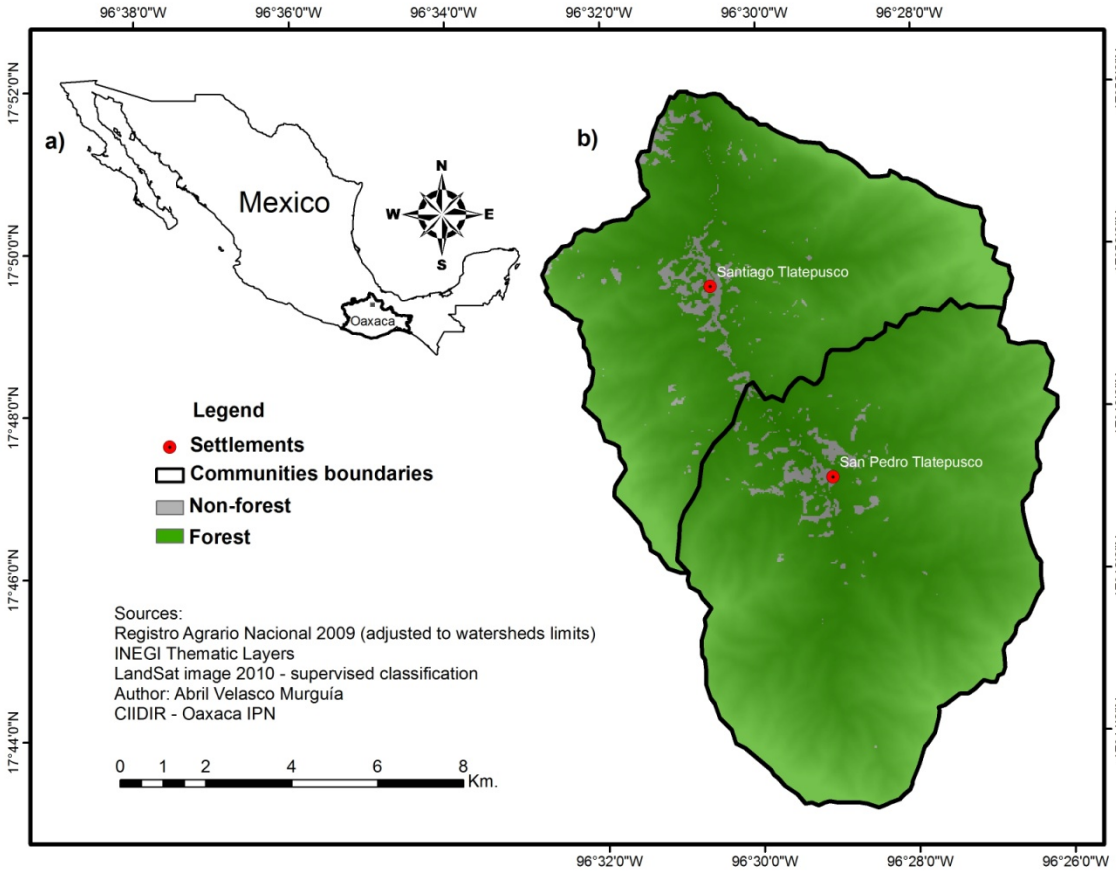
CHAPTER II

STUDY AREA

My research was conducted in the communities of Santiago Tlatepusco and San Pedro Tlatepusco (hereafter Santiago and San Pedro, respectively), in the Chinantla Alta region, the home of the Chinantec indigenous peoples, located in the northeast portion of the state of Oaxaca, Mexico (Figure 2.1). The Chinantla forms part of the Sierra Norte Region, which is a "Priority Area for Biodiversity Conservation" (Conabio 2008). These communities have been chosen because they are part of a larger research project being carried out by CIIDIR-Oaxaca and FIU, the Sierra Norte Research Project. The project has initially focused on the six communities of the Regional Committee of Natural Resources of the Chinantla Alta (CORENCHI) and my two focal communities are in the region.

The state of Oaxaca is located between the Tropic of Cancer and the Equator and is situated in southern Mexico. Eight geographical regions: Cañada, Costa, Istmo, Mixteca, Papaloapan, Sierra Norte, Sierra Sur and Valles Centrales, divide the state, each characterized by cultural and physical characteristics (Maze 1998). The topography is extremely irregular as a result of constant tectonic movements, so that at least eleven physiographic regions have been recognized (Velazquez et al. 2003). The soils and climate are diverse and their variations depend heavily on elevation which ranges from sea level up to over 3000 m (Velazquez et al. 2003).

Figure 2.1. Map of Study Area. a) Map of Mexico, showing the location of Oaxaca, the small dot towards the north of Oaxaca shows the location of the Chinantla region were the two study sites are located. b) Map of the two studied communities, showing their forest cover and non-forest cover. Map author: Abril Velasco.



OAXACA AND SIERRA NORTE

Oaxaca is ranked fifth globally in terms of terrestrial biodiversity (Conabio-Conanp 2007) and its biogeographical location and physical features make it the most biologically important state in the country, with 8405 vascular plants, 190 mammals, 736 birds, 245 reptile species, and 1103 butterfly species (Garcia-Mendoza 2004). There is a great diversity of ecosystems in this mountainous region, such as lowland tropical humid forests, scrub and dry forests, low-stature live oak forests, oak forests, pine-oak forests

(WWF 2007), and a great extension of magnificent cloud forests and high evergreen forests (Arriaga et al. 2000).

In spite of its biological richness, there are few state or federal protected areas in Oaxaca (Robson 2007). Rather, 82.3% of its forested-lands are under the management and control of approximately 1400 local communities (Madrid et al. 2009). The majority of these (more than 75%) are indigenous communities, with far fewer *ejidos* of mixed background (Atlas Agrario del Estado de Oaxaca 2002). Eighteen percent of Mexico's indigenous populations - the highest percentage of any state in Mexico, live in Oaxaca (Fox 1996). Approximately 70% of Oaxaca's inhabitants are indigenous and their presence in the region typically dates back to pre-Hispanic times (Robson 2009). The Zapotecs and the Mixtecs are the two major indigenous groups to which the Oaxaca's inhabitants are affiliated (Weitlaner & Castro 1973).

According to Robson (2009), the Sierra Norte is a rugged, highland region that comprises the southern limits of the Sierra Madre Oriental mountain chain. The Sierra Norte Region of Oaxaca has been considered as a priority region for conservation in Mexico, because of low fragmentation of natural areas and because the biggest and best conserved cloud forests in Mexico are found in this region (Arriaga et al. 2000). The diversity of climatic conditions in this area is related to the constant influence of the Gulf of Mexico and the Pacific Ocean on either side, which provide for varying humid, dry and temperate conditions (Robson 2009). The spatial and vertical distribution of climatic elements has led to multiple soil and vegetation types (Robson 2009). Home to four of the six principal vegetation types found in Mexico (Rzedowski 1978), the Sierra Norte is

nationally and internationally renowned for its concentration of biological diversity (Conabio-Conanp 2007).

LA CHINANTLA

The word Chinantla is derived from the Aztec word *chinamitl*, meaning "an enclosed space" (Schultes 1941), and is located approximately between 17°22-18°12N and 95°43-96°58W, in a remote and rugged area covering approximately 366,243 ha (~3,660 km^2) (Figel 2008). Elevations in the Chinantla range from 50 m to 3200 m over a distance of approximately 50 km (Van der Wal 1999). Slopes ranging between 10° and 50° result from the abrupt topography (Velazquez-Rosas & Meave 2002). In regards to the climate, this region is extremely humid and is considered one of the rainiest regions of Mexico according to Velazquez-Rosas & Meave (2002).

The most common vegetation types found in the Chinantla according to Martin (1996) are tropical evergreen forest (200 m – 1600 m), dry tropical forest (1000 m – 1200 m), montane cloud forest (1000 m – 2600 m), oak and oak-pine forests (1400 m – 2000 m), and temperate pine-oak forest (2000 m – 3200 m).

SANTIAGO TLATEPUSCO AND SAN PEDRO TLATEPUSCO

Santiago and San Pedro are communities of indigenous people from the Chinantec ethnic group, and both belong to the Municipality of San Felipe Usila. The word Tlatepusco which is the name both communities share, has its etymological origin in the Chinantec word *kuo*, signifying "liana land" (*tierra del bejuco*) (Weitlaner & Castro 1973). Total forest cover of both communities is approximately 11,675 ha (Figure

2.1) and total non-forest cover for both communities is approximately 396 ha (Velasco 2011). The forest cover type refers to old-growth forests, second-growth forests and shade-coffee fields. Non-forest cover includes rivers, but mainly refers to anthropogenic surfaces such as agricultural lands, pastures, human settlements, and shrub vegetation including bracken fern (Velasco 2011). The slopes directly above both communities are the areas that have reportedly been densely covered with bracken fern for decades. Although from the map bracken fern cannot be distinguished as a distinct isolated land-use unit, it is clear from the informal interviews that bracken fern invaded areas are only located in the areas surrounding the communities, and not in the *milpa* or coffee growing areas.

Santiago's communal lands occupy 5,928 ha (Ibarra et al. 2011), of which approximately 96% belongs to forest cover, and the other 4% to non-forest cover (Velasco 2011). Altitudes range from 250 m and 2800 meters (Ibarra et al. 2011The population includes of approximately 591 residents about 90 households, and 151 legal members (*comuneros*) recognized by the General Assembly (Table 2.1). San Pedro's communal lands occupy approximately 6,875 ha, of which approximately 98% belongs to forest cover, and the other 2% to non-forest cover (Velasco 2011). San Pedro's population includes approximately 200 residents, 30 households, and about 50 legal members (*comuneros*) recognized by the General Assembly (Table 2.1).

Table 2.1. San Pedro and Santiago's Population, Total Area, Forest/Non-Forest Cover, VCA and PHS Areas

	San Pedro	Santiago	Both Communities
Population	200	591	791
Population density (p/km^2)	2.9	9.9	6.2
Total surface (ha)	6,875	5,928	12,803
Forest cover (%)	98	96	~92
Non-forest cover (%)	2	4	~6
VCA area (ha)	5,050 (73%)	4,300 (72%)	9,350 (73%)
PHS area (ha)	2,947 (43%)	2,822 (48%)	5,769 (45%)

Regarding community governance, Mexican agrarian law recognized and granted legal land tenure to the rural communities (*ejidos* and *comunidades*). The *comuneros* are legally recognized men and women, over the age of 18, who have rights over the use of their agricultural lands, but by community decision they do not own them and cannot sell them. The highest decision making authority in the *comunidades* is the General Assembly, in which all *comuneros* should participate. According to the agrarian law, each community's General Assembly should meet at least once every six months, and decisions should be made by a majority vote of the present *comuneros*.

Both are remote communities with no access roads. Because there are just forest trails, the only way to get to the communities from Usila, the nearest town with a road, is by foot or with pack animal. On average, it takes two hours to walk to Santiago, and four hours to walk to San Pedro, depending on walking pace and load. The Santiago River passes through the middle of both communities, with houses on both sides of the river, which are connected by a hammock suspension bridge in each community. Both communities have electricity. There is no sewage system and water for all purposes is manually obtained from the river. There are few phones in Santiago and one phone in San Pedro, and communications depend primarily on radios. Homes are typically built with

cement and the roofs are made out of tin. Although there are still some homes characterized by wood walls, mud floors and a thatched roof, the villagers prefer the cement and tin houses because they do not require as much work to build, and tin roofs are much more long lasting and do not require as much repairs as thatched roofs. In terms of infrastructure, in Santiago there is one Catholic Church, one school, one health center, one visitor lodge (built with the purpose of attracting tourists), and when I was there, construction of a community center was initiated. In San Pedro, there is also a Catholic Church, several Evangelical Churches, a community center, a pre-school plus an elementary school, and a brand new unfinished multi-purpose community house/tourist lodge and museum, built by Italian volunteer students.

Subsistence corn agriculture and coffee as a cash crop are the principal agricultural crops in both communities. The inhabitants depend primarily on the cultivation of *milpas*, which are composed of maize (*Zea mays*), beans (*Phaseolus vulgaris*) squash (*Cucurbita moschata*), chilli (*Capsicum annuum*), and *tepejilote* (*Chamaedorea tepejilote*), among other species. *Milpas* are most typically grown during the *temporal* or rainy season, but if necessary *milpas* can be cultivated during the *tonamil* or dry season. All *milpa* cultivation uses swidden or slash-and-burn methods. As mentioned earlier, shade-coffee is grown in these communities as the main source of cash revenues. After the International Coffee Crisis back in the late 1980's, some organizations of small farmer cooperative confederations, such as CEPCO (*Coordinadora Estatal de Productores de Café de Oaxaca*), were formed to produce certified organic coffee, which is more attractive and sells at a better price in international

markets than non-organic coffee (Hite 2011). The studied communities also grow yucca and pineapple as additional food sources.

Little is known about the history of the two towns. According to Escalante-Lara & Romero-Julian (n.d), apparently San Pedro and Santiago were founded around the year 1421, when a group of people abandoned a place called *Montaña del Águila*, and part of the population founded what is now Santiago, and the rest of the population founded San Pedro. It is also known that in June of 1928, a major flood occurred in San Pedro which devastated the town. Heavy rains along with the flood, caused landslides in the mountains around San Pedro, and some inhabitants have said that those areas affected by landslides did not recovered to forests, but instead were invaded by bracken fern, and to date remain invaded by this fern (E. Duran pers. com., Nieratka 2011).

Since the mid-2000s the two study communities have become members of a six-community organization known as the Regional Natural Resource Committee of the Upper Chinantla (*Comité Regional de Recursos Naturales de la Chinantla*-CORENCHI) (Bray et al. forthcoming). These Chinantec communities are interested in ecosystems and biodiversity conservation, and therefore have voluntarily set aside a large amount of their territory to accomplish their land community conservation goals (Bray et al. forthcoming). As previously mentioned, these conserved lands are known in Mexican legislation as Voluntary Conserved Areas (*Areas de Conservación Voluntaria*-ACVs), and may be considered what the International Union for the Conservation of Nature (IUCN) calls Indigenous/Community Conserved Areas (ICCAs). The main objective of ICCAs is to conserve tropical forests and enhance community economy. My study region is characterized for its high number of such areas, where Santiago's VCA area comprises

approximately 4,300 ha and the PHS area is approximately 2,822 ha, and San Pedro's VCA area is approximately 5,050 ha and PHS area is around 2,947 ha. It is worth noting that in both communities the areas under VCA and PHS programs roughly overlap (Table 2.1).

The IUCN has defined ICCAs as "natural and modified ecosystems, including significant biodiversity, ecological services and cultural values, voluntarily conserved by indigenous groups and local communities through customary laws or other effective means" (Borrini-Feyerabend et al. 2004). Community conserved areas are characterized by three main features:

- Some indigenous peoples and local communities are concerned about the relevant ecosystems related to them whether culturally and/or because of livelihoods.
- Such indigenous and local communities are the major stake- and power holders in decision making and implementation of decisions regarding the management of the ecosystem at stake, suggesting that some type of community authority exists with the capability of enforcing regulations.
- The voluntary management decisions of such communities lead to the conservation of habitats, species, ecological services and associated cultural values (Borrini-Feyerabend et al. 2004).

Mexico's community conservation has been enabled by a policy framework which is supported by the country's constitution and national legislation that governs land and natural resource rights (Martin et al. 2010). The community conservation phenomenon in Mexico began to be officially recognized in 1996, when Mexico's general environmental law (*Ley General del Equilibrio Ecológico y la Protección al*

Ambiente-LGEEPA) article 59 was reformulated, allowing communities to legally reserve land for conservation (Martin et al. 2011). And in 2003 a program to certify communal and *ejidal* reserves was started by the National Commission of Natural Protected Areas (*Comisión Nacional de Áreas Naturales Protegidas*-CONANP) (Martin et al. 2011). A reform to the LGEEPA in 2008, permitted communities to register community reserves as ACVs, a new federal protected areas category, which has been incorporated into the National Registry of Protected Areas (*Registro Nacional de Áreas Naturales Protegidas*) (Martin et al. 2010).

Mexico is an important center for ICCA development, because of its community conservation experiences, which include the official recognition of common property rights and ACVs (Martin et al. 2011). According to Martin et al. (2010) Oaxaca is one of eight Mexican states which has laws that specifically address the direction in which indigenous peoples can engage in natural resources conservation. Oaxaca's communities have undertaken an active role in establishing ICCAs, for example, by 2009, a total of 375,457 ha were designated for community conservation by 126 self-mobilized Oaxacan communities (Martin et al. 2011). According to Martin et al. (2011), the indigenous communities of Oaxaca have high levels of internal organization, relative political autonomy, collective institutions and communal land tenure models that contribute to resource management resilient approaches. In Oaxaca, there are few nationally designated parks, mainly because of popular resistance to incorporate communal lands in government protected areas. The limited number of nationally designated parks, in combination with Oaxaca's rich biodiversity and proactive local communities which aim for sustainable livelihoods, have enabled the implementation and establishment of

complex and highly organized community level conservation programs, like the CORENCHI communities in the Chinantla (Martin et al. 2010).

In addition to have voluntarily set aside a great portion of their territories for conservation purposes, the CORENCHI communities have taken advantage of the government's payment for environmental services program (Table 2.1). In the mid-2000's, the CORENCHI communities enrolled in a Payment for Hydrological Services Program (PHS), as a way to receive monetary retributions for the conservation in which they were already active (Nieratka 2011). Prohibition in land use change is the only stipulation required by the government agency (*Comisión Nacional Forestal*-CONAFOR) that regulates the PSH program. To comply with this requirement, it is now mandatory in the communities to build fire breaks around the agricultural plots in preparation for cultivation. In addition, communities have created internal regulations to ensure compliance with PHSs program stipulation of no land use change. These regulations include a self-imposed hunting ban, except for nuisance animals in maize fields (Nieratka 2011).

In spite of the communities' conservation interest, the two study communities are facing the particular case of the bracken fern problem, which constitutes a potential burden to their subsistence agriculture practices. Although bracken fern is a native species that occurs naturally in the understory of the study site's forests, it can rapidly become invasive in disturbed areas, such as agricultural areas, where certain conditions favor bracken's establishment. Invasive species, such as bracken fern in my study area, can inflict serious impacts on the ecosystem processes that are fundamental to secured livelihoods' access, including the loss or alteration of goods (e.g. agricultural products)

and services (e.g. aesthetic beauty) (Pejchar & Mooney 2009). The studied communities specifically requested a study on the bracken fern problem and on their techniques to control it (E. Duran pers. com.), and thus my study is a response to the request of the two communities. It has been suggested that the recent establishment of the Voluntary Conserved Areas has created a new context, and a new limitation on land use for agriculture, specifically in the case of Santiago, which may make bracken fern land invasion more problematic than before, but it has not been evaluated the cumulative impact of the conserved areas and bracken fern.

RESEARCH METHODS

DATA COLLECTION

This research study took place in the summer of 2011 (May to July) including a two-week field course sponsored by CIIDIR-Oaxaca and FIU, where I was introduced to the Chinantla region. In this course I had the opportunity to learn the social-ecological context of the study communities and informal interviews were conducted with some key informants who were knowledgeable community members. These informal interviews were performed following the guidelines of Bernard (2002). Through the informal interview instrument, I learned about the context of the bracken fern problem and the main methods by which bracken fern is attempted to be controlled within these two communities. All key informants spoke Spanish, thus no translator was needed. On the basis of this newly acquired knowledge, the structured interview instrument performed in this study was refined. Prior consent was obtained by the Institutional Review Board (IRB) at Florida International University (FIU). The indigenous communities also require

that anyone performing research in the communities needs to obtain approval from the General Assembly of each community. During this field course consent from local authorities and the General Assembly of Santiago was obtained. In San Pedro the consent from the General Assembly was obtained after the field course, when I returned to this community to conduct interviews.

In the two study communities, Santiago and San Pedro, structured interviews were administered to obtain information on their demographic characteristics, agricultural activities, perceptions of bracken fern, techniques utilized to recuperate invaded lands, and perceptions of the Voluntary Conserved Areas (VCAs). Structured interviews involve asking a group of selected informants to respond to the same set of questions, which allows for a valid comparison of data (Bernard 2002). The questionnaire was created following the guidelines of Bernard (2002), Nardi (2003) and for the household demographic questions (see Appendix 1, Box 1) the ESRC (2004) guidelines were utilized. To improve the interview instrument, four pre-test interviews were conducted and the interview instrument was adjusted accordingly (following suggestions by Schneider & Geoghegan 2006).

In Santiago there are approximately 90 households, and 18 surveys completed, representing 20% of the households. In San Pedro there are approximately 30 households, and 17 surveys completed, representing 57% of the households.

Households represent the main productive units in these indigenous communities, thus interviews were conducted at the household level. For consistency, only the head of households were selected to answer the questions for the household. The heads of households are the most knowledgeable regarding the agricultural activities, therefore the

best suited to answer the questions on the interview. In addition, the General Assembly of these communities is composed of legal community members (*comuneros*) which at the same time can be the head of households (not all *comuneros* are head of households, there can be more than one *comunero* in each household: father, grandfather, sons, brother-in-law, etc.).

The interview process started in Santiago. To avoid bias, I wanted to obtain a random sample and to achieve it a Microsoft Excel random numbers chart was generated. A list of all active *comuneros* was taken from the 2005 Santiago's *Estatuto Comunal* (Communal Statutes). Since this list was from 2005, two members of the *Comité de Turismo e Investigación* (Committee of Tourism & Research) helped to update the list. Once updated, the random numbers list was generated. These two members of the *Comité de Turismo e Investigación* revised the list to ensure that no two *comunero*s lived in the same house. If this occurred, one of the *comunero*s would be taken out of the list and replaced by another *comunero* from a different house.

In San Pedro, the method for selecting the individuals to be interviewed differed of that in Santiago. In San Pedro, the majority of the households were visited, and asked if they were willing to be interviewed for the project. Because only few residents were willing to participate in the interview process, a monetary incentive of $40 Mexican pesos was provided to the respondents. Resident's lack of willingness to participate in the survey became an issue for the purposes of my research and the research project was regarded with mistrust among the communities. Apparently, the mistrust was rooted in tensions in the communities between NGOs and over the subject of student research in the community. The tensions may have influenced some respondents, and this is evident

in San Pedro's surveys, where many questions about the VCAs where not asked because many respondents were unwilling to answer some of the VCAs and the PHS program related questions.

The survey included four sections (see Appendix 1). Section 1 focuses on household demographics. Mainly I was interested in knowing the structure of households in terms of agricultural production. Children younger than seven years of age do not participate in agricultural activities, so data were gathered only from persons older than seven. Following ESRC (2004), the first section of my survey focuses on "the household as an organization", thus questions in Section 1 ask basic demographic information of the household members such as age, sex, relationship to household head, whether or not the person participates in agricultural activities, how does the person participate, and highest level of formal education obtained thus far.

Section 2 inquiries about agricultural activities at the household level. The agricultural activities surveyed were cultivation of *milpa*, coffee, yucca, pineapple, and livestock. For *milpa* cultivation, questions included if they had parcels during different growing seasons (*tonamil*: dry season and *temporal*: rainy season) in 2010. Whether or not the parcels were cultivated in fallows fields (*acahual*) (of what age). How many parcels they had and if before being cultivated the parcels had some bracken fern invasion. If the *milpa* was cultivated where there was some bracken's invasion, they were asked why they decided to cultivate their *milpa*s in such an area, and to describe the quality (high, moderate or low) of the obtained maize harvest in each of the two 2010 growing seasons.

I also asked questions about the cultivation of coffee, yucca and pineapple. Included questions focused on the number of active plots of each of these agricultural activities, size of plots, and if any of these parcels were cultivated where there was some bracken fern invasion. If they responded positively to the last question, they were then asked why they cultivated there, and how was the quality (high, moderate or low) of the obtained harvest for each crop. When harvests were moderate or low they were asked to specify if such harvests were the result of nuisance animals attacks (and which species), of low quality of the soil, or because of any other factor. They were also asked in which year they cleared the plots with bracken fern for the first time. If yucca and pineapple were cultivated in bracken fern areas, two additional questions were asked: 1) how long does it take them to walk to each of these parcels, and 2) if they sold products that were harvested.

For livestock, I specifically wanted to know what type of animals they had (cows, sheep, mules, other) and how many of each. Where were the animals kept (pastures, tied to the houses, river bank, other). If the animals were kept in pastures, I was most interested in knowing the size of the pasture, and if there was bracken fern invasion in these pastures before putting the livestock there. If the answer to this last question was yes, they were asked to respond which animals and in which year were the animals put there, why they decided to put the animals in a bracken fern invaded area, and what type of plants were present in the pastures at the time of the interview (grass, bracken fern, trees). If there were trees and grass, informants were asked if they planted them there. If bracken fern was no longer dominant, then the next question was whether they eradicated

the fern, if they did not, then they were asked to explain what happened to bracken fern (how was eliminated).

Section 3 specifically inquires about bracken fern perceptions, knowledge and control techniques. Perception and knowledge questions included: when did bracken fern appear in their communities. Whether or not bracken fern areas have increased, decreased or remained the same. How many hectares are invaded by bracken fern in their respective community. They were also asked to compare which type of vegetation (bracken or fallow) is less labor-intensive to clear and why. To state if during the past five years they have abandoned any yucca and/or pineapple plot which was invaded by bracken fern prior to cultivation, and if they answered yes, they were asked to specify what type of vegetation is now present in those abandoned parcels (bracken fern, fallow, pasture, other crop). They were also asked if they think bracken fern invasion limits the cultivation areas of crops, whether or not they think that bracken fern provides them any benefit, to specify which one(s) and explain why there is or there is not benefit(s). Informants were asked what other land uses (*milpa*, coffee fields, fallow, forest, other crops) would they prefer to see in bracken fern invaded areas, and whether or not they believe it is possible to recuperate all areas currently invaded with bracken fern to other land uses and to explain their answer. I also asked respondents if they consider that bracken fern to be a problem and why.

In Section 3, perceptions on soils in bracken fern invaded areas were also included, since I considered it important to learn what the inhabitants of these communities know about the soil in bracken invaded areas. This can provide a hint on the current soil quality conditions of these invaded areas. More specifically, respondents

were asked to indicate how many types of soil they could differentiate in bracken fern invaded areas. Soil categories were described by color, since this is how farmers classify their soils. For example, in the studied communities black soil is suitable for agriculture, whereas yellow soil is not suitable for agriculture. Respondents were asked to describe soil categories, in terms of depth, texture (sticky, sandy, other), and if the quality of each soil type was good for the cultivation of maize, coffee, yucca/pineapple, fruit trees, trees/firewood. After describing the soil types present, respondents were asked to state to the best of their knowledge, which of the soil types mentioned is the one that prevails in the bracken fern invaded areas.

Regarding bracken fern control techniques, interviewees were asked to describe all the steps involved in clearing a bracken fern invaded plot for yucca/pineapple cultivation. How many days were needed to clear it and how many people worked clearing it. They were asked to describe all the steps involved in planting and growing the yucca/pineapple crops, and to explain how was bracken fern kept under control while the crop was growing. Informants were also asked to explain how they learned to clear bracken invaded plots and to grow crops in the invaded areas. They were asked to explain what they did with the plots after the harvest (abandoned it, left to rest, planted another crop, planted trees). If the answer was they left the plot to rest, they were asked whether or not they did something to keep bracken fern under control, and if they did, then they were asked to specify what exactly they did.

The final section of the structured interviewed, Section 4, inquired about perceptions on the Voluntary Conserved Areas (VCAs). Mainly I was interested in asking whether or not informants believe that there are enough areas to cultivate *milpa* in their

communities. Respondents were asked if before the establishment of the VCAs, they had *milpa*s within the VCAs. If they answered yes to this last question, they were asked to indicate whether or not they were able to find a good quality plot to establish their *milpa*, similar to the one they had within the VCA. They were also asked whether or not they believe that bracken fern limits the area available for *milpa* cultivation, particularly now that the land within VCAs cannot be used for agriculture (*milpa*). Respondents were also asked whether or not what they get paid from the PHS program is enough to purchase sufficient maize and beans to satisfy households needs, whether or not they agree with the self-imposed hunting ban on non-nuisance animals, whether or not they believe that the VCAs and bracken fern areas have caused an increase in the number of nuisance animals, and whether or not they believe that the bracken fern areas have caused an increase in the number of non-nuisance animals. Respondents were also asked to list any nuisance animals that seek refuge in the bracken fern invaded areas, to indicate which agricultural crop each mentioned animal attacks the most, and if they have seen the nuisance animals in the bracken fern areas. Lastly, the interviewees were shown illustrations of mammals from Beletsky (1999), and asked to point out which of those animals they have seen in the bracken fern areas. Lastly, they were asked to classify each mammal as nuisance or non-nuisance, and to list the activities they saw them performing.

Each interview lasted between 45 to 65 minutes (one hour on average) and was recorded 89% of the times. The remaining 11% were not recorded because the interviewees declined recording. A translator, who was able to translate the questions between Spanish and Chinantec, was present on most interviews. Twenty-three percent of the interviews were conducted in Spanish, because the interviewees spoke fluent Spanish,

thus the presence of a translator was not necessary. Even though most of the translators spoke fluent Spanish, undoubtedly, language was a barrier. The translation problem might have introduced several biases, but these are difficult to assess. It is not known how much information was lost between translations. In Santiago, four different translators were used, and in San Pedro one translator helped with all interviews. All the translators were trained before the interviewing process. The training process consisted in reading to them each of the questions in the interview, and verifying that they understood each question. They were advised not to provide their own answers but only what the interviewees said and not to lead the interviewees into any particular answer.

DATA ANALYSIS

Interview data preparation involved entering the data and coding it into a Microsoft Excel spreadsheet, creating a database with the responses of the 35 interviews. Because of small sample sizes, the data presented in my thesis include only descriptive statistics, which I used to describe the basic features of the data, providing simple summaries about my sample. I was mainly interested in calculating the central tendency of the majority of the questions. Thus I chose to use the mean (or average) as the method to describe central tendency. Average calculations provided me with a simple method to draw conclusions about local knowledge and perceptions on bracken fern.

I did not make comparisons between the two studied communities. Rather I treated the 35 interviews as my whole sample because I was interested in understanding local knowledge and perceptions in general and not in a separate manner. In addition my design does not allow for comparisons since I paid one group but not the other group. As

well, the two communities together occupy the watershed of the Santiago River, so the invasive plant is treated as a common phenomenon at the level of the watershed. There is also no reason to believe that the presence of and reaction to the invasive varies between the two communities.

CHAPTER III

RESULTS

This chapter presents the results of the structured household interviews, supplemented with data from informal interviews, and is divided into sections that address the households as productive units, the main agricultural systems, local knowledge and perception on *Pteridium aquilinum*, motivations to control it, the existing local control techniques, and perceptions on VCAs.

In total 35 structured interviews were conducted in the two communities (18 in Santiago and 17 in San Pedro). In these communities males are normally the heads of household, thus the majority of the interviews, 89%, were conducted with males. Females were interviewed only when a woman was the head of the household, because they were widows and had no male children available to replace the father, or because the male head of household designated the wife to respond the interview. The mean age of interviewees was 45 years. The average number of household members per household was 5, and the average age of these members was 23 years. Households were composed in average of 55% females and 45% males (Table 3.1).

Table 3.1. Principal Demographic Characteristics of 35 Households Interviewed (only >7 years old)*

Number Males Interviewed	31 (89%)		
Number Females Interviewed	4 (11%)		
	Average	**Min**	**Max**
Mean Age of Interviewees	45	17	88
Average Number of All Household Members	6	2	11
Average Number of Household Members	5	2	9
Mean Age of Household Members	23	8	88
Average Number of Males per Household	2.4 (45%)	0	5
Average Number of Females per Household	2.8 (55%)	1	6

*This study focuses on the population that actively participates in agricultural activities, therefore children 7 years and younger are not taken into account. 87% of household members are older than 7 years of age (this information is based on informal interviews).

HOUSEHOLDS AS PRODUCTIVE UNITS

Because I was interested in understanding the demands on household labor for dealing with the invasion of bracken, I asked how many households members participated in the principal agricultural activities of slash-and-burn, sowing, weeding, harvesting and firewood gathering. The results are in Table 3.2. Seventy-three percent of the household members (older than seven years old) are active participants in the agricultural activities within their households. As we shall see, household members between ages 8-12, only contribute with 2% of the agricultural labor. The limited participation in agricultural activities is because the children are still too small to make greater contributions and because they occupy their time attending school. The sex distribution of the 73% active participants in agricultural activities is 46% males and 54% females in the 35 households (Table 3.2). These results are almost identical to the sex distribution per household presented in Table 3.1.

Table 3.2. Total and Division by Gender of Participation in Agricultural Activities (n= 35)

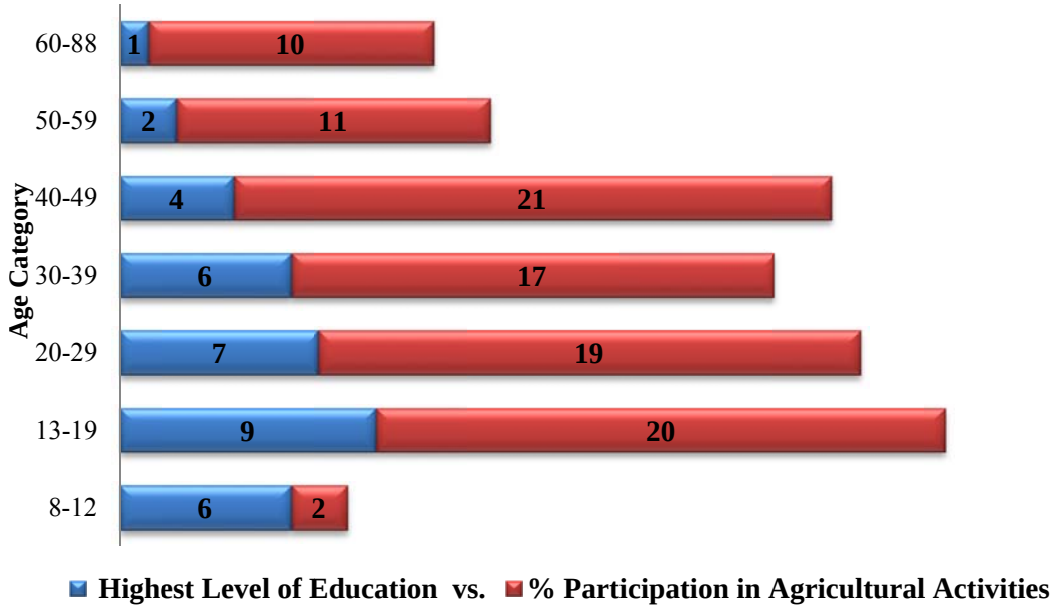
Principal Agricultural Activities	Average (%) of household members which participate in Agricultural Activities	Average (%) of Males which participate in Agricultural Activities	Average (%) of Females which participate in Agricultural Activities
Slash-and-Burn	52%	90%	7%
Sowing	91%	51%	49%
Weeding	94%	50%	50%
Harvesting	91%	50%	50%
Firewood Gathering	66%	16%	81%
Total	73%	46%	54%

Table 3.2 summarizes the averages in total and by gender of household members with active participation in the five agricultural categories. It was found that slash-and-burn methods are mainly practiced by males (90%), and firewood gathering is mainly performed by women (81%). The other three activities (sowing, weeding and harvesting) are performed almost equally by men and women. As we shall see, agricultural activities are also defined by type of activity. The main agricultural categories are cultivation of *milpa*, shade-coffee, yucca and pineapple. According to informal interviews, *milpa* and coffee are cultivated in bigger plots compared to the smaller yucca and pineapple plots.

I found that 77% of the active participants in agricultural activities (males and females) lie within the age range of 13-49 years, which makes this the prime laborer age-range. Participation of people in the age range of 50-88 averages 21%, and the remaining 2% belongs to children ages 8-12 (Figure 3.1). There is a clear relationship between age and level of education among the household members that actively participate in agricultural activities. In average, the younger household members have achieved higher

levels of education (ages 8 – 19), whereas the older members have achieved lower levels of education, as shown in Figure 3.1.

Figure 3.1. Highest Education Level Achieved* and Percentage of Participants in Agricultural Activities by Age Category (n=35)



*12th grade is the maximum grade that can be achieved.

MAIN AGRICULTURAL PRODUCTION SYSTEMS

Maize is the subsistence crop in these indigenous communities and thus the most important agricultural activity practiced here. In total 97% of the interviewed households cultivated their maize, occasionally associated with other crops, in the agricultural plots known as *milpa* in 2010. The average time to get to the *milpa* plots at the walking pace of Chinantec people was 79 minutes (one hour and 19 minutes). To contextualize *milpa* cultivation in the study site, the interview questionnaire asked about the *milpa* plots cultivated in 2010 in the two main growing seasons, *temporal* or rainy season, and *tonamil* the dry season (Table 3.3). Interviewees indicated that the rainy growing season

is when the majority of the inhabitants grow their *milpas*, and in occasions some households cultivate in the dry season because maize harvests from prior growing season was not enough to satisfy the households' maize needs.

Bracken fern affects only one-third of the *milpas*. Of the households that had *milpa* during either or both seasons, nine (27%) reported that bracken fern was present to some extent in the *milpa* plots prior to clearing them for planting. Out of these nine households, four reported that quality of the *milpa* harvest had been good, four said harvest quality had been moderate, and one said quality had been low (Table 3.3). Of the eight households that reported moderate or low maize harvest quality, two attributed it only to the low quality of the soil, one attributed it only to nuisance animals (white-nosed coati (*Nasua narica*), collared peccary (*Pecari tajacu*), squirrel (*Sciurus spp.*), and three attributed it to nuisance animals (same mentioned above plus rat) and to other factors. These data suggest that bracken fern does not have a negative effect on maize production and as we shall see, bracken fern can be very difficult to eradicate from a plot, this if evidence that bracken fern invasion of milpa plot is not a serious problem.

Table 3.3. *Milpa* Plots Cultivated in 2010 and Bracken Fern Presence (n=35)

Had *milpa* in 2010	97%		
Had *milpa* in rainy growing season	91%		
Had *milpa* in both growing seasons	46%		
Utilized same *milpa* plot for both seasons	44%		
Plot was a fallow prior to maize cultivation	95%		
	Average	**Min**	**Max**
Fallow length (years)	6.8	1	25
Distance to *milpa* (minutes)	79	10	150
Bracken present prior to plot clearing	27%		
	Good	**Moderate**	**Low**
Quality of *milpa* harvest where bracken was present (n=9)	4.5%	4.5%	1%

Coffee is by far the most important income-generating crop. Table 3.4 summarizes the main characteristics of the active coffee plots at the time of the interview. Eighty-six percent of the households interviewed had coffee plots, and the number of plots per household varied between one and four. A slight majority, 53% of coffee plots holders had only one plot with an average size of 1.33 ha.

The declaration of the VCAs included the rule that no land use change is allowed in the area, but this excluded new coffee fields within the VCAs. However, existing coffee fields within the VCAs were "grandfathered-in" and residents could continue to farm there, but could not expand. The survey showed that two-thirds of farmers (67%) had their coffee plots outside the VCAs, suggesting it was not a highly favored area to begin with, while 23% had their coffee plots within the VCAs. Ten percent were not sure whether their coffee plots are located within or outside VCAs, suggesting a lack of knowledge by some farmers regarding the conserved areas boundaries.

Bracken fern has had some effect on coffee cultivation, although this appears to be limited in its impact. One third, ten out of 30 coffee plot holders, reported that bracken fern was present to some extent in the plots before the coffee was planted. Two (20%) of these ten respondents, reported that coffee harvest quality was good in these plots with bracken, six (60%) said harvest quality was moderate, and two (20%) reported low harvest quality. Only a minority attributed the moderate or low coffee harvest quality to poor soil quality, while the majority attributed it to other factors. Nuisance animals were not reported to cause decreased coffee harvests quality, indicating they are not a threat to coffee fields. These data suggest that bracken fern is not considered problematic in coffee fields.

Table 3.4. Coffee Plots and Bracken Fern Presence (n=30)

Had active coffee plots	86%			
	1 Plot	**2 Plots**	**3 Plots**	**4 Plots**
Number of coffee plots	53%	23%	20%	3%
Average size (ha)*	1.33	1.43	2.8	3
	Within	**Outside**	**Does not Know**	
Coffee plots location in reference to VCAs	23%	67%	10%	
Bracken present prior to plot clearing	33%			
	Good	**Moderate**	**Low**	
Coffee quality where bracken was present (n=10)	20%	60%	20%	
	Average	**Min**	**Max**	
Age of plots where bracken was present (years)	13	7	40	

*Sum of averages for more than one plot.

Yucca and pineapple are not subsistence crops but complement the diets of these two communities. The majority, 71% of the interviewed households had active yucca plots, of which 80% had only one plot, and 20% had two plots (Table 3.5). Ninety-two percent of the yucca plot holders reported that to some extent bracken fern was present prior to clearing the plot for cultivation. The average age of these plots was five years and the average walking time to get to them was 22 minutes (as opposed to 79 minutes to walk to *milpa* plots). Yucca crops are planted on the slopes directly above the communities, in areas that have reportedly been dense with bracken for decades. Of the yucca plot holders that cultivated where there was prior invasion of bracken fern, only 13% sold a small part of their yucca harvest. The other 87% produced only for household consumption or have not harvested yet.

Of the yucca plot holders, 24% reported that the quality of their last yucca harvest was good. Seventeen percent said quality had been moderate and 41% said quality had been low (Table 3.5). The other 17% had not harvested yet, therefore could

not answer this question. Eighty-one percent of the yucca plot holders attributed moderate or low harvest quality only to nuisance animals, which by eating it affect its production. Pest animals affecting yucca included pocket gopher (*Orthogeomys hispidus*), white-nosed coati (*Nasua narica*), raccoon (*Procyon lotor*), squirrel (*Sciurus spp.*), collared peccary (*Pecari tajacu*), lowland paca (*Agouti paca*) and Montezuma's oropendola (*Psarocolius montezuma*). Fifteen percent of the respondents attributed moderate or low harvest quality to nuisance animals and to other factors such as a "plague". Only 4% attributed low yucca yields to poor soil quality. Informal interviews suggested that the nuisance animals were perceived to be a result of a hunting ban in the VCAs. Ibarra et al. (2011) also revealed in their Santiago study that nuisance animals' populations have reportedly been increasing, adversely affecting agricultural fields. They also report that the nuisance animal multiplication is associated to the implementation of the VCAs and PHS programs in Santiago.

Regarding pineapple cultivation, only 31% of the households interviewed had active pineapple plots, with no more than a single plot per household, and an average size of 0.27 ha (Table 3.5). It was reported that the majority, 90% of the pineapple plots, had some degree of bracken fern invasion prior to clearing the plot for cultivation. The average age of these plots was five years and the average walking time to get to them was 26 minutes. One household reported a distance from its house to its pineapple plot of 150 minutes, but as an extreme outlier was not taken into consideration in the statistics of "distance to plot" variable (this particular household cultivated the pineapple in the surrounding area of where its *milpa* was cultivated).

Of the active pineapple plot holders, 30% reported good quality of their last pineapple harvest, 50% reported moderate harvest quality, and 20% said quality was low. Eighty-six percent of the pineapple plot holders attributed moderate or low harvest quality only to nuisance animals. More specifically, the reported nuisance animals that ate the pineapple included some birds, such as *Psarocolius Montezuma,* some mammals, such as rats (different species), white-nosed coati (*Nasua narica*), common opossum (*Didelphis marsupialis*), Mexican agouti (*Dasyprocta mexicana*), and some reptiles such as *terete*, an unidentified lizard. Only 14% attributed the moderate or low pineapple harvest quality to both nuisance animals and poor soil quality. All of the produced pineapples were for household consumption and none were sold.

Table 3.5. Yucca Plots (n=25), Pineapple Plots (n=11) and Bracken Fern Presence

	Yucca		Pineapple
Had active plots	71%		31%
Number of plots	**1 Plot**	80%	100%
	2 Plots	20%	0%
Average size (ha)	**1 Plot**	0.25	0.27
	2 Plots	0.65*	n/a
Bracken present prior to plot clearing	92%		91%
Harvest quality where bracken was present Yucca (n=23) Pineapple (n=10)	**Good**	24%	30%
	Moderate	17%	50%
	Low	41%	20%
	Not Harvested Yet	17%	n/a
Age of plots where bracken was present (years)	**Average**	5	5
	Min	<1	1
	Max	33	10
Distance to plots where bracken was present (minutes)	**Average**	22	26**
	Min	5	15
	Max	40	60**
Sold Part/Whole Harvest (n=23)	13% (Sold Part)		0%

*Sum of averages of two plots. **150 minutes away plot not counted.

In the studied communities land use for livestock purposes is a minor component of the landscape. Forty-nine percent of the interviewed households possessed at least one livestock animal, the mule being the most common one. Only one household possessed three cows. The majority, 75% of the households, kept their mules tied to their homes, 19% kept them in pastures, and 12% kept them on the river bank. The three cows were kept in pastures. The three reported pastures were 1 ha in size and they had some degree of bracken fern invasion prior to being pastures. It was reported by the pastures holders that vegetation at the time of the interview mainly included grass and trees (mango, nance (*Byrsonima crasifolia*), oak), and that bracken was little or no longer present. In general grass was introduced by pasture owners, but trees apparently appeared following natural ecological succession.

Pasture holders stated that since mules and cows can feed on the three invasive plant species (two ferns and one invasive grass) present in the study area, they purposely introduced livestock in these pastures, to attempt to get rid of these invasive species. But livestock feeding on bracken could be counterproductive, as it is known that *Pteridium* can cause carcinogenic effects on mammals (Marrs & Watt 2006, Crane 1990).

LOCAL KNOWLEDGE AND PERCEPTIONS ON BRACKEN FERN

Table 3.6 summarizes local knowledge and perception on bracken fern related topics. More than half of the interviewees, 66%, believe that bracken fern has been present in their communal lands for more than 100 years, and 23% believe it has been present between 50-100 years. Only a minority, 11% believe bracken has been present for less than 50 years. In regards to change in size, half of the interviewees, 51%, do not

think there has been any size change in bracken fern invaded areas since they can remember. Thirty-four percent of the sample believes the invaded areas have increased, and the other 14% actually believe there has been a reduction in size of invaded areas.

One of the questions in this section specifically asked the interviewees to estimate how many hectares were invaded by bracken in their respective community. But this was a difficult question to answer, given that there has not been any attempt to measure the extent of the invasion in the study site, and because farmers are not used to such calculations. In general, the majority of the informants (69%) believe there are a lot of hectares invaded by bracken fern, but they do not how many. The other informants did not know. Given the uncertainty of the answers, this question was not included in Table 3.6.

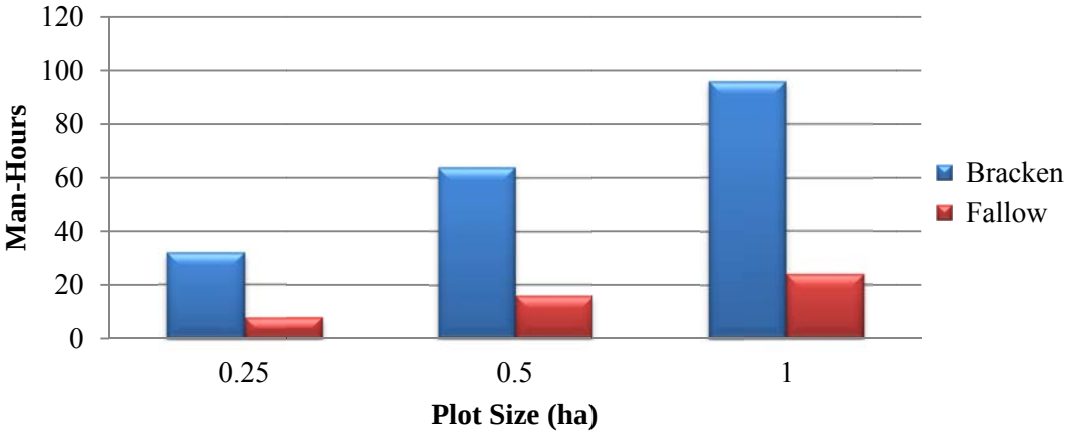
When asked about their preferences for land uses they would like to see instead of bracken, the majority, 97% and 94%, responded that instead of bracken they would prefer to see fallow land for *milpa* cultivation and forest, respectively. In regards to agriculture, 71% would like to see *milpa* plots, 60% would like to see coffee fields and 40% would like to see other crops. Regarding the restoration possibility of these degraded areas, about half of the respondents, 51%, believe that all bracken invaded areas have the potential of being restored to fallow cultivation areas or crops. The other half does not think restoration can be achieved.

Bracken fern is considered as a problem by 91% of the interviewees. Informants provided several reasons why they view it as a problem, and I summarized these reasons into four which will be explained in more detail in the Chapter V 1) clearing areas invaded by bracken is a labor demanding activity, 2) soil is of poor quality, and none of

their subsistence crops (maize, beans, etc.) thrive if cultivated there, 3) bracken is persistent and difficult to get rid of, and 4) burning these areas is dangerous. As was noted earlier, bracken is seen by farmers as an important limiting factor for cultivation of maize in the areas right around the communities, but not for the cultivation of yucca and pineapple.

Interviewees were asked whether clearing a fallow required less labor than clearing an area with bracken. One hundred percent of the interviewees agreed that clearing a fallow is less labor intensive than clearing an area with bracken fern. This question directly relates to reason number one above as of why bracken is considered a problem, given that it actually states the difficulty of clearing these areas compared to clearing fallows. According to the informal interviews, labor required to clear a plot with bracken is approximately four times more than the amount of labor required for clearing a fallow forest (Figure 3.2).

Figure 3.2. Labor Required to Clear Bracken Fern Plots and Fallow Forest Plots of 0.25 ha, 0.5 ha and 1 ha*



* Information to create this figure was taken from anecdotal information gathered during informal interviews.

Furthermore, 71% of the interviewees did not perceive any benefit from bracken fern areas, and only 29% of the interviewees did perceive some benefits. The few benefits mentioned included that these invaded areas: 1) have potential to become pastures since livestock can feed on the invasive fern on the dry season, when there is no regular feeding grass (zacate) available, 2) firewood can be extracted, 3) in the long-term and through continuous labor these areas have some agroforestry potential (for example mango and sugarcane), and 4) produce good yucca/pineapple harvests. The benefits of producing pineapple in bracken invaded areas has been reported by Edouard (n.d) and Edouard et al. (2004) in their Chinantla study, where high pineapple yields were generated and farmers at stake were able to commercialize it in local and regional markets and thus generated some income, part of which was invested in paying for the hired extra-labor needed to work in these invaded parcels.

To see if yucca and/or pineapple plots had been abandoned due to bracken fern invasion, informants were asked if during the last five years they had abandoned yucca/pineapple plots, and 83% responded affirmatively. According to the informants, the vegetation in these abandoned plots at the time of the interview was, in descending percentage values: fallow, bracken, bracken and other vegetation, other crops, and pasture (Table 3.6).

Table 3.6. Local Knowledge and Perception on Bracken Fern (n=35)

Since when do they know bracken areas exist in the study site	**>100 years**	66%
	50-100 years	23%
	10-50 years	11%
Have bracken areas changed in size	**No Change**	51%
	Decreased	14%
	Increased	34%
Instead of bracken would like to see	**Fallow**	97%
	Forest	94%
	Milpa	71%
	Coffee	60%
	Other Crops	40%
Believe all bracken areas can be restored to fallows or crops	51%	
Believe bracken is a problem	91%	
Agree that is less labor intensive to clear a fallow than bracken	100%	
Believe bracken invaded areas offer any benefit	29%	
Abandoned yucca/pineapple plots in last 5 years prior invaded by bracken	83%	
Current vegetation in these abandoned plots (n=29)	**Fallow**	34%
	Bracken	28%
	Bracken + Other Vegetation	21%
	Other Crops	14%
	Pasture	3%

Interviewees were also asked to classify soil types in areas of bracken fern invasion. Seven different soil types were reported. The classification was based on soil color, which according to informal interviews is how Chinantec people classify their soils. Table 3.7 lists the different soil types and some characteristics associated with each type. The respondents were asked to list the soil types they knew are present in bracken fern invaded areas and the most common mentioned ones were black, yellow, red and orange. Brown, gray and purple types were mentioned, but less often.

A list of crops (maize, coffee, yucca/pineapple, fruit trees, trees/firewood, other) was provided to the respondents, and asked whether the quality of each soil type was good to produce each of the mentioned crops. The quality of black soil in bracken areas was reported to be good to grow all crops, especially yucca/pineapple crops, followed by trees/firewood, maize and fruit trees. On the basis of this information, black soil was determined to have high quality. On the contrary, yellow, red and orange soil categories were reported to have poor quality for the production of maize, fruit trees and coffee, but yucca and pineapple were reported to grow well in the invaded areas. The informants also mentioned that some trees/firewood can grow in these yellow, red and orange soil categories, but in general informants believe that these soils are of poor quality. The less often mentioned soil categories, brown, gray and purple, were reported to have poor quality in which only yucca/pineapple can be produced and maybe some trees have the potential to grow. Regarding the texture, respondents agreed that black soil has sandy texture, and yellow, red and orange soils have clay texture (Table 3.7).

Informants were asked which of the listed soils was the most abundant in the bracken invaded areas. Out of the entire sample, only 33% said that black soil was the most abundant. The remaining 67% listed the non-black soil types as the most abundant. Thus, according to the provided information, the most common soils in the invaded areas are the ones that present poor quality.

Table 3.7. Knowledge of Soils on Bracken Fern Areas (n=35)

Color	# of Times Mentioned	Production Potential							Depth (cm)	Texture
		Y/ P	T/ FW	FT	M	C	O	NO PP		
Black	30	●	◘	♦	◘	○	○		10-100	Sandy
Yellow	19	●	◘					♦	10->100	Clay
Red	9	●	◘				♦	○	15-100	Clay
Orange	7	●	◘					♦	n/r	Clay
Brown	3	●	◘						25	Sandy + Clay
Gray	2	●	◘						n/r	Sandy
Purple	1							●	20	Sandy

Y/P=yucca/pineapple; T/FW=trees/firewood; FT=fruit trees; M=maize; C=coffee; O=other; NO PP=no production potential; ●=most mentioned; ◘=2nd most mentioned; ♦=3rd most mentioned; ○=less often mentioned; n/r=no response.

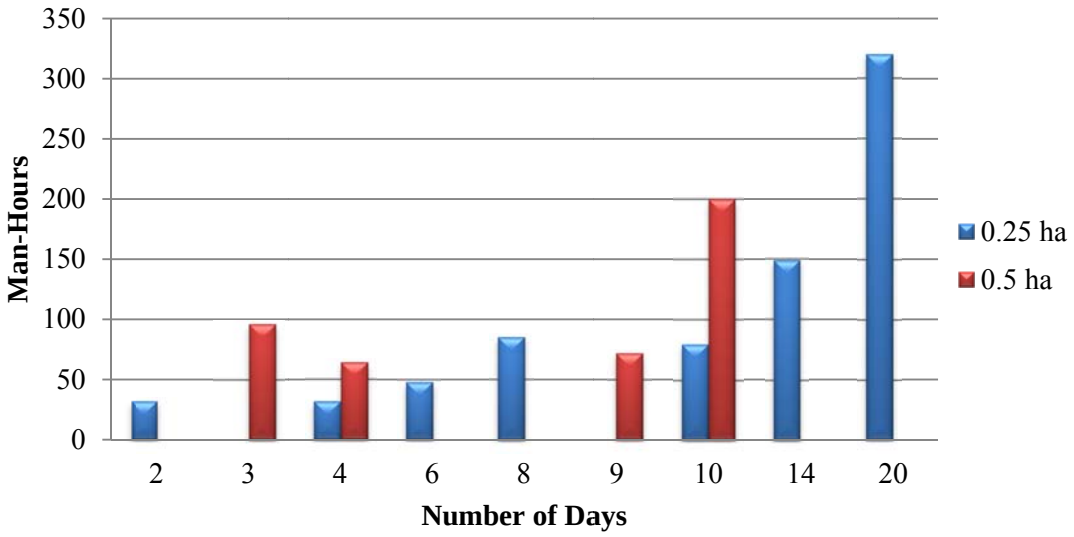
LOCAL TECHNIQUES TO CONTROL BRACKEN FERN

During the conception of this thesis, there was an assumption that these communities had developed diverse novel strategies to control bracken fern and to attempt the restoration of the agricultural functionality of these degraded lands. Nonetheless, during informal interviews I found that the control strategies are limited to mechanical controls which consist of manually cutting bracken with machetes and/or pulling the roots up by hand, followed by biological controls which consist of planting yucca and/or pineapple to generate shade which inhibits the growth of bracken. To learn about these bracken control methods, respondents were asked to provide detailed information on one crop cultivated in a bracken invaded area in the last five years. I included a detailed description of these methods in Appendix 3. Eighty-eight percent provided information on bracken control techniques practiced in yucca (74%) and pineapple (14%) plots, 6% provided information on bracken control techniques practiced in *milpa* and coffee fields, and the other 6% did not practice any control techniques.

There was only one interviewee who had attempted a different method to control bracken. The method consisted of planting *cedro* (*Cedrela sp*). In his own words: "*I planted cedro in a bracken invaded area and it is growing well. Cedro is a tree species known for its good and high-valued timber, and it thrives in prior bracken invaded areas*". Planting timber species to recover the functionality of these bracken degraded areas, has been reported by Edouard (n.d) in his study in San Juan Lalana in the Chinantla region. Edouard reported that *cedro* and oak (*Tabebuya rosea*) timber species, planted with organic fertilizer were the species with the highest rate of growth.

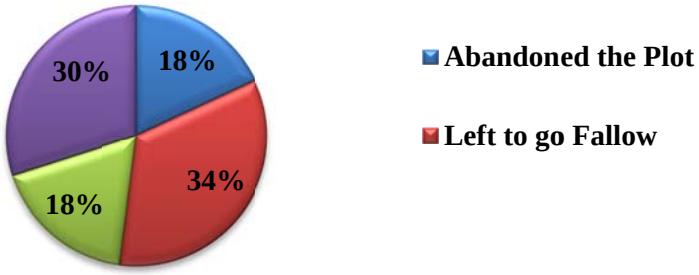
I was also concerned with how much household labor is necessary to clear bracken fern plots in preparation for agriculture. For this purpose, I calculated labor in terms of needed man-hours to clear bracken invaded plots of 0.25 ha and 0.5 ha, which are the most common plot sizes for yucca and pineapple cultivation. Man-hour value computations were made according to three variables: 1) number of days, 2) number of hours per day, and 3) number of workers needed to clear bracken invaded plots of either 0.25 ha or 0.5 ha (Figure 3.3). It is worth noting that according to the collected data regarding household labor applied to clearing areas covered with bracken fern, there is not a clear relationship between plot size, hours/days in the field and number of workers needed to accomplish this task. This variability may be related to errors in estimates or to differences in work capacity of individual household members, related to gender or age.

Figure 3.3. Labor Needed to Clear Bracken Fern Plots of 0.25 ha and 0.5 ha (n=35)



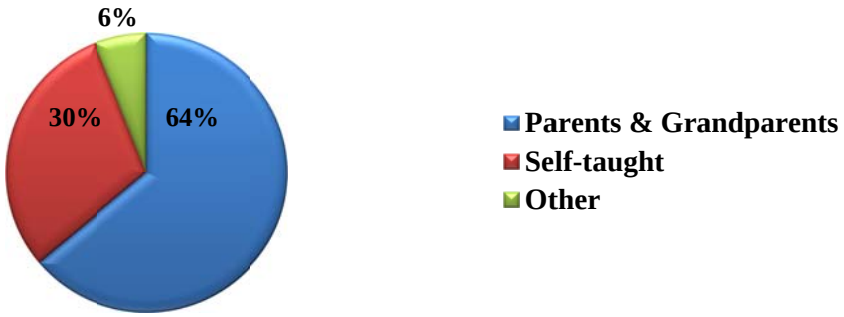
Regarding the land use of the plots where bracken control methods were practiced, 30% of the informants reported their plots were still active because the crops were not mature yet and thus had not harvested yet. Of the 70% that had already harvested, 18% used the same plot to plant again a crop, 18% abandoned the plot completely, and the other 34% left the plot to go fallow for future agricultural use. None of the respondents that left the plot to go fallow did anything to control the growth of bracken because they reported that is uncommon for bracken to re-grow in this type of fallows (Figure 3.4).

Figure 3.4. Land Use After Harvesting the Plots Cultivated where Bracken was Present (n=35)



I was also interested in knowing how the bracken control techniques knowledge was learned among the interviewees. Thus, the survey specifically asked from whom did they learn the control techniques, and two-thirds of the informants responded they inherited the knowledge from their parents and grandparents, indicating that traditional knowledge on bracken fern control techniques has been transmitted on a generational basis. Thirty percent responded they self-taught via trial and error, and the other 6% said they learned from observing others (Figure 3.5).

Figure 3.5. Different Ways in which Knowledge on Bracken Control Techniques is Acquired (n=35)



I was also interested in learning the ecological function of bracken fern areas in supporting the presence of mammals, especially nuisance animals. For this purpose the survey asked the informants to list nuisance animals they had seen in the bracken invaded areas. Eighty percent (28 respondents) of the interviewees had seen nuisance animals in bracken areas. A total of eight species of mammals were mentioned by the informants during this exercise (Table 3.8). According to the informants, seven of the eight mentioned pest-animals species are mostly harmful to maize and yucca crops (except the common opossum which preys on bananas). These results might suggest that bracken fern areas play a positive ecological role in supporting animal species, but at the same time the invaded areas can play a negative role in human livelihoods by supporting animals that are harmful to agricultural fields.

Table 3.8. Nuisance Animals Present in Bracken Fern Areas (n=28)

English Name (Scientific Name)	Number of Times Mentioned	Number of Informants that Have Seen It	Feeds On			
			M	Y	AC	O
White-nosed coati (*Nasua narica*)	23	22	x	x		
Collared peccary (*Pecary tajacu*)	15	14	x	x		
Northern raccoon (*Procyon lotor*)	8	7	x	x		x*
Squirrel (*Sciuris spp.*)	6	6	x	x		
Paca (*Agouti paca*)	2	2	x	x		
Mexican agouti (*Dasyprocta mexicana*)	8	7	x	x		
Rat (unidentified)	2	2			x	
Common opossum (*Didelphis opossum*)	1	1				x**

M=maize; Y=yucca; AC=all crops; O=other; *other=sugar cane; **other=bananas.

To corroborate the information provided above and with the purpose of learning what other mammals, besides nuisance animals, are supported by bracken fern areas, I showed the interviewees the illustrations of mammals from Beletzky's (1999), and asked them to point out any species they had seen in bracken fern areas. The majority of the informants (97%) pointed out from the illustrations at least one mammal (Table 3.9). In total, 14 mammal species were recognized, out of which seven are the same as the ones mentioned in the previous exercise. The only species in these two lists that is not shared is the rat, which is not included in the mammals' illustrations showed to informants.

According to the interviewees, seven of the 14 species shown in Table 3.9 are considered nuisance animals. The majority of these animals utilize the bracken fern areas, to carry out different activities such as hiding, walking, sleeping, resting, eating, making nests in the invaded areas. Seven of the species in Table 3.9 are non-nuisance animals, and there was even one report of a jaguar sleeping in a bracken fern area. The presence of non-nuisance animals might also indicate a positive ecological role of the invaded areas in being habitat for wildlife.

I was interested in learning if the respondents perceived bracken areas as habitat for wildlife (nuisance and non-nuisance). For this purpose, I asked them if they believe that bracken fern areas increase the number of nuisance and non-nuisance animals and two-thirds of the informants responded affirmatively, 17% answered negatively, and the other 17% did not know or did not answer. If it is true that VCAs are responsible for the increased presence of nuisance animals in the communities, as some farmers believe, bracken fern areas could be contributing to the exacerbation of the pest-animals problem by providing refuge areas for harmful animals.

Table 3.9. Presence of Mammals in Bracken Fern Areas (n=34[1])

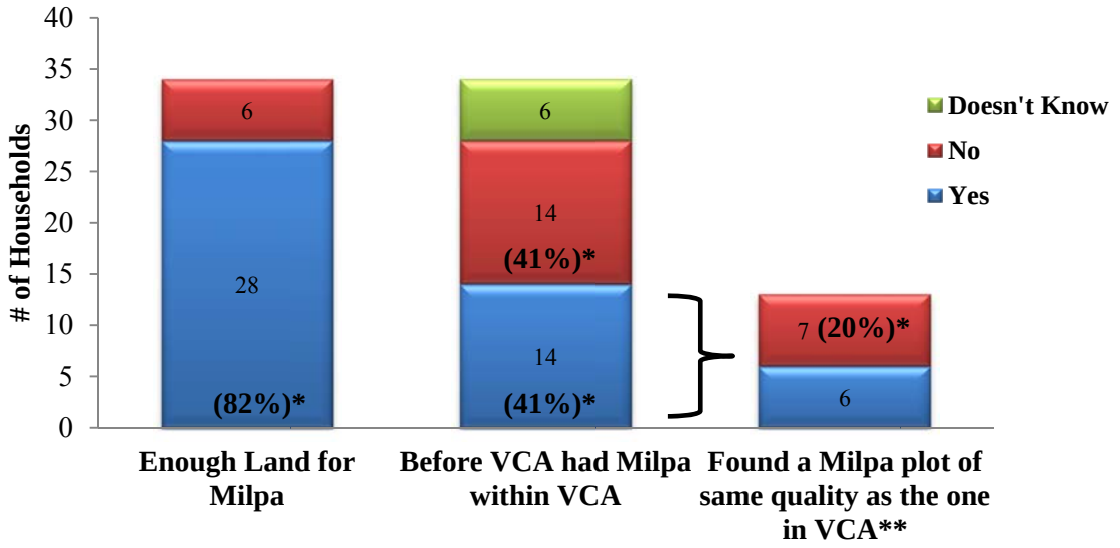
English Name (Scientific Name)	Number Times Informants Recognized It in Book	Nuisance	Non-Nuisance	Activity						
				h	w	s	r	e	n	l
Nine-banded armadillo (*Dasypus novemcinctus*)	29		x	x	x	x	x	x	x	x
White-nosed coati (*Nasua narica*)	26	x		x	x	x	x	x	x	x
Red brocket deer (*Mazama americana*)	22		x	x	x	x	x	x		x
Collared peccary (*Pecari tajacu*)	21	x		x	x	x	x	x	x	
Common opossum (*Didelphis opossum*)	19	x		x	x	x	x		x	x
Mexican agouti (*Dasyprocta mexicana*)	16	x		x	x	x	x	x	x	
Squirrel (*Sciuris spp.*)	15	x		x	x	x	x	x	x	
Paca (*Agouti paca*)	14	x		x		x			x	x
Northern tamandua (*Tamandua mexicana*)	13		x	x	x	x	x	x		
Hog-nosed skunk (*Conepatus mesoleucus*)	11		x	x	x	x	x	x		x
Northern raccoon (*Procyon lotor*)	10	x		x		x				x
Jaguar (*Panthera onca*)	1		x			x				
Gray four-eyed opossum (*Philander opossum*)	1		x	x					x	
Mexican hairy porcupine (*Sphiggurus mexicanus*)	1		x							

[1]San Pedro's *Comisariado* left out; h=hides; w=walks; s=sleeps; r=rests; e=eats; n=has nest; l=lives; *0=the informant's father saw it.

LOCAL PERCEPTION ON VOLUNTARY CONSERVATION AREAS (VCAs)

I was also interested in learning how VCA and PHS programs have affected land use in the study site, as well as the local perception on the potential relation between establishment of conserved areas and the increase in nuisance animals reported in informal interviews. In spite of the establishment of the VCAs, 82% of the interviewees believe that in their respective communities there is still enough land for every family to have *milpa* plots. Before the establishment of VCAs, 41% of the informants had *milpa* within the lands that are now designated as VCAs. After the establishment of the VCAs, 43% (6) out of the 41% (14) informants mentioned above, were able to find a *milpa* plot of the same or similar quality as the one they used to have within the VCA. The other 50% (7) had trouble finding a *milpa* plot of equivalent quality to the plot they used to have in the VCAs (Figure 3.6). It is worth noting that one (7%) informant, reported still having a *milpa* plot within the VCA, because he did not agree with the restriction that VCA imposes over agriculture production.

Figure 3.6. Perceptions on Availability of Land for *Milpa* Cultivation After Establishment of VCA (n=34[1])



[1]San Pedro's *Comisariado* left out; *Percentage representing n=34; **One household reported still having a *milpa* plot within the VCA.

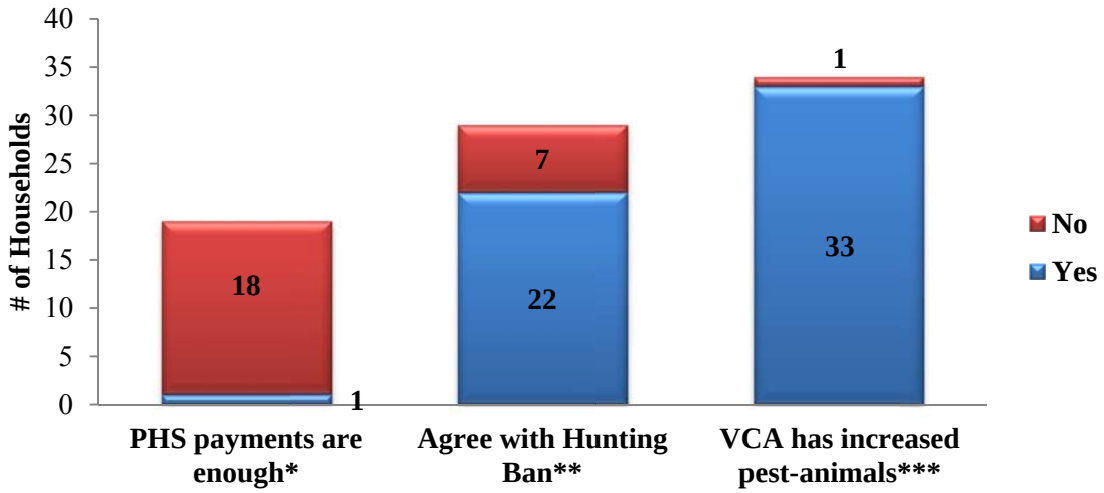
The question regarding if payments from the PHS program were worth the restrictions placed on forest use for agriculture (*milpa*s), was not asked to San Pedro's interviewees (except to the first interviewee) because of the project research mistrust issue explained earlier. For the 19 informants that were asked the question, the majority, 95% (18), felt that payments from the PHS program were not worth the restrictions placed on forest use for agriculture. Only one interviewee felt payments were worth the restrictions, but did not state why (Figure 3.7). In general, informants felt that the monetary incentives received from PHS program were not enough to cover the costs of purchased foodstuffs, like maize, beans and other comestibles.

It is worth noting that out of the 19 interviewees that were asked the question about PHS payments, 11 did report having had *milpa* within the VCA before its establishment, while the other seven did not. Six of the seven that did not have *milpa*

within VCA, responded payments from PHS program were not enough to compensate for the restrictions on cultivating *milpa*s within the VCAs, but they did not have *milpas* within VCA to begin with. On the basis of this discrepancy, I would speculate that these six informants that had never suffered any restriction, were implying that they would like to receive more money from the PHS program, and because of the way the question was phrased, they had to link it to restrictions. Therefore, no important findings can be concluded from this question.

Seventy-six percent (22) of the interviewees agreed with the self-imposed hunting restriction on non-nuisance animals, mainly because they claimed that non-nuisance animals are harmless to crops, thus there is no need to hunt them. Ninety-seven percent said they believe the VCAs have triggered an increase in the number of nuisance animals (Figure 3.7).

Figure 3.7. Local Perceptions on Some Aspects of Conservation Programs and Measures



*(n=19)=15 households in San Pedro left out; **(n=29)=6 households in San Pedro left out; ***(n=34)=San Pedro's *Comisariado* left out.

This chapter presented the results of the 35 structured household interviews, supplemented with data from informal interviews, and was divided into sections that addressed the households as productive units, the main agricultural systems, local knowledge and perception on *Pteridium aquilinum*, motivations to control it, the existing local control techniques, and perceptions on VCAs. In the households as productive units section, I found that 73% of the household members participate in the principal agricultural activities of slash-and-burn, sowing, weeding, harvesting and firewood gathering. The main agricultural systems are the cultivation of *milpa*, shade-coffee, yucca and pineapple. According to informal interviews, *milpa* and coffee are cultivated in bigger plots compared to the smaller yucca and pineapple plots.

In the local knowledge and perceptions on bracken fern section, I found that *milpa* plots are found at a greater walking distance (79 minutes) from the towns that the yucca/pineapple plots (22-26 minutes). Results from this section suggest that bracken fern does not have a negative effect on maize or coffee production and that bracken fern invasion of milpa plot is not currently a serious problem. The majority perceives bracken as a problem, and do not perceive many benefits from it. In general, bracken fern areas have poor quality soils where maize does not thrive, but where yucca and pineapple crops grow well. Bracken's invasion in my study site is mainly controlled by cultivating yucca and pineapple crops. Informants reported good yucca and pineapple harvests, but pointed out that nuisance animals attacked the crops and destroyed the harvests.

Although, establishment of VCAs has restricted the amount of agricultural areas, most informants believe there is enough land for every household to cultivate *milpas.* Informants were able to find *milpa* plots outside the VCAs, but around 20% felt they

were not always of the same quality of *milpa* plots within VCAs, and apparently one household still has a *milpa* within the VCA. There is a sense among most farmers that the increase in numbers of nuisance animals is related to the VCAs. Bracken fern areas apparently have a positive ecological functionality, given that it was reported that 15 mammals' species utilize the invaded areas in diverse ways.

In the next chapters I will mainly discuss: 1) local knowledge, perceptions and motivations to control bracken fern, 2) bracken's fern impact on land use and degree to which VCAs and bracken fern combined may be impacting availability of agricultural lands, 3) ecological value of bracken fern areas, 4) impacts of bracken fern invasion on local livelihoods, 5) positioning of my study as a unique case study of bracken fern in southern Mexico. In addition I will conclude important findings and formulate some practical recommendations.

CHAPTER IV

ANALYSIS

HOUSEHOLDS AS PRODUCTIVE UNITS

In most of the rural areas of developing countries, the household is considered the basic unit of production, reproduction and decision making of familial labor power on both a daily and a generational basis (Deere & de Janvry 1979), as in the case in San Pedro and Santiago. Factors like the remote location, lack of roads, low access to local markets, low educational levels, and few local employment opportunities contribute to the persistence of subsistence agriculture among the studied indigenous communities. Therefore, the demography of each household is relevant given that the production system of these communities is completely based on family labor which is applied mainly to the subsistence (*milpa*) fields and to the cash generating (coffee) fields. It is important to look at the availability of household labor to understand if the labor required to deal with bracken fern invasion is placing a strain on the households. Utilizing too much household labor in clearing and controlling bracken fern could reduce the availability of labor for basic subsistence crops. This could be particularly damaging to the household economy since, as we shall see, what is obtained from invaded areas are complementary diet products which many times get eaten by nuisance animals before harvesting.

The lifecycle of a household refers to the predictably changing composition of its size, age and sex, and is shaped by several variables such as fertility, morbidity, mortality and migration (de Sherbini et al. 2008). The results of my study revealed that the average point in the lifecycle of the households at the time of the interview was characterized by a relatively high number of individuals per household, on average young and almost

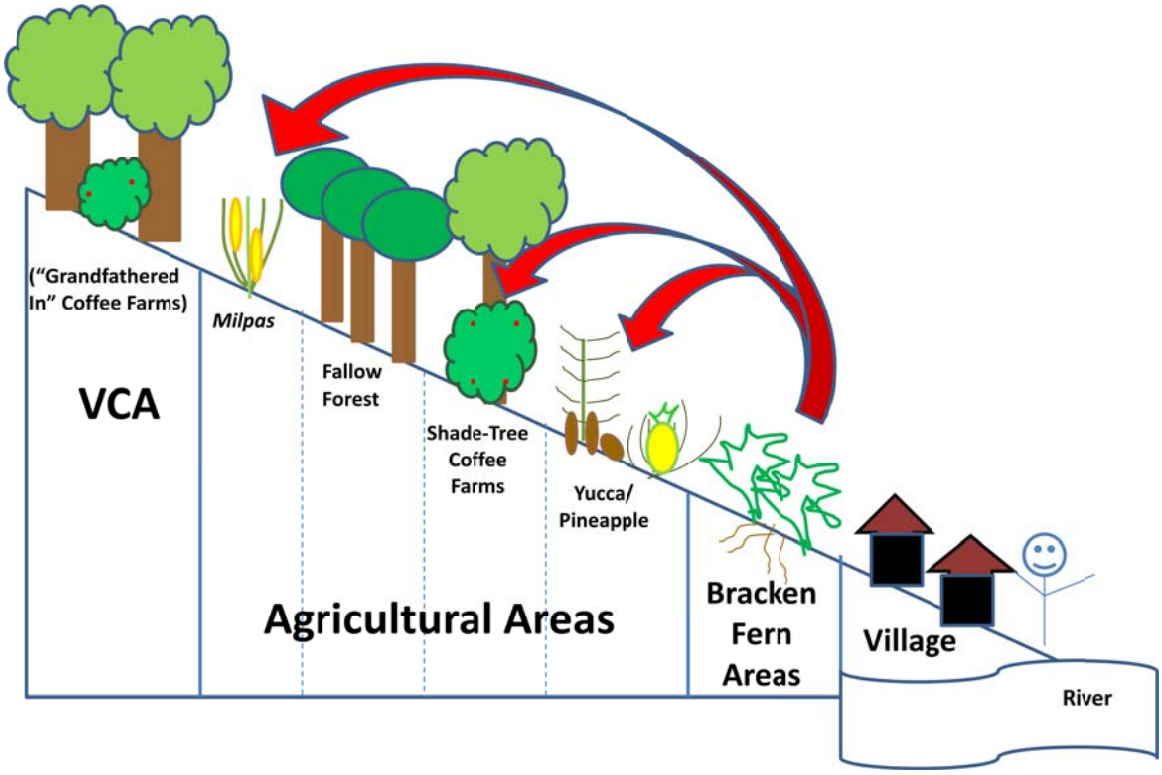
equally distributed by gender (Table 3.1). The agricultural labor force of the households is composed by the majority (73%) of the household members, and the other 27% either belongs to elderly adults that no longer participate in agricultural production or to children under the age of seven, which will eventually be incorporated to the family farm labor force as they grow older, in order to increase it. The relative high household size in my study site (6), compared to Mexico's national average (3.9) (INEGI 2012), could be explained by the increase in need of children to help at home and in fields to keep land in production (demand for farm labor), lack of security in illness and old age (Marcoux 1999), and lack of other employment opportunities.

The results of my research also show that the gender division in household labor is almost equally distributed among men (46%) and women (52%), as well as among individual agricultural activities (sowing, weeding, harvesting), except for two that are distinctly differentiated by the gender that performs them. These activities are: 1) the slash-and-burn method, which on average is 90% a male activity, and 2) the firewood gathering, which on average is 81% a female activity. The gender division of these two activities is not uncommon in rural areas. While men participate more in land preparation activities (slashing and burning), rural women in Latin America, in addition to their domestic work and child caring, engage in diverse activities such as food gathering, firewood collection, agricultural activities (planting, weeding, harvesting, threshing crops), and raising domestic animals (Rimarachin-Cabrera et al. 2001).

MAIN AGRICULTURAL PRODUCTION SYSTEMS AND BRACKEN FERN

As revealed by the results, three main agricultural land use units are embedded within the study site's land use system: 1) *milpa* as the subsistence crop/system; 2) coffee as the cash income generating crop; and 3) yucca/pineapple as complementary crops to diversify the diet (Figure 4.1). Livestock/pastures production is not a common land use unit in the study site.

Figure 4.1. Land Use Profile and Bracken Fern Invasion



Since maize is the basis of native people's diets across Mexico, this crop occupies approximately 90% of the *milpa* multi-crop system (Rimarachin-Cabrera et al. 2001). *Milpa* is the traditional food system and key agricultural element of local livelihoods in the study site (Ibarra et al. 2011), and is characterized by its diversity of crops, mainly: maize, beans, squash and chili. Edible plants such as *quelites* (leafy greens) grow wild within the *milpa*, and are gathered by the inhabitants to complement their diets (Ibarra et

al. 2011). Maize is of the upmost importance in these communities, not only to feed the human population, but it is also used to feed domestic animals, such as chickens, turkeys, mules, dogs and even fish in recently introduced aquaculture ponds.

Milpa in the study site is produced for subsistence purposes, and it is practiced under the swidden cultivation method. Under this method, vegetation is cut in the dry season between January and May, and burnt as late in the season as possible, soon after the first rains (usually late May), sowing is done in June and harvest in November and December (Van der Wal 1999). As shown in the results of my study, in 2010 *milpa*s were cultivated mostly in the rainy season, and some households cultivated *milpa* during the dry growing season because they did not have a good harvest during the rainy season. After harvesting, plots are left to fallow for an average of seven years. These results are congruent with the study by Van der Wal et al. (2006), in which they found that in the Chinantla region, *milpa*s are cultivated mainly in the rainy season (June-November), and then left to fallow for five to ten years.

My results show that in these communities *milpa*s are located at a great distance from the towns, and inhabitants have to walk on average 79 minutes (others as far as 150 minutes) to get to their *milpa* plots. Not only they have to walk, but they have to carry with them tools to work in the fields and when they harvest they have to carry the produce back to the towns. These results are corroborated by Van der Wal's (1999) study in Santiago, where he found that most *milpa* fields are located more than 5 km away from the village, in the higher parts of the catchment area, in the mountain rain forest or "*selva alta perennifolia de montaña*", at an altitude interval of 400 m to 900 m (Santiago's altitude is 120 m).

As shown in my results only a minority of *milpa* plot holders (27%) reported bracken fern presence prior to clearing for maize cultivation. Out of these 27% households, only 6.5% reported low quality *milpa* harvest, apparently related to poor soil quality because of the fern's presence. In fact, among the informants, I heard more complaints about poor *milpa* harvests due to nuisance animals than because of poor soil quality. These results suggest that bracken fern is not an immediate threat to the cultivation of *milpa* in these communities.

There were different reasons why 27% of the households cultivated *milpa* where there was some extent of bracken fern presence. Some informants claimed that they were motivated to do it, while others felt obliged. Here I quote the diverse reasons:

Felt Motivated	Felt Obliged
- "*it was a good fallow, and there was not much bracken*" - "*the majority of the plot was a good fallow*" - "*we cleared and weeded the plot with the aim to get rid of bracken*" - "*we wanted the soil to improve in that plot in order to get rid of the bracken*"	- "*there was a fire four years ago in my fallow, and after that bracken fern invaded it….when we returned to cultivate milpa, 30% of the plot was invaded by bracken*" - "*fortunately the majority of the plot was fallow, but either way we are forced to cultivate in those fallows, because we cannot cultivate in the VCA*" - "*my plot used to be a good fallow, but now bracken has taken over my milpa and there is a lot of it…my harvest was bad because the soil is not good anymore. There are not much places left to cultivate that is why we have to use those plots*" - "*the best fallows with tall trees are too far away, we cultivated our milpa there because it was the nearest place, but there was a lot of bracken*"

The above quotations might suggest two things. First, that even though bracken fern is not a generalized problem for *milpa* cultivation, there is evidence that it can establish in *milpa* plots if favorable conditions are created. Second, a minority of the

interviewed farmers (20%) perceived that apparently VCAs have reduced the amount of available agricultural land in the communal territories, and according to the affected farmers they have had to utilize the bracken invaded plots because their options regarding available agricultural areas were limited.

Coffee cultivation is an important agricultural activity in the study site, as evidenced by 86% of the households that reported having active coffee fields at the time of the interview (Table 3.4). These communities have had a long history of coffee production mainly for the generation of income. Coffee cultivation is conducted in an agroforestry system in which it is grown under shade trees. After establishment of the VCAs no new coffee fields are allowed to be opened within them, but before its establishment many households had their coffee fields in the areas that now are part of the VCAs, and since a coffee field represents a much higher investment than a corn field, these fields were allowed to remain within the VCA after its establishment (D. Bray pers. com.). This "in-holding" explains the 23% households in my study that have active coffee farms within the VCAs. It is interesting noting that 10% of the interviewees did not know if their coffee fields were within or outside the VCA, but this could be explained by the fact that the limits of the different land uses in the study site are still not well defined, generating "spatial" uncertainty among the inhabitants.

As shown in my results, 33% of the coffee farmers reported some extent of bracken presence (not invasion) in the coffee fields prior to cultivation. As reported by Van der Wal (1999), coffee is principally grown bordering the river's tributaries at lower altitudes (below 500 m), and this proximity of coffee fields to the villages' outskirts where bracken appears to be more abundant, could explain bracken's fern presence in

coffee fields. But taking into account bracken's ecology and the agroforestry system under which coffee is grown in the study site, I do not believe that bracken has the potential of becoming a threat to coffee farms, because the shade provided by the canopy trees keeps bracken under control and prevents it from becoming invasive.

The predominant motivation to cultivate coffee in areas where bracken was present was because those areas presented proper soil characteristics for coffee cultivation. In addition, others were motivated to get rid of the invasive fern, and few others rather than motivated felt obliged, because of lack of options. The following comments exemplify these motivations and lack of options:

Motivation: Proper soil for coffee cultivation	Motivation: To get rid of bracken	Lack of options
- *"that plot had good soil for coffee, because it was neither too dry nor to moist"* - *"I searched for a flat plot with nearby availability of water, and I found a fallow with these characteristics that had some bracken, but the soil was good for coffee"* - *"that plot had good soil to cultivate coffee and I did not want to waste it"* - *"I chose that plot because it was a fallow, and although it had some scattered bracken, the terrain was good for coffee and it did not have too many stones"*	- *"I cultivated in that fallow with bracken because it was near to my house, and because I want to get rid of bracken"* - *"I cultivated coffee in that plot to see if by doing it bracken would stop growing"*	- *"I used that plot for my coffee field because there are no much more areas where to, it is there or there"* - *"that plot was a forest fallow with bracken..I cultivated there to try to get rid of the fern and because there were not anymore areas where to cultivate"*

As mentioned earlier, even though yucca (*Manihot esculenta*) and pineapple (*Ananas comosus*) crops are not staple foods, they are important in the study site because they complement local diets (*personal observation*, Van der Wal 1999). Yucca is especially important because during certain annual festivities, is utilized to make

specialty tortillas which are highly appreciated by the locals (Weitlaner & Castro 1973). Yucca and pineapple crops are not only important for the local diet, but because by cultivating them, either intentionally or not, bracken fern gets controlled. In the absence of remotely sensed images of bracken's fern extent in the study site, distance to get to yucca (22 min) and pineapple (26 min) plots acted as an indicator that confirmed that invaded areas are located close to the villages.

At least 90% of the yucca and pineapple plots reported in my results were invaded by bracken fern prior to cultivation. In the San Juan Lalana's case study in the Chinantla, which also suffers bracken fern invasion, Edouard et al. (2004) found that pineapple production exhibited high yields in bracken invaded areas. According to their study pineapple plants do not seem to be negatively affected by the nearby presence of bracken and its allelopathic compounds. As evidenced by Weitlaner & Castro's (1973) study in the Chinantla region, "third category" soils are used to cultivate yucca, and are characterized for being the least productive soils in the area. There is no information on the reasons for bracken's fern establishment or when it exactly established in the study site, but as we shall see, I will hypothesize that it is quite possible that the soil got degraded due to centuries of agricultural use, which favored the establishment of the fern at least a hundred years ago.

Since degraded soils are not a limiting factor for the cultivation of yucca and pineapple in my study site, production of high quality harvests of these two crops would be expected. But according to the results of the households that harvested, only between 24-30% of both crops' harvests were good. On the other hand, between 59-70% of the harvests were moderate/low. As explained by the informants, it is not that the quality or

yields of the harvests *per se* were bad, in fact the harvests were good, but the major problem was that nuisance animals ate the yuccas and the pineapples before the farmers had the chance to harvest them. This issue is demonstrated by the results which show that yucca and pineapple poor harvests were in their majority (81% for yucca and 86% for pineapple) attributed to nuisance animals. As one of the interviewees mentioned about his yucca harvest: "*the yucca harvest in my plot was good, but the pocket gopher which goes underneath the soil, ate about half the harvest…the coatis, raccoons and squirrels also ate part of the yucca harvest….what they left was consumed by the family*"; and what other interviewee commented regarding his pineapple harvest: "*the pajaros pepe (bird species) ate around half of the pineapple harvest….what the bird left, was consumed at the house*". Since the majority of yucca and pineapple harvests were eaten by the pest-animals, the farmers that cultivated these two crops were not able to sell the yields and thus did not generate any income.

Locals know that bracken invaded areas have good potential for yucca and pineapple cultivation, which is evidenced by the 92% (n=25) and 91% (n=11) yucca and pineapple plots that were invaded by bracken prior to cultivation, respectively (Table 3.5), which reportedly had good harvests but where attacked by pest-animals. In fact, it could be said that the relative proximity to the villages of these invaded areas and their potential to cultivate yucca/pineapple, represent a two-fold incentive for farmers: 1) diet enrichment, and 2) bracken control. First, to diversify their diet farmers cultivate yucca and pineapple in areas invaded by bracken fern. My results show that the majority of the households have at least one small plot (0.25 ha) that gets utilized for periods of approximately five years to produce yucca/pineapple. The size of these plots is

constrained by the large quantity of labor and time (approximately first two years) required for bracken's clearing and maintenance of invaded areas as mentioned in the previous chapter. Second, through the cultivation of yucca/pineapple, households are contributing to control the invasiveness of the fern.

The following comments from interviewees depict the motivations to cultivate yucca/pineapple in areas with bracken fern:

Motivations: Good soil for yucca/pineapple	Motivations: Bracken control
- *"yucca/pineapple can grow in the invaded areas"* - *"that area is where yucca is produced*" - "*yucca/pineapple grow well there*" - "*that area is not good for milpa or coffee cultivation. Only yucca grows well there*" - "*the soil in those areas is good to cultivate yucca*" - "*that is the only area where yucca grows*" - "*there the soil is hard, and yucca grows well*" - "e*ven though soil is not good, pineapple grows well there"*	- "*we cultivated there to try to at least get rid of a little bit of bracken*" - "*so that bracken disappears*" - "*by cultivating, bracken starts getting removed*" - "*with the aim of getting rid of it*" - "*I cleared the plot so that bracken does not come back*" - "*if you cultivate there often, bracken diminishes, because the soil softens*" - "*to take advantage of the invaded areas*" - "*I do not want bracken to grow anymore*" - "*so that trees can grow*" - "*when weeding by pulling up the root of the fern by hand, it stops growing*"

LOCAL KNOWLEDGE AND PERCEPTIONS ON BRACKEN FERN

As stated before, there is no information on when bracken established, neither the drivers of invasion in the study site, and as Schneider (2010) mentions, in tropical landscapes the use of remotely sensed data for spatial characterization of plant invasion is rare. Therefore, on the absence of this type of data, my study relies on the local knowledge and perceptions on bracken fern. According to the interviewees responses, when the majority of them where born, bracken was already part of the landscape, thus it

has been a familiar sight for them all their lives. The majority of the interviewees (89%) believe that bracken fern areas have existed in their communities for at least 50-100 years (or more).

Even the oldest of the interviewees, between ages 69 to 88, who were born in these communities, claimed that bracken fern has been in the studied landscape for more than 100 years, and for them bracken occurs naturally in the areas where it currently is located. For example, one of the interviewees in Santiago, born in 1923, said "*I remember bracken since I was little. There was a flood in 1920, but the water did not reach the mountain and bracken remained the same*". A female interviewee from San Pedro born in 1942, commented "*when my parents used to chat, sometimes they would mention that since they remember bracken already existed*". Another interviewee, born in San Pedro in 1941 remembers "*my parents used to say that bracken has always been there, and I believe the same*". Another interviewee in San Pedro, who was born in 1936 in another community, commented "*I am from El Barrio, a nearby community. I arrived to live here in San Pedro in 1956 and when I got here bracken was already established*".

Regarding change in size of bracken invaded areas, more than half of the interviewees did not believe that invaded areas have increased, they actually said that these areas have not changed in size, and even some said that that there has been a reduction in size. This means that locals in general do not perceive that bracken fern is expanding in their communal territories, which could indicate that expansion of bracken *per* se is not the main concern of farmers regarding the bracken problem. There is a more generalized sense that bracken is a problem because the sites where it is located have

poor soil quality, and maize does not thrive there, than a sense of bracken being a direct threat to the agricultural production of subsistence crops, but this will be discussed later.

The results regarding the comparison between what land uses interviewees' would like to see in bracken invaded areas, and the feasibility of converting those areas to other land uses (Table 3.6), show that as it would be expected, the interviewees would like to see other land uses, mainly forests, fallows, *milpa*s and coffee fields. This reflects that even if locals believe bracken occurs naturally and is part of the landscape, they would like to see more productive land uses for these sites, which as they acknowledge are of little benefit to them. As shown in the results, there are divided opinions on whether the invaded areas can be restored or not: half of the interviewees believe that restoring all the invaded areas to fallow forests and/or crops is not possible, whereas the other half believes it could be possible (but highly difficult). The following are the most salient provided reasons for the possible and non-possible restoration of invaded areas:

Restoration is possible	Restoration if not possible or highly difficult
1) only if everyone goes out and help 2) bracken could be eliminated by planting trees and plants 3) investing large quantities of labor 4) with time they could be restored (example from one of the informants: ""*my late grandfather cleared a plot that was invaded by bracken….for many years he cultivated yucca in that plot…..and now there is forest fallow*") 5) black and humid soils have the potential of being restored (red and dry soils cannot be restored)	1) soils in the invaded areas have characteristics of unproductive soils: yellow (bad quality), hard and dry 2) soils in invaded areas are of intrinsic poor quality and besides they have too much fern roots and seeds (the soil is good only for bracken's growth) 3) clearing areas with bracken is labor demanding and difficult to clear 4) given the poor soil quality of invaded areas, people do not have enough interest in eradicating the fern 5) except for yucca/pineapple, crops like maize grow small

I condensed the reasons why the majority of the informants (91%) see bracken as a problem, into four main ones, which are described below:

1) Clearing areas invaded by bracken is a labor demanding activity or simply cannot be cleared. In the survey there was one question that asked whether or not clearing a fallow was less labor intensive than clearing a bracken invaded area. All (100%) of the interviewees stated that clearing a fallow forest is a much less labor demanding activity, compared to clearing a bracken invaded area. The impenetrable bracken fern thickets make access difficult and the high density of the fern diminishes the visibility of the laborer, exposing them to the risk of being bitten by snakes. Whereas in fallow forests, the predominant vegetation type are trees (shrub cover is not as dense as in bracken areas) facilitating the clearing activity. In addition, the trees provide shade from the sun, making the job more bearable. Also, trees in fallows are "easier" or softer to cut with the machete, whereas bracken has a hard bark which requires more energy and time to cut. Lastly, fallow forests are not as flammable as bracken fern areas.

2) Soil in bracken invaded areas is not of good quality, and maize does not thrive in those soils. This statement tallies with what other authors like Edouard et al. (2004) have found in their studies of bracken fern in the Chinantla region. According to these authors, farmers who cultivated in high density bracken areas obtained low maize yields, often times lower than 600 kg/ha, when in general 1 to 1.5 t/ha is what normally is obtained.

3) Bracken is persistent and difficult to get rid of. Even if it gets slashed and/or pulled up from the roots, it grows again rapidly. According to Schneider & Geoghegan's (2006) study of bracken invasion in Southern Mexico, eradicating the fern invasion with

traditional weeding techniques is ineffective because of the enduring underground rhizome system of the fern.

4) Burning these areas is dangerous, since there is plenty of dry plant litter and the fire can easily and rapidly get out of control, with the risk of spreading to adjacent forests and/or to active agricultural areas. According to bracken's fire ecology, this is a species known for its fire-adaptability, and for its flashy fuel characteristics, meaning that it promotes fires due to its highly flammable layer of dried fronds (Crane 1990).

The majority of the interviewed households (83%) at some point in the last five years had abandoned at least one yucca/pineapple plot (Table 3.6). This finding suggests that farmers have been actively trying to turn these invaded lands into productive ones. Keeping in mind the crop-fallow cycles involved in swidden agriculture, one would think that the yucca/pineapple farmers abandoned their plots after harvesting them, so that they would become fallow fields. But as mentioned in my results, only five households left these plots to become fallows, five households abandoned them due to low yields, and ten households abandoned them due to nuisance animals. This latter finding is significant in terms of the negative impact that nuisance animals can have over the local restoration efforts to turn these invaded areas into productive ones. These are some illustrative comments in reference to the pest-animals' issue:

"*I do not want to cultivate there anymore because nuisance animals eat everything*"
"*nuisance animals eat the harvests, thus it is not worth to cultivate there anymore*"
"*in just one night, the opossums and the agoutis ate 60 pineapples*"
"*the yucca got eaten by the agoutis and the coatis*"

After abandonment of the yucca/pineapple plots, natural succession and other pathways have followed (Table 3.6). Unfortunately, bracken either by itself or

accompanied by other vegetation, accounts for almost half, 49% (14), of the reported land cover after plot abandonment, probably because the plots were not utilized long enough to be able to eliminate bracken's rhizome system. On the other hand, fallows account for near 34% (10) of the land cover after plot abandonment, which indicates that restoration pathways to natural succession types are possible, apparently if the plot is utilized and maintained somewhat continuously for periods for several years. One of the interviewed households even reported that they left a yucca plot go fallow for 6-7 years and at the time of the interview they were planning on cultivating maize in that plot, and if it turns out fruitful this would be an example of a successful restoration effort.

Given the lack of historical land use/cover data, this study cannot confirm whether the reported low soil quality in the current invaded areas is directly related to bracken or not. Thus, the possibility that current degraded areas presented poor quality soils before the establishment of the fern cannot be discarded. Furthermore, because of lack of information on soil's chemistry on the study site, my study cannot conclude that soils where bracken is present are in fact of poor quality, which one would tend to conclude after hearing the farmers claim that bracken fern areas have poor quality soils and that subsistence crops do not thrive if cultivated there. Actually the literature suggests that bracken does not erode the soil and it may actually increase soil fertility by bringing large amounts of phosphate, nitrogen and potassium through litter leaching, stem flow (Crane 1990), and root exudates (Hartig & Beck 2003). In their Chinantla region study, Edouard et al. (2004) carried out some soil sampling tests and found that soils where bracken is present are not neither more poor nor more acid than the rest of the region's soils. On the basis of Edouard et al. (2004) study, again it could be speculated that

bracken could not be the sole responsible for degraded soils in my study site, and that the probability that the soils were already poor when bracken established exists.

Bracken's inherent allelopathy (phenomenon in which produced biochemical's inhibit the growth of nearby plants) could be one feasible explanation for low yields of *milpas*, fruit trees and even coffee. The literature reports that once bracken is removed, other plants are inhibited for a full growing season apparently because of active phytotoxins (toxins produced by plants) that remain in the soil, potentially inducing allelopathic interference on other plant species (Crane 1990**,** Marrs & Watt 2006). This possibly explains why maize on my study area, renders low yields or it just does not thrive when cultivated in bracken fern areas. It is also possible that yucca and pineapple plants are more resistant to bracken's allelopathic effects, and therefore produce higher yields when cultivated in areas where bracken has been present. Or as mentioned earlier, the other plausible explanation for maize not to thrive in the invaded areas, could be that the quality of the soil in the invaded areas is inherently poor, regardless of the presence of the fern. Yucca for example is known to be tolerant of poor soils and is found in environments that are typically dry and hot (Knox 2010), and pineapple plants are tolerant to dry soils and grow best in moderately fertile and well-drained soils, with full sun exposure (Crane 2009).

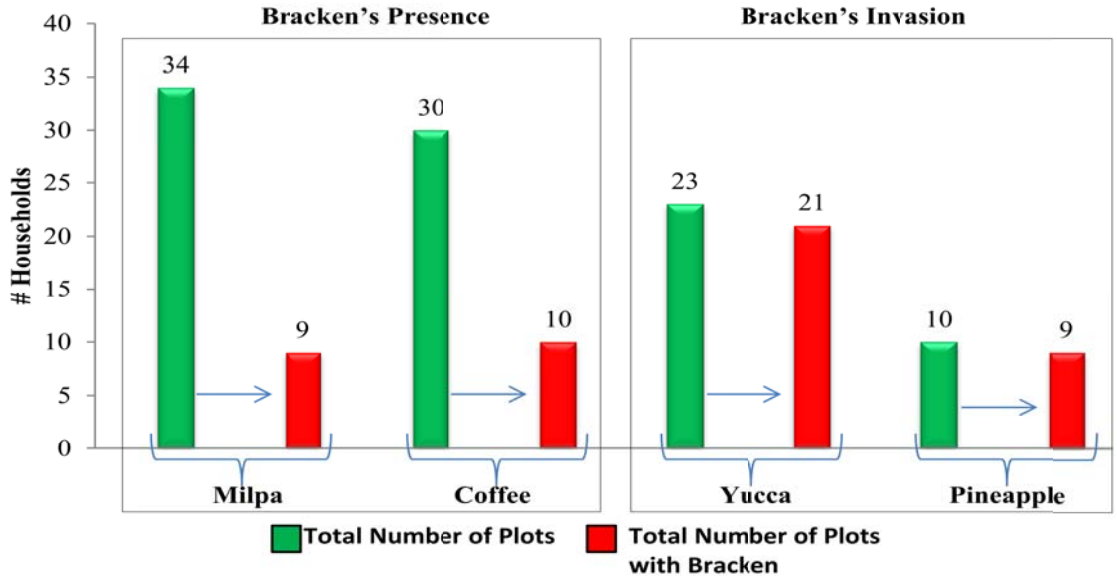
CHAPTER IV

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

LINKING BRACKEN, VCAS AND LOCAL LIVELIHOODS

The map of my study area (Figure 2.1) shows the current forest and non-forest covers of the two communities, where the non-forest cover is mainly composed of anthropogenic surfaces such as agricultural parcels, pastures, human settlements, and also includes shrub vegetation, mainly bracken fern. Santiago and San Pedro's non-forest cover accounts for just 4% and 2%, respectively, but because bracken's presence has not been characterized in these communities, how much of this small percentage of non-forest cover corresponds to bracken fern invaded areas remains unknown. Originally, it had been thought by some observers that bracken had invaded approximately 30% of the communal territory of each studied community. However, on the basis of the remotely sensed non-forest cover information, jointly with the information gathered in the interviews, it can be concluded that currently bracken fern is not a severe problem in my study area given that its invasion is present at very low percentages. More specifically, bracken has only heavily invaded small areas of the two communities, mainly the outskirts of the settlements, where farmers cultivate yucca and pineapple. But as far as the agricultural areas where *milpas* and coffee fields are located, informants reported only some bracken's moderate and sporadic presence, but no invasion (Figure 5.1).

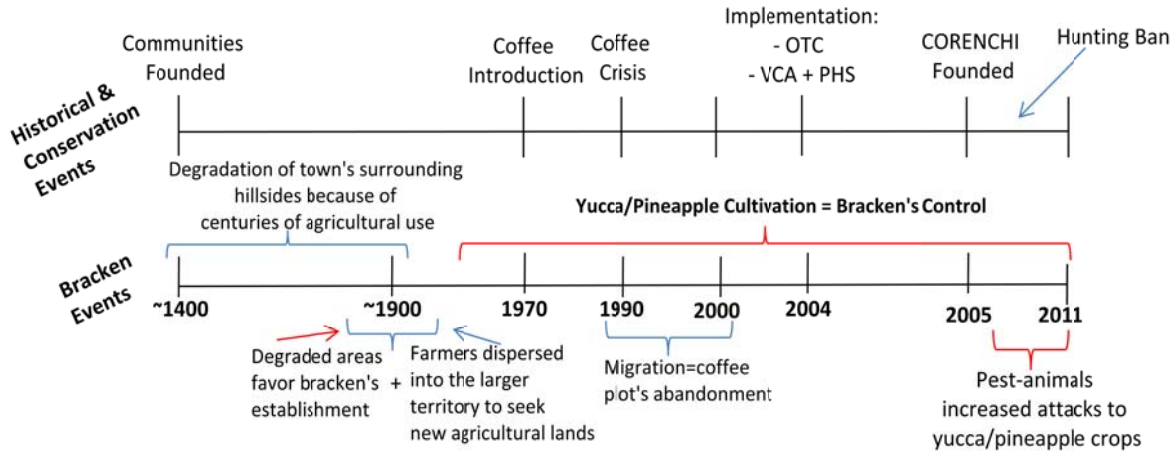
Figure 5.1. Number of Households with Active Agricultural Plots and Number of Plots with Bracken's Presence/Invasion



These are pre-Hispanic communities which established in these territories more than 500 hundred years ago (Figure 5.2) and little is known about the historical relationships between the local human activities and the invasion of the fern. But the most probable scenario, is that the ancestors of these communities established their villages in areas where the surrounding hillsides where apt for agriculture, but after centuries of use, these hillsides became degraded and most probably that is when bracken overtook them. The invasion could have affected farmers' land use decisions, where land abandonment due to bracken fern invasion may have occurred, causing the dispersion of farmers into the larger territory seeking new agricultural lands. For unclear reasons once they dispersed, up to 100 years ago, the fern has not been perceived as an overwhelming problem, because apparently farmers have always had to walk long distances to get to their *milpas*, and the invaded areas have been used to produce yucca and pineapple. As we might see, a new context has been created in which the old fern areas plus the recent

establishment of VCAs, might be creating modest pressure on agricultural land availability.

Figure 5.2. Timeline of Study Site's Historical, Conservation and Bracken Fern Events



Even though, bracken's invasion is currently reduced to some small areas around the towns, management of these invaded lands is advisable to avoid long-term potential expansion to the agricultural areas, which could be detrimental to local traditional agricultural practices and livelihoods. The negative effects that bracken can impose over agricultural areas, forest ecosystems and landscapes, have been documented by Schneider (2004, 2006, 2008) Schneider & Fernando (2010), and Schneider & Geoghegan (2006) in various studies in the Yucatan Peninsula region in southern Mexico. During the last twenty years, the area covered by bracken fern in cultivated landscapes in Yucatan has increased four-fold (Schneider 2006), impeding regular plant succession and increasing the number of forest areas opened for agricultural purposes (Schneider 2004). Disturbances such as land opening for crops or pastures establishment and its associated frequent fires, constitute the main causes of bracken invasion in the Yucatan Peninsula region, and have facilitated the replacement of secondary growth vegetation for bracken

(Schneider 2006**,** Schneider & Fernando 2010). Bracken in the Yucatan region poses major difficulties, particularly because bracken impedes forest regeneration, and thus interrupts the traditional crop-fallow cycle dynamics in such a way that when a plot gets heavily invaded by the fern, some farmers decide to permanently take the invaded plot out of rotation, and feel obliged to expand the agricultural frontier by opening forested areas (Schneider 2006). But it is worth noting that bracken in my study site is not a threat to conserved forests, because the current conservation measures do not allow agricultural expansion to forested areas under the VCA and PHS programs.

Ample similarities regarding land tenure systems, agriculture type and methods, and crop-fallow cycles, exist between the Yucatan Peninsula region and my two studied communities. As in my study area, in the Yucatan region the land tenure system is communal (*ejidos* in Yucatan; *comunidades* in my study), subsistence agriculture (*milpa*) is practiced, land opening is done by swidden agriculture methods, and fallow cycles are typically between 9-10 years. This parallel allows for the prediction in my study site, of a potential scenario of expansion of bracken's invasion towards agricultural areas in the long-term, similar to the one that has occurred in the Yucatan region, if bracken's invasion is not managed and controlled on time.

In this scenario, bracken's expansion to agricultural areas could be encouraged during two distinct stages of the swidden agricultural method practiced in my study site. Because of bracken's fire ecology, the first opportunity to invade a plot, would be during the burning stage that follows after land has been cleared for agriculture. A second opportunity for bracken to invade could be the period in which the land is left fallow after agricultural use, where the land goes from an active state to an inactive one. In this

inactive state the plot does not have any vegetation cover, creating characteristic conditions of open areas where bracken can thrive because of full sunlight availability and low competition in the absence of other plants. Both land burning and fallow stages create favorable conditions for the establishment of the fern.

On the basis of the perceptions gathered in the interviews, it would appear that bracken's invasion has remained constrained to the surrounding areas of the communities and that invaded areas have not increased in size at least for the past several decades. Until now, bracken fern invasion does not appear to have created any land use pressures, because of the very large availability of agricultural lands in the territory of the communities and the low population densities (6.2 people/km^2). However, the communities' proposal and acceptance of a voluntary conservation area in 2004 may have changed the availability of agricultural lands, and recent research in Santiago has suggested that the VCA in particular has damaged food sovereignty in my study site (Ibarra et al. 2011), although this article makes no reference to bracken fern invasion.

The study by Ibarra et al. (2011) in the community of Santiago, found that maize production decreased from ~31 to ~21 *zontles* (local measurement of area maize yields) of maize/year after the establishment of the VCAs and PHS program. In addition, they reported that the production of black beans has almost disappeared, because typically these beans were cultivated in the higher elevation parcels which are now under conserved programs. These authors' study argued that the prohibition of land use change in three-quarters of Santiago's territory (currently under the conservation scheme), have resulted in decreased areas to practice agriculture, shorter fallow cycles, diminished soil quality and production reduction (Ibarra et al. 2011). Long term declines in agricultural

production have also been linked to different subsidies and emigration, and thus it would be advisable to consider all possible factors that might have influenced the agricultural production decline, not only the conservation programs.

Before the establishment of the VCAs and PHS program, there were no restrictions as to where to cultivate, and thus agriculture was practiced in a more extensive manner. Most *milpas* were concentrated in a few areas of the community, but some farmers would scatter both *milpas* and fallow fields within the forests, creating a patchy landscape where openings for agriculture occurred in a matrix of intact forest, in which invasion of the fern was unlikely, because as explained earlier, even if bracken was present on the understory of the forests, the shade provided by the canopy of the trees would keep bracken at very low densities.

But after the certification of the conserved areas in my study site, at least 70% (~9,350 ha) of the communal lands (12,803 ha) are under the VCA program, and approximately 45% (~5,769 ha) of the lands are covered by the PHS program. The territories covered under these two conservation programs roughly overlap, accounting for approximately 70% of the communal territories (Table 2.1). Through the use of a land use planning exercise called a Community Territory Land–Use Zoning (*Ordenamiento Territorial Comunitario* –OTC), the other 30% (~3,453 ha) of the study site was designated in its majority to agricultural areas and a small fraction to urban zone. Land-use zoning was implemented in the study site in 2004, with the aim of organizing the territories on the basis of types of land use. The implementation of the land-use zoning facilitated the establishment of the different conservation programs, and formalized the areas that had already been conserved for decades. Under this new land-use zoning

model, the scenario of land-use intensification and of increased pressures on agricultural land availability could be possible. In this potential scenario, agricultural areas could be used more often and thus burned more frequently, creating conditions of disturbed areas that would favor bracken's establishment, like it might have occurred in the initial scenario, explained earlier, in which bracken established in the surrounding hillsides of the villages after degradation due to centuries of agricultural use.

In addition, intensification of land use for agriculture, is a practice with potential detrimental consequences to the quality of subsistence crops like maize, as intensification produces loss of soil quality, and with time production and quality of maize and other important crops could start diminishing, possibly threatening traditional livelihoods of these communities which historically have subsisted on the crops they harvest. However, because of the study site's low population density levels, I would speculate increased land-use intensification and high pressures on agricultural lands only in the longer term.

In spite of my speculation for the above mentioned longer term scenario, the results of my thesis show that after VCAs establishment only 20% of my sample reported trouble finding lands of equivalent quality to the agricultural lands they used to have within conserved areas, and 41% did not even have *milpa* within the conserved area to begin with. Thus, I would characterize this as a relative modest increased pressure on agricultural land availability on my study site after establishment of the conservation programs. Furthermore, my results also indicate that the majority of the interviewees, 82%, considered that despite of the establishment of the conserved areas, there is still enough land for every household to have *milpa* plots within their communal territories (Figure 3.6). Although, only a modest increased pressure was reported, comments like the

following from one of the informants, remind us of the potential scenario of increased pressures on the land and cultivation intensification on designated agricultural areas:

"*Fallow fields are located at higher altitudes where milpa production is best…but those lands are now under conservation….at lower altitudes however* [where agricultural areas are located] *maize quality is lower. In addition, now each year the same plots are cleared for cultivation, whereas before fallows were rotated, but since now we are conserving we cannot use those fallows anymore…..the repetitive use of the same areas depletes the soils and they lose their nutrients*".

Combined with the conservation agreements of maintaining forest cover and on avoiding land use changes on the conserved areas, a self-imposed hunting ban was also implemented by the communities, with the aim of augmenting the conservation efforts in the study site. According to my results, 76% of the 35 interviewees (Figure 3.7) agreed with the hunting restrictions on non-nuisance animals, because they felt that since this type of animals are harmless to *milpas*, there is no need to kill them. During informal and structured interviews, I perceived high levels of confusion among the interviewees on whether or not this hunting ban also applies to nuisance animals. The confusion was rooted on the basis that some interviewees mentioned that the ban did not allow hunting of any kind of animals (including nuisance animals). Whereas others mentioned that the ban only restricted the hunting of non-pest animals, but that hunting nuisance animals was permitted. Ibarra et al. (2011) mentioned in their study, that the ban does allow the hunting of 10 species of nuisance animals, but only within the *milpas*, for being considered a threat to the harvests. But the authors also mentioned that in spite of this exception the farmers are afraid to hunt these nuisance animals because they believe that sanctions from the entities issuing the PHS payments will translate into cancellation of

the disbursements. I believe this fear has caused the confusion that currently exists on whether the hunting ban includes all kind of animals or just non-pest animals.

Independently from the confusion associated to the hunting restrictions, 97% of my sample considered that the establishment of the conservation programs and the associated conservation measures, have caused an increase in the number of nuisance animals (Figure 3.7). Congruently to what my interviewees felt, Ibarra et al. (2011) reached the conclusion that the auto-imposed hunting ban is causing nuisance animals to multiply and are adversely affecting the agricultural production. The linkage between a) the reportedly increase of nuisance animals which apparently has been one of the unintended consequences of the establishment of conserved areas, and b) the efforts that these communities have put forth until now to attempt to control bracken fern and recuperate some of the areas sequestered by the fern, is of outstanding importance for my research. Mainly because nuisance animals reportedly destroy yucca and pineapple crops and harvests (Figure 5.3), diminishing the efforts, in terms of time and labor, that many farmers have inputted in clearing and weeding the bracken invaded areas to make them productive. The nuisance's animal problem discourages farmers to recuperate bracken invaded lands, posing a threat to local restoration efforts, and potentially causing adverse effects on local diets and traditional food systems by diminishing the production of complementary crops.

Figure 5.3. Active Yucca and Pineapple Plots: Bracken's Absence/Presence Prior to Cultivation and Number of Plots with Prior Bracken's Presence Attacked by Pest-Animals

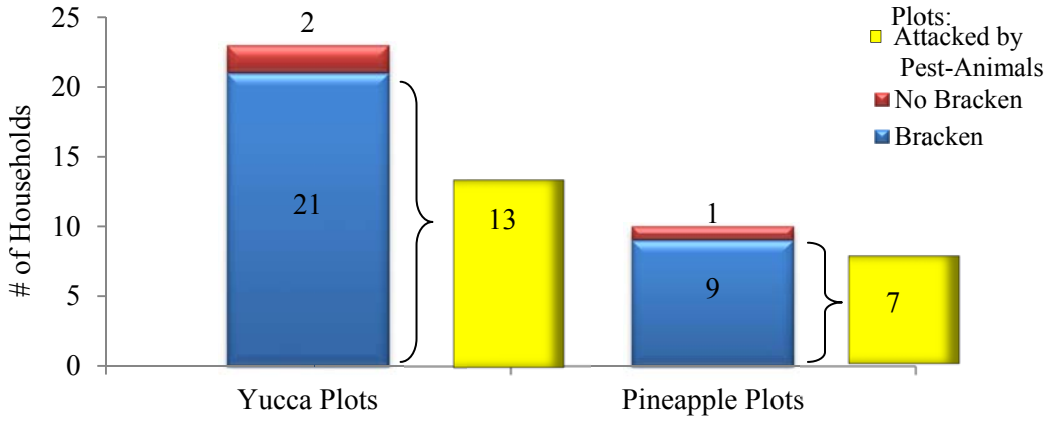
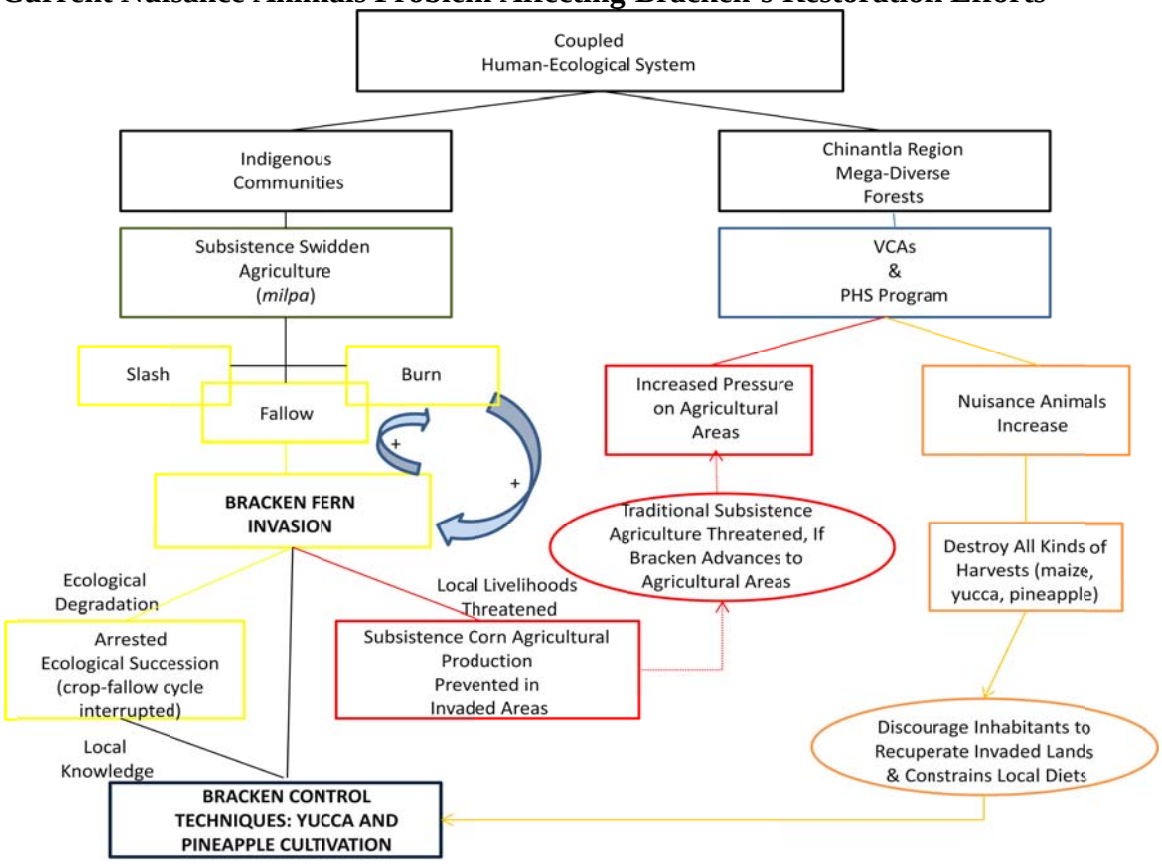


Figure 5.4. Graphical Representation of Multi-Temporal Scenarios Regarding Initial Bracken's Establishment, Possible Long-Term Bracken's Expansion and Current Nuisance Animals Problem Affecting Bracken's Restoration Efforts



Yellow: scenario which speculates that bracken's invasion was the result of centuries of agricultural use of the hillsides of the villages. Orange: increased nuisance animals attacks to yucca/pineapple crops. Red: long-term bracken's expansion to *milpas* scenario.

ECOLOGICAL VALUE OF BRACKEN FERN AREAS

My study shows that bracken invaded areas in the study site present both ecological degradation and ecological functionality. Bracken causes ecological degradation, because it impedes natural succession and forest regeneration, and because the produced dry plant litter promotes fires. On the other hand, bracken areas present a usually unrecognized ecological value, especially in supporting wildlife (Crane 1990, Marrs & Watt 2006). My results show a total of 14 mammals' species that were seen by informants, performing different activities in bracken fern areas (Figure 3.9). Two of these 14 species are important for conservation purposes, because they are currently listed as critical endangered (*Dasyprocta mexicana*) and near threatened (*Panthera onca*) (IUCN 2012). This finding might suggest that bracken areas contribute to my study site's spatial heterogeneity, in which old-growth forests, second-growth forests, agroforestry systems (coffee farms), agricultural fields and bracken areas can create a mosaic of vegetation that might enhance wildlife fluxes and diversity.

The literature also reports that bracken invaded areas offer other ecological benefits, such as prevention of soil erosion by splash and possibly prevention of landslides (Hartig & Beck 2003). In addition, bracken fern can increase soil fertility by bringing larger amounts of phosphate, nitrogen, and potassium into circulation through litter leaching and stem flow, and its rhizomes have the ability to mobilize phosphate from inorganic sources (Crane 1990, Hartig & Beck 2003, Edouard et al. 2004). The above mentioned ecological benefits might challenge the generalized idea that bracken invaded areas should always be considered as ecologically degraded areas, but that

different contexts exist and that the ecological impacts of bracken's invasion should be done on a case by case basis.

IMPACTS OF BRACKEN FERN INVASION ON LOCAL LIVELIHOODS

Although bracken fern *per se* does not offer any benefit for farmers in my study site, except for young bracken shoots that provide a form of fodder for mules, the areas where bracken invades do provide some benefits (Table 5.1). For more than a hundred years, farmers at the study site have utilized the invaded areas to produce yucca and pineapple, which are the crops that best grow in those areas. And some farmers reported that the invaded areas can serve as pastures for livestock. Although, locally important crops like maize and coffee do not grow well in the invaded areas, informants recognized that some trees, especially the ones that serve for firewood, can grow in those areas. Although there are designated agricultural areas for maize/coffee cultivation, no areas have been designated for firewood extraction, and many times farmers have to bring firewood from places as far as their *milpas*. Since invaded areas are located in the surrounding hillsides close to the villages, conversion of some of these lands to firewood extraction areas would be beneficial for these communities. For harboring different species of mammals, especially two of high conservation interest (*Dasyprocta mexicana* and *Panthera onca*), bracken fern areas in my study site can be conceived as areas of high conservation value. Erosion control and landslides prevention, could be indirect benefits that bracken fern offers, although these were not mentioned by the informants.

Informants reported a mosaic of soils in bracken invaded areas (Table 3.7), which farmers could take advantage of. The problem is that clearing and controlling bracken's

growth is a complex and difficult task (Table 5.1), and farmers do not always have the necessary incentives to invest household labor in such activities. Another problem associated with bracken, is the dangerous fuel load that results from the accumulation of dry plant litter, which promotes fires that can easily and rapidly get out of the farmer's control. The use of fires for swidden agriculture is a regular practice, and thus farmers are very concerned about fires rapidly spreading to conserved forests, *milpas* and coffee fields, threatening their conservation efforts and their subsistence and cash crops.

Table 5.1. Positives and Negatives of Invasion of Bracken Fern

Positives	Negatives
Good areas for yucca/pineapple cultivation	Control is labor intensive and time demanding
Potential as firewood extraction areas close to villages	Soil quality not proper for maize/coffee cultivation
High conservation value for providing wildlife habitat/refuge areas	Dry plant litter promotes fires that can easily get out of control
Erosion control/landslides prevention	Ecological succession arrested
Fodder for cattle/pasture areas	Literature reports carcinogenic effects on cattle

UNIQUE CASE STUDY OF BRACKEN IN SOUTHERN MEXICO

Compared to the existing three case studies presented in Chapter I (Lacandon Maya of Chiapas, Yucatan Peninsula in Campeche and San Juan Lalana in Chinantla Baja), my case study represents a unique case study of bracken fern in *southern* Mexico (Table 5.2). The four studies represent distinct cases of the coupled human-ecological system and all four present some similarities, regarding land tenure type (communal) and type of agriculture practiced (subsistence corn/swidden agriculture). Despite these

similarities, my study site presents a unique case regarding bracken's overall context, past and present history of the invasion.

First, the establishment of bracken in my study site is believed to have happened more than 100 years ago, apparently due to centuries of agricultural use, whereas in the other three cases studies it is a relative recent (<50 years) phenomenon, caused by colonization processes and/or cattle establishment. In my study site, there is very little or no intensification of land use and very modest land pressures related to the establishment of conserved areas, but until now there is no indication that bracken has expanded because of this. On the contrary, the other three case studies reported increased land use intensification and higher pressures on the land which have led to bracken's invasion. In addition, the size of the invasion in my study site has remained stable or has only slightly increased, as opposed to at least two of the case studies (Yucatan and Lalana) where the invasion increased.

Although all four case studies take place in rural communities immersed or surrounded by large expanses of forests, my case study is unique in the sense that is the only one under a conservation scheme (i.e. VCA and PHS programs), which places it in a different context than the other studies. Bracken is not a threat to conserved forests in my study site, because agriculture is not allowed in those areas, and thus there are no opportunities for bracken to become invasive. A different case happens in at least the Yucatan and San Juan Lalana studies, where since there are no restrictions regarding change of land use in forest ecosystems, farmers have the option to abandon the invaded plots, and expand the agricultural frontier by clearing forests to open new agricultural plots.

Lastly, of the four case studies, mine is the only one that discusses the positive impact that bracken fern areas can have for wildlife conservation. By supporting at least 14 mammal species, two of them listed as threatened by UICN, bracken invaded areas in my study can provide a new perspective on the important ecological role they can play in some contexts.

Table 5.2. Case Studies Comparison of Bracken Fern in Southern Mexico

	My Study	**Lacandon**	**Yucatan**	**San Juan Lalana**
Communal land tenure	Yes *comunidad*	Yes *comunidad*	Yes *ejido*	Yes *comunidad*
When did invasion start	>100 years	<50 years	<50 years	<50 years
Invasion due to colonization	No	Yes	Yes	No
Invasion due to cattle	No	No	Yes	Yes
Land use intensification	No	Yes	Yes	Yes
Increased land pressures	No	Not discussed	Yes	Yes
Invasion increase	Stable	Not discussed	Yes	Yes
Conservation programs	Yes	No	No	No
Threat to forests	No	Not discussed	Yes	Yes
Bracken supports wildlife	Yes	Not discussed	Not discussed	Not discussed
Control method	Yucca/Pine-apple cultivation	Fast growing pioneer species: Balsa	Not discussed	Forestry species and pineapple cultivation

CONCLUSIONS

Bracken fern invasion in my study site is minimal, occupying less than 5% of the communal territories. The invasion is localized in the surrounding hillsides of the

villages, and in this thesis, I propose the scenario that these hillsides were degraded due to centuries of agricultural use which created favorable conditions for bracken's establishment. Once this happened, more than a hundred years ago, farmers dispersed into the larger territory to cultivate their *milpas*, and since then bracken has not been perceived as an overwhelming problem. Coffee fields are not threatened by bracken, given that coffee is grown under the shade of the trees, where bracken is kept at low densities.

Bracken is not an immediate threat to *milpas*, but I present the scenario where bracken could expand and invade agricultural areas if in the long-term there is an increase in intensification and pressures on agricultural land availability. The potential costs associated with expansion of bracken fern to agricultural areas would be reduced productivity of subsistent crops, specifically maize. My study suggests that after establishment of the current conservation programs (VCAs and PHS), only 20% of my sample reported trouble finding *milpa* plots of equivalent soils as the ones they used to have within the now conserved areas. Similarly, 80% of my sample felt that there are still plenty of lands for every household to have *milpas*. On the basis of these data, I would characterize this as relative modest increased pressure on availability of agricultural land.

Farmer's have been actively using the bracken invaded areas for the cultivation of yucca and pineapple, because these are plants that do not require rich soils to thrive, and thus produce high yields. Yucca and pineapple are locally important because they complement local diets, farmers occasionally can generate some cash from selling the produce, and because yucca in particular is used to make specialty tortillas during certain festivities. Cultivation of yucca and pineapple is the main method in which bracken fern

gets controlled in my study site. Some farmers cultivate these crops for 1) diet enrichment only, others do it 2) to try to control bracken fern invasion, and others do it for both reasons. But unfortunately, informants reported that nuisance animals are continuously attacking the yucca and pineapple crops, discouraging farmers to continue trying to make the invaded lands more productive. Informants confirmed that clearing and weeding bracken fern is a labor demanding and time consuming activity, and thus nuisance animal's attacks to yucca and pineapple crops minimize bracken's invasion control efforts. In an effort to contribute to conservation measures, these communities self-imposed a hunting ban which apparently has been responsible for the increase in numbers of nuisance animals.

Although bracken fern is not overwhelming in my study site, it is noticeable to the farmers living there because in general, management of these areas involves large quantities of labor, time dedication, the risk of uncontrolled fires exists, and clearing invaded areas can be dangerous because of snake bites. In addition, farmers know that the invaded areas are not apt for cultivation of *milpa* or coffee, because they claim that invaded lands result in lower maize yields, and coffee cultivation would require a complex forest assemblage, which invaded lands lack. Farmers do not perceive that bracken is an issue that can expand to the agricultural areas, as in general they believe that bracken's invasion has not changed in size over the years, and because the presence of bracken in the hillsides of their villages has been a familiar sight since they were little.

Besides the negative connotations of bracken invaded areas, there are some less explored contributions of these sites, especially for conservation purposes. My results suggest that bracken areas can serve as habitat or at least as refuge sites for at least 15

mammals' species, two of them (*Dasyprocta mexicana* and *Panthera onca*) of high conservation value because of their threatened status (UICN 2012). But it is also important noting around half of the mammals' species that find refuge in bracken areas are nuisance animals. Other possible benefits of invaded areas would be erosion control and landslides prevention. In the scenario that the village's surrounding hillsides were degraded and lacking any type of vegetation, rainwater runoff would result in soil loss and the risk of landslides threatening the settlements would be greater.

RECOMMENDATIONS

On the basis of the results from my research, I would like to make some practical recommendations to the two studied communities that I believe would be beneficial for both the human and ecological systems involved.

1) Preventive action. Uncertainty exists on whether bracken fern can potentially expand to the zoned agricultural areas, but since it already occurred once in the hillsides of the villages, it could happen again in a long-term scenario of increased pressures of land availability because of the conservation restrictions. Thus I recommend implementation of informative sessions to create awareness among the communities on the potential risk that expansion of bracken may impose on their agricultural areas, especially to *milpas*.

2) Restoration. I would recommend to keep cultivating yucca/pineapple as the traditional method of bracken control. In addition, I would also suggest diversifying the control portfolios, to include other methods, such as the planting of c*edro* (*Cedrela sp*), which is a high-valued timber species that besides contributing to the restoration efforts of the degraded areas, could be a source of income for these communities. Other restoration

methods could include the use of *balsa* (*Ochroma pyramidale*) to restore the invaded areas, as the Lancandon indigenous people in Chiapas do it. Other viable option would be to plant firewood species, which would be beneficial for farmers, because they would have firewood extraction areas close to town, and would not have to spent much time and energy carrying firewood from as far as some *milpas*.

3) Do not burn bracken. Information sessions on how to manage invaded areas, should include teaching bracken's fire ecology to farmers in a simple manner. I would recommend not burning the bracken invaded areas, because fire removes biological competition and favors brackens permanence.

4) Wildlife conservation. Given that bracken fern areas can serve as habitat for many mammals' species, I would recommend maintaining some patches of bracken to promote a mosaic of diverse vegetation types that might enhance wildlife fluxes and diversity.

5) Hunting ban education. I highly suggest that the authorities create awareness among the community members on every aspect of the hunting ban, and emphasize on the fact that they are allowed to hunt at least 10 nuisance animals' species. If pest-animal's populations get controlled, yucca and pineapple crops would not be attacked by these animals, and farmers would be encouraged to restore invaded areas and turn them productive.

REFERENCES

Arriaga L, Espinoza JM, Aguilar C, Martínez E, Gómez L, Loa E. (coordinadores). 2000. Regiones terrestres prioritarias de México. México: Comisión Nacional para el Conocimiento y uso de la Biodiversidad.

Atlas Agrario del Estado de México. 2002. Gobierno del Estado de Oaxaca/Secretaria de Asuntos Indígenas/Secretaria de la Reforma Agraria/Instituto Nacional Indigenista. Oaxaca, México.

Bayer CropScience. 2005. Available from: http://docushare.bayercropscience.co.uk/Asulox.pdf

Beletsky, L. 1999. Tropical Mexico. The Ecotraveler's Wildlife Guide. Academic Press, San Diego, CA.

Bernard, H.R. 2002. Research Methods in Anthropology, 3rd edition. Altamira Press, Walnut Creek, CA.

Borrini-Feyerabend, G., A. Kothari, and G. Oviedo. 2004. Indigenous and Local Communities and Protected Areas: Towards Equity and Enhanced Conservation. IUCN, Gland, Switzerland and Cambridge, UK. xviii + 111pp.

Braid, K.W. 1959. Bracken, a review of the literature. Commonwealth Agricultural Bureaux, Hurley, Berkshire, UK.

Bray, D.B., L. Merino-Perez, P. Negreros-Castillo, G. Segura-Warnholtz, J.M. Torres-Rojo, and H.F.M Vester. 2003. Mexico's Community-Managed Forests as a Global Model for Sustainable Landscapes. Conservation Biology **17**:672-677.

Bray, D.B. 2012. Personal Communication.

Bray, D.B., E. Duran, and O.A. Molina-Gonzalez. Forthcoming. Beyond harvests in the commons: multi-scale governance and turbulence in indigenous/community conserved areas in Oaxaca, Mexico. Forthcoming International Journal of the Commons.

Crane, J.H. 2009. Pineapple growing in the Florida home landscape. HS7. Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences IFAS, University of Florida. Original Publication 1975. Reviewed October 2006 and November 2009. Florida.

Crane, M.F. 1990. Pteridium aquilinum. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire

Sciences Laboratory (Producer). Available at: http://www.fs.fed.us/database/feis/plants/fern/pteaqu/introductory.html

Conabio, 2008. Regiones Terrestres Prioritarias de Mexico. Available at: http://www.conabio.gob.mx/conocimiento/regionalizacion/doctos/terrestres.html.

Conabio-Conanp-TNC-Pronatura-FCF/UANL. 2007. Análisis de vacíos y omisiones en conservación de la biodiversidad terrestre de México: espacios y especies. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Comisión Nacional de Áreas Naturales Protegidas, The Nature Conservancy – Programa México, Pronatura, A.C., Facultad de Ciencias Forestales de la Facultad Autónoma de Nuevo León, México. Ciudad de México, México.

Deere, C.D., and A. de Janvry. 1979. A conceptual framework for the empirical analysis of peasants. American Journal of Agricultural Economics **61**:601-611.

De Sherbini, A., L.K. VanWey, D. McSweeny, R. Aggarwal, A. Barbieri, S. Henry, L.M. Hunter, W. Twine, R. Walker. 2008. Rural household demographics, livelihoods and the environment. Global Environmental Change **18**:38-53.

Douterlungne, D., S. I. Levy-Tacher, D. J. Golicher, and F. R. Danobeytia. 2008. Applying indigenous knowledge to the restoration of degraded tropical rain forest clearings dominated by braken fern. Restoration Ecology 1-8.

Duran, E. 2010. Personal Communication.

Edouard, F., J. Jimenez, and M. Cid. 2004. Restauración de áreas invadidas por copetate en la región de la Chinantla, Oaxaca, México. Revista de Agroecología. 34-37.

Edouard, F. n.d. Apropiación de sistemas agroforestales y gestión del territorio en la región de la Chinantla. MS.

Escalante-Lara, J.M., and F.M Romero-Julián. n.d. San Pedro Tlatepusco: EL Pueblo Que se Inundo. Cuaderno de Antropología de la Universidad Autónoma Metropolitana. Serie 1, Volumen 6.

ESRC Research Group. 2004. Well-being in developing countries (WeD). Resources and needs questionnaire (RANQ). Bangladesh, Ethiopia, Peru and Thailand. University of Bath, United Kingdom.

Figel, J.J. 2008. Community *Protected Areas and the Conservation of Jaguar (Pantera onca) and Their Prey in the Chinantla Region of the Sierra Norte, Oaxaca, Mexico*. Unpublished Master's Thesis. Florida International University, Miami, Florida.

Fox J. 1996. National Electoral Choices in Rural Mexico. Pages 185-209 in L. Randall editor. Reforming Mexico's Agrarian Reform, ME Sharpe.

Garcia-Mendoza, A. J. de Jesus Ordonez M, M. Briones-Salas editors. 2004. Biodiversidad de Oaxaca. Mexico City, Mexico: Instituto de Biologia de la UNAM, Fondo Oaxaqueno para la Conservacion de la Naturaleza, y el World Wildlife Fund.

GISP. 2008. Invasive species and poverty: exploring the links. Global Invasive Species Program. South African National Biodiversity Institute. Cape Town, South Africa. Available from: http://www.gisp.org/

Harmer, R., R. Boswell, and M. Robertson. 2005. Survival and growth of tree seedlings in relation to changes in the ground flora during natural regeneration of an oak shelterwood. Forestry **78**:21-32.

Hartig, K., and E. Beck. 2003. The bracken fern (*Pteridium arachnoideum* (Kaulf.) Maxon) dilemma in the Andes of southern Ecuador. Ecotropica **9**:3-13.

Hite, E. 2011. Transformations of a Coffee Landscape in southern Mexico: a case study of emigration and conservation in the Sierra Norte, Oaxaca. Unpublished Master's Thesis. Florida International University, Miami, Florida.

Humphrey, J. W., and M. D. Swaine. 1997. Factors affecting the natural regeneration of Quecus in Scottish oakwood. I. Competition from *Pteridium aquilinum*. J. Appl. Ecol. **34**:577-584.

Ibarra, J.T., A. Barreau, C., del Campo, C.I. Camacho, G.J. Martin, and S.R. Maccandless. 2011. When formal and market-based conservation mechanisms disrupt food sovereignty: impacts of community conservation and payments for environmental services on an indigenous community of Oaxaca, Mexico. International Forestry Review. **13**(3):318-337.

INEGI. 2012. Available from: http://www.inegi.org.mx/

Know, G.W. 2010. Agave and yucca: tough plants for tough times. ENH1159. Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences IFAS, University of Florida. Florida.

Lawrence, D., H. F. M. Vester, D. Perez-Salicrup, J. R. Eastman, B. L. Turner II, and J. Geoghegan. 2004. Integrated analysis of ecosystem interactions with land-use change: the southern Yucatan peninsular region. Pages 277-292 in DeFries, R. S., G. P. Asner, and R. A. Houghton editors. Ecosystems and land use change. American Geophysical Union, Washington D.C.

Ley Agraria de México. 2008. Nueva Ley publicada en el Diario Oficial de la Federación. México. 41 p.

Little, D. J., and J. F. Collins. 1995. Anthropogenic influences on soil development at a site near Pontoon, Co Mayo. Irish J. of Food and Agricul. Research **34**:151-163.

Liu, J., T. Dietz, S.R. Carpenter, M. Alberti, C. Folke, E. Moran, A.N. Pell, P. Deadman, T. Kratz, J. Lubchenco, E. Ostrom, Z. Ouyang, W. Provencher, C.L. Redman, S.H. Schneider, and W.W. Taylor. 2007. Complexity of coupled human and natural systems. Science **317**:1513-1516.

Lowday, J. E. 1987. The effects of cutting and asulam on number of frond buds and biomass of fronds and rhizomes of bracken *Pteridium aquilinum.* Annals of Applied Biology **110**:175-184.

Madrid, L., J.M. Nunez, G. Quiroz, and Y. Rodriguez. 2009. La propiedad social forestal en Mexico. Investigacion Ambiental **1**:179-196.

Marcoux, A. 1999. Population and environmental change: from linkages to policy issues. FAO. Available from: http://www.fao.org/sd/wpdirect/WPre0089.htm.

Marrs, R. H., and J. E. Lowday. 1992. Control of bracken and the restoration of heathland. II. Regeneration of the heathland community. Journal of Applied Ecology **29**:204-211.

Marrs, R. H., M. G. Le Duc, R. J. Mitchell, D. Goddard, S. Paterson, and R. J. Pakeman. 2000. The ecology of Bracken: its role in succession and implications for control. Annals of Botany **85**:3-15.

Marrs, R. H., and A. S. Watt. 2006. Biological flora of the British Isles: *Pteridium aquilinum* (L.) Kuhn. Journal of Ecology **94**:1272-1321.

Martin, G.J. 1996. Comparative Ethnobotany of the Chinantec and Mixe of the Sierra Norte, Oaxaca, Mexico. Doctoral Dissertation, Anthropology Department, University of California, Berkeley.

Martin, G.J., C. del Campo, C.I. Camacho, G. Espinoza-Sauceda, and X. Zolueta Juan. 2010. Negotiating the Web of Law and Policy: Community Designation of Indigenous and Community Conserved Areas in Mexico. Policy Matters **17**:195-204.

Martin, G.J., C.I. Camacho-Benavides, C.A. del Campo, S. Anta, F. Chapela, M.A. González. 2011. Indigenous and community conserved areas in Oaxaca, Mexico. Management of Environmental Quality: An International Journal **22**:250-266.

Maze B. 1998. Global Commodity Chains, Alternative Trade and Small-Scale Coffee Production in Oaxaca, Mexico. Master's Thesis. Oxford, Ohio: Miami University.

Nardi, P.M. 2003. Doing Survey Research: A guide to Quantitative Methods. Allyn and Bacon, Columbus, Ohio.

Pakeman, R. J. and R. H. Marrs. 1992. The conservation of bracken, *Pteridium aquilinum* (L) Kuhn-dominated communities in the UK, and an assessment of the ecological impact of bracken expansion or its removal. Biological Conservation **62**:101-114.

Pakeman, R. H., M. G. Le Duc, and R. H. Marrs. 2000. Bracken distribution and control methods: their implications for the sustainable management of marginal land in Great Britain. Annals of Botany **85**(Supplement B):37-46.

_____. 2001. Integrating bracken control and vegetation restoration. Moorland Research Review 1995-2000. North York Moors National Park Authority, Helmsey, UK.

_____. 2005. Bracken control, vegetation restoration and land management. Rural Development Service, London.

Pakeman, R. H., R. H. Thwaites, M. G. Le Duc, and R. H. Marrs. 2002. The effects of cutting and herbicide treatment on *Pteridium aquilinum* encroachment. Applied Vegetation Science **5**:203-212.

Pejchar, L., and H. Mooney. 2009. Invasive species, ecosystem services and human well-being. Trends in Ecology and Evolution **24**:497-504.

Perez, P., S. Anta, and F. Mondragon. N.d. Los ordenamientos territoriales en las comunidades de la Chinantla Alta, Oaxaca. Ms.

Rimarachin-Cabrera, I., E. Zapata-Martelo, and V. Vazquez-Garcia. 2001. Gender, rural households, and biodiversity in native Mexico. Agriculture and Human Values **18**:85-93.

Rhone-Poulenc. N.d. Bracken management handbook: integrated bracken management – a guide to best practice. Rhone-Poulenc, Ongar.

Robson, J. P. 2007. Local approaches to biodiversity conservation: lessons from Oaxaca, southern Mexico. Int J Sust Dev **10**:267-286.

Robson, J. P. 2009. Out-migration and commons management: social and ecological change in a high biodiversity region of Oaxaca, Mexico. International Journal of Biodiversity Science & Management. **5**:21-34.

Nieratka, L. 2011. Do payments for hydrological services reduce povery and strengthen social capital? An examination of household welfare and collective action in the Sierra

Norte of Oaxaca, Mexico. Unpublished Master's Thesis. Florida International University, Miami, Florida.

Rzedowski, J. 1978. Vegetacion de Mexico. Mexico: Limusa.

Schneider, L.C. 2004. Bracken fern invasion in southern Yucatan: A case for land-change science. Geographical Review **94**:229-241.

Schneider, L.C. 2006. Invasive species and land-use: the effect of land management practices on bracken fern invasion in the region of Calakmul, Mexico. Journal of Latin America Geography **5**:91-107.

Schneider, L.C. 2008. Plant invasions in an agricultural frontier: linking satellite, ecological and household survey data. Pages 117-141 in Millington, A., and W. Jepson editors. Land-change science in the tropics. Changing agricultural landscapes. Springer, New York.

Schneider, L.C., J. Geoghegan. 2006. Land abandonment in an agricultural frontier after a plant invasion: the case of bracken fern in southern Yucatan, Mexico. Agricultural and Resource Economics Review **35**:167-177.

Schneider, L.C., and N. Fernando. 2010. An untidy cover: invasion of bracken fern in the shifting cultivation systems of southern Yucatan, Mexico. Biotropica **41**:41-48.

Schultes, R.E. 1941. The meaning and usage of the Mexican place-name "Chinantla". Botanical Museums Leaflets, Harvard University. **9**:101-116.

Stewart, G. B., E. Cox., M. Le Duc, R. Pakeman, A. Pullin, and R. Marrs. 2008. Control of Pteridium aquilinum: meta-anlysis of a multi-site study in the UK. Annals of Botany **101**:957-970.

Turner, B.L., P.A. Matson, J.J. McCarthy, R.W. Corell, L. Christensen, N. Eckley, G.K. Hovelsrud-Broda, J.X. Kasperon, R.E. Kasperon, A. Luers, M.L. Martello, S. Mathiesen, R. Naylor, C. Polsky, A. Pulsipher, A. Schiller, H. Selin, and N. Tyler. 2003. Illustrating the coupled human-environment system for vulnerability analysis: three case studies. Proceeding of the National Academy of Sciences **100**:8080-8085.

IUCN. 2012. IUCN Red List of Threatened Species. Version 2012.1. Available from: www.iucnredlist.org.

Van der Wal, H. 1999. Chinantec Shifting Cultivation: Interactive Land Use. A Case Study in the Chinantla, Mexico, on Secondary Vegetation, Soils and Crop Performance under Indigenous Shifting Cultivation. Treemail Publishers, Treebook 3. Heelsum, The Netherlands.

Van der Wal, H., J.D. Golicher, S. Caudillo-Caudillo, M. Vargas-Dominguez. 2006. Plant densities, yields and area demands for maize under shifting cultivation in the Chinantla, Mexico. Agrociencia **40**:449-460.

Velasco, M. A. 2011. Análisis de cambios en la cobertura arbolada en nueve comunidades del Norte del Estado de Oaxaca y su relación con la acción colectiva para la conservación del bosque, el manejo y uso del suelo. Tesis de Maestría. CIIDIR-Oaxaca. Instituto Politécnico Nacional. México.

Velasco, M.A. 2012. Map of Forest and Non-Forest Cover in Two Indigenous Communities in the Chinatla Region, Oaxca, Mexico.

Velazquez, M. C., E. Duran, I. Ramirez, J-F. Mass, G. Ramirez, and J-L. Palacio. 2003. Land-use cover processes in highly biodiverse areas: the case of Oaxaca, Mexico. Global Env. Change. **13**:175-184.

Velazquez-Rosas, N., and J. Meave. 2002. Elevational variation of leaf traits in montane rain forest tree species at la Chinantla, southern Mexico. Biotropica **34**:534-546.

Vitousek, P.M., and L.R. Walker. 1989. Biological Invasion by *Myrica faya* in Hawaii: Plant Demography, Nitrogen Fixation and Ecosystem Effects. Ecological Monographs **59**:247-265.

Watt, A. S. 1955. Bracken versus heather: a study in plant sociology. Journal of Ecology, **43**:490-506.

Watt, A. S. 1976. The ecological status of bracken. Botanical Journal of the Linnean Society **73**:217-239.

Webster, B. D., and T. A. Steeves. 1958. Morphogenesis in Pteridium aquilinum (L.) Kuhn. – General morphology and growth habit. Phytomorphology **8**:30-41.

Weitlaner, R., and C.A. Castro. 1973. Usila, morada de colibries. Papeles de la Chinantla VII, Serie Cientifica 11. INAH. 268 p. D.F., Mexico.

Williams, G. H., and A. Foley. 1976. Seasonal variations in the carbohydrate content of bracken. Botanical Journal of the Linnean Society **73**:87-93.

Williams, G. H., and D. Fraser. 1979. The effect of asulam, frond cutting and ground mineral phosphate on the yields of swards dominated by bracken [*Pteridium aquilinum* (L.)]. Grass and Forage Science **34**:95-100.

World Wildlife Fund (WWF) Mexico. 2007. Mexican Forest Program: Sierra Norte. Available at http://www.wwf.org.mx/wwfmex/prog_bosques_fs_sn_en.php.

APPENDIX 1 – STRUCTURED INTERVIEW IN ENGLISH

Structured Household Survey for the Project:
Local Knowledge and Perceptions of Bracken's Fern Invasion in San Pedro Tlatepusco and Santiago Tlatepusco

Community: **Santiago** **San Pedro**	**Date of Interview:**	**Guide's Name:**	**Translator's Name:**	**Place and Time:**	**Household Interviewed #**

Protocol: *1) make appointments in the houses 2) ask for the head of the house 3) if the head of the house is not home, do the interview with the spouse or elder child.*

Introduction:
Good afternoon. My name is Carolina Berget. I am part of a research team of IDRC-Oaxaca and Florida International University in the United States. I am working with Elvira Duran and David Bray. I am studying bracken fern in your community. This should take one hour of your time. I have the *comisariados'* permission to do research in the community. All data and information that you give me during the survey will serve as part of my study only and are completely confidential. I hope that the results from this research help your community to develop a project that can help improve the productivity of the invaded areas. If you decide to participate in the study he makes a series of questions hoping that their answers are as complete as possible because the data that we collect could serve the community. May I continue? Thank you!

SECTION 1 –DEMOGRAPHY OF THE HOUSEHOLD

1.1 Name: _____
1.2 Gender: F_____ M_____ **1.3** Age _____ (or in which year were you born): _____
1.4 Marital Status: _____
1.5 How many people live in your house, including you? _____
1.6 How many children under 7 years of age live in your house? _____

Box 1. The Household as an Organization (Taken from RANQ (2004)).
Please provide me with the following information only for people in your household older than 7 years of age:

1.7 ID	**1.8** Name	**1.9** Age	**1.10** Sex 1…Male 2…Female	**1.11** Relationship to the head of household	**1.12** Helps in the agricultural activities? 1… Yes 2… No	**1.13** How does she/he helps?	**1.14** Highest level of education achieved?
1	**Head of Household**	**See question 1.3**	**See question 1.2**	**N/A**			
2							
3							
4							
5							
6							
7							
8							
9							
10							

SECTION 2 – AGRICULTURAL ACTIVITIES

MILPA

Box 2. Please respond the following questions regarding *milpa*:

2010:			
2.1 How many *milpa* plots did you have?	*Tonamil* 2010	2.1a Plot 1:	2.1b Plot 2:
	Temporal 2010	2.1c Plot 1:	2.1d Plot 2:
2.2 How long did it take to get there?	*Tonamil* 2010	2.2a Plot 1:	2.2b Plot 2:
	Temporal 2010	2.2c Plot 1:	2.2d Plot 2:
Before being cultivated the plot had:			
2.3 Bracken?	*Tonamil* 2010	2.3a Plot 1:	2.3b Plot 2:
	Temporal 2010	2.3c Plot 1:	2.3d Plot 2:
2.4 *Milpa* of *Temporal*?	*Tonamil* 2010	2.4a Plot 1:	2.4b Plot 2:
2.5 Fallow – of what age?	*Tonamil* 2010	2.5a Plot 1:	2.5b Plot 2:
	Temporal 2010	2.5c Plot 1:	2.5d Plot 2:

If any of the milpa plots was cultivated where bracken was present prior to cultivation, make the following questions. If the answer is NO, then proceed to COFFEE FIELDS, question 2.8:

2.6 Why did you decide to cultivate *milpa* where bracken was present prior to cultivation?

_____

2.7 How was your 2010 *milpa* harvest in the plot where bracken was present? Good_____ Moderate _____ Low _____
If it was moderate or low, ask the following:
a) Because of nuisance animals: Yes_____ No _____ Which? _____
b) Poor soil quality: Yes _____ No _____
c) Any other factor: Yes _____ No _____ Which?_____

COFFEE FIELDS

2.8 Do you currently have coffee fields? Yes ____ No ____ **2.9** How many plots? _____
2.10 How many hectares (in total) do you have? _____
2.11 Is any of the coffee fields within the AVC? Yes _____ No _____
2.12 Is any of the coffee fields in a plot where bracken was present prior to cultivation? Yes _____ No _____

If any of the coffee fields was cultivated where bracken was present prior to cultivation, make the following questions. If the answer is NO, then proceed to YUCCA, question 2.16:

2.13 Why did you decide to cultivate coffee where bracken was present prior to cultivation?_____

2.14 How was your last coffee harvest where bracken was present? Good_____ Moderate _____ Low _____
If it was moderate or low, ask the following:
a) Because of nuisance animals: Yes_____ No _____ Which? _____
b) Poor soil quality: Yes _____ No _____
c) Any other factor: Yes _____ No _____ Which?_____

2.15 In which year did you first clear the coffee plot where bracken was present? P1_____ P2 _____

YUCCA
2.16 Do you currently have yucca plots? Yes _____ No _____ **2.17** How many plots? P1 _____ P2 _____
2.18 How many hectares? P1 _____ P2_____
2.19 Is any of the yucca plots cultivated where bracken was present prior to cultivation? Yes: P1__ P2 __ No: P1___ P2 ___

If any of the yucca plots was cultivated where bracken was present prior to cultivation, make the following questions. If the answer is NO, then proceed to PINEAPPLE, question 2.25:

2.20 Why did you decide to cultivate coffee where bracken was present prior to cultivation?_____
2.21 How was your last yucca harvest where bracken was present? Good_____ Moderate _____ Low _____
If it was moderate or low, ask the following:
a) Because of nuisance animals: Yes_____ No _____ Which: _____
b) Poor soil quality: Yes _____ No _____
c) Any other factor: Yes _____ No _____ Which:_____

2.22 In which year did you first clear the yucca plot where bracken was present? P1_____ P2 _____
2.23 How long does it take you to walk to the plot(s) where bracken was present? P1_____ P2 _____
2.24 Were you able to sell any of your last yucca harvest (from the plot that had bracken)? Yes _____ No _____

PINEAPPLE

2.25 Do you currently have pineapple plots? Yes _____ No _____ **2.26** How many plots? P1 _____ P2 _____

2.27 How many hectares? P1 _____ P2_____

2.28 Is any of the pineapple plots cultivated where bracken was present prior to cultivation? Yes: P1__ P2__No: P1___ P2 ___

If any of the yucca plots was cultivated where bracken was present prior to cultivation, make the following questions.
If the answer is NO, then proceed to LIVESTOCK, question 2.34:

2.29 Why did you decide to cultivate coffee where bracken was present prior to cultivation?_____

2.30 How was your last pineapple harvest where bracken was present? Good_____ Moderate _____ Low _____

If it was moderate or low, ask the following:

a) Because of nuisance animals: Yes_____ No _____ Which: _____

b) Poor soil quality: Yes _____ No _____

c) Any other factor: Yes _____ No _____ Which:_____

2.31 In which year did you first clear the pineapple plot where bracken was present? P1_____ P2 _____

2.32 How long does it take you to walk to the plot(s) where bracken was present? P1_____ P2 _____

2.33 Were you able to sell any of your last pineapple harvest (from the plot that had bracken)? Yes _____ No _____

LIVESTOCK

2.34 Do you currently have? Cows _____ Sheep _____ Mules _____ Other_____

2.35 How many? Cows _____ Sheep _____ Mules _____ Other_____

2.36 Where do you keep them? Pasture____ Tied to the House _____ River's Bank _____ Other _____

If the response is PASTURE, then ask the following two questions. If the response is Tied to the House or River's Bank, then go to Section 3, question 3.1:

2.37 What is the size (ha) of the pasture where you keep the animals? _____

2.38 Before putting the animals there, was bracken present? Yes _____ No _____

If the answer is YES, then make the following questions:

2.39 What animals did you put in the pasture? Cows____ Sheep_____ Mules _____ Other_____

2.40 In what year did you put the animals there? _____
2.41 Why did you decide put those animals in an area with bracken? _____
2.42 What plants are there now? Grass _____ Bracken_____ Trees _____ What type? _____

If there are GRASS or TREES, then ask:
2.43 Did you sow the grass/trees? Si ____No____

If bracken is not overwhelming anymore, then ask:
2.44 Did you get rid of bracken? Si____ No_____
If the answer is NO, then ask:
2.45 What happened with the bracken? _____

SECTION 3 – BRACKEN FERN (Chinantec pronunciation: co'mah'na, co'mah'ju)

3.1 When did bracken fern appear in their communities?
Between 10-50 years _____ Between 50-100 years _____ More than 100 years _____
Observation: _____
3.2 Since you remember, bracken areas in your community have: Increased_____ Decreased_____ No-change _____
3.3 Of the total hectares of you community, how many do you think are invaded by bracken? _____
3.4 Which activity is less labor-intensive, clearing a fallow field or clearing a plot invaded by bracken?_____
3.5 Why? _____
3.6 Have you abandoned a yucca and/or pineapple plot, in the last 5 years? Yes _____ No _____

If the answer is YES, then ask the following questions. If the answer is NO, then go to question 3.9:

3.7 What type of land cover is there now? Bracken ___ Fallow____ Pasture_____ Other crop (which) _____
3.8 Why did you abandon the plot? _____

3.9 Do you think that bracken fern invasion limits the cultivation areas of: *Milpa*__ Coffee__ Firewood Extraction Areas____
3.10 Do you think that bracken fern provides you any benefit (*firewood extraction, timber extraction, pastures*)?
Yes _____which?_____ No ____
3.11 Why? _____

3.12 What other land uses would you prefer to see in bracken invaded areas: *Milpa*_____ Coffee____ Fallow____ Forest____
Other crops_____ which: _____

3.13 Do you believe it is possible to recuperate all areas currently invaded with bracken fern to other land uses?
Yes ____ No____
3.14 Why? _____
3.15 Do you consider bracken is a problem? Yes ____ No____
3.16 Why?_____

SOILS
3.17 How many different soil types do you know there are in bracken invaded areas? _____
Box 3. **3.18** Please describe each type?

	3.18a Color	3.18b Depth	3.18c Quality of soil good to cultivate: 1..Maize 2..Coffee 3..Yucca/pineapple 4..Fruit-tress 5…Trees/Firewood 5..Other	3.18d Texture: 1..Sandy 2..Clay 3..Other	Notes
Type 1:					
Type 2:					
Type 3:					
Type 4:					

3.19 Which of the soil types mentioned is the one that prevails in the bracken fern invaded areas? _____

BRACKEN CONTROL TECHNIQUES We are now going to talk about the way you control bracken fern:

3.20 Describe all the steps involved in slashing a bracken fern invaded plot for yucca/pineapple (*milpa*/coffee) cultivation:
1._____
2._____
3._____
4._____
5._____

6._____

3.21 How many days (hours) did you need to clear the invaded plot? _____
3.22 How many people worked opening the invaded plot? _____

3.23 Describe all the steps involved in planting and growing the yucca/pineapple crops:
1._____
2._____
3._____
4._____
5._____
6._____

3.24 How was the bracken fern kept under control while the crop (yucca/pineapple) was growing? _____
_____

3.25 How did you learn to clear the plots and grow crops in the bracken fern invaded areas? _____

3.26 What did you do with the plot after the last harvest? Abandoned it _____Left fallow_____ Planted another crop_____ which? _____ Planted trees_____ which? _____

If the answer was LEFT FALLOW, ask the following question. If answered any of the other options, then go to Section 4, question 4.1:
3.27 Did you do something to keep bracken fern under control? Yes___ No____
If the answer is YES, then ask the following question:
3.28 Please explain what did you do?_____

SECTION 4. VOLUNTARY CONSERVED AREA (VCA)

4.1 Do you believe that in your community there are enough areas to cultivate *milpa?* Yes_____No_____

4.2 Before the establishment of the VCAs, did you have *milpa* within the VCA? Yes _____ No _____

If the answer is YES, then ask question 4.3. If the answer is NO, then go to question 4.4.

4.3 Please indicate if you were able to find a good quality plot, similar to the one within the VCA, to establish you *milpa*? Yes _____ No _____

4.4 Do you believe that bracken fern limits the area available for *milpa* cultivation? Yes _____ No _____

4.5 Do you consider that what you get paid from the Payments for Hydrological Services Program (PHS) is enough to purchase enough maize and beans to satisfy your households needs? Yes _____ No _____

4.6 Why? _____

4.7 Do you agree with the self-imposed hunting ban on non-nuisance animals? Yes_____ No _____

4.8 Why? _____

4.9 Do you believe that the VCAs and bracken fern areas have caused an increase in the number of nuisance animals? Yes___ No___

4.10 Please list any nuisance animals that you know seek refuge in the bracken fern invaded areas? Yes ____ No ____

Box 4.

4.10a Which?	4.10b Which crop does it forage the most?	4.10c Have you seen it on bracken areas?

4.11 Do you think bracken fern areas have caused an increase in the number of non-nuisance animals? Yes ____ No ____

4.12 Please point out which of these animals have you seen in the bracken fern areas?
See illustrations in Beletzty (1999): Pages: 395, 403, 405, 407, 409, 413, 415.
Box 5.

4.12a Mammal's Name	4.12b Nuisance / Non-Nuisance	4.12c Have you seen it on bracken areas?	4.12d What have you seen it doing?

4.13 Do you believe that the bracken fern areas have caused an increase in the number of non-nuisance animals?
Yes___ No____

END OF THE INTERVIEW!! THANK YOU VERY MUCH FOR THE INFORMATION AND FOR YOUR TIME!!!!

APPENDIX 2 – STRUCTURED INTERVIEW IN SPANISH

Encuesta de hogares para el proyecto: **Conocimiento y Percepción Local sobre la Especie Invasiva*, Pteridium aquilinum*, en las comunidades San Pedro Tlatepusco y Santiago Tlatepusco en la Chinantla.**

Comunidad: Santiago **San Pedro**	**Fecha Encuesta:**	**Nombre Guía:**	**Traductor:**	**Lugar y hora de entrevista:**	**Hogar Encuestado #**

Protocolo: 1) hacer la cita en la casa; 2) preguntar por el comunero(a); 3) si no está dejarle el mensaje e intentar nuevamente.

Introducción:

Buenas tardes. Mi nombre es Carolina Berget. Soy estudiante de la Universidad Internacional de la Florida en los Estados Unidos y con el Dr. David Bray hago una investigación para mi tesis. Mi estudio también está asesorado por la Dra. Elvira Duran del CIIDIR-Oaxaca. Estoy estudiando el helecho, el copetate y el camalote y hablé de mi proyecto en la Asamblea del sábado 28 de mayo de este año, allí me dieron autorización para hacer esta investigación en su comunidad. Todos los datos e información que usted me dé van a ser totalmente confidenciales. Espero que lo que resulte de este trabajo ayude a la comunidad como la base para hacer algún proyecto que mejore el potencial productivo o ecológico de la zona con HECOCA. Esta entrevista le tomara una hora de su tiempo.

Si usted decide responderme las preguntas, voy a proceder a hacer mi entrevista. Me permite continuar? Si la respuesta es sí, entonces Gracias!!

SECCION 1 – DEMOGRAFIA DEL HOGAR

1.3 Me puede dar su nombre: _____

1.4 Género: F_____ M_____ **1.3** Edad _____ (o Año en que nació): _____

1.4 Estado Civil: _____

1.5 Me podría decir cuántas personas viven actualmente en su casa incluyéndolo a usted? _____

1.6 Cuantas niños menores de 7 siete años viven en su casa? _____

Cuadro 1. El Hogar Como Una Organización (Tomado de RANQ (2004)).
Por favor darme la siguiente información solo de las personas de siete años en adelante:

1.7 ID	**1.8** Nombre	**1.9** Edad	**1.10** Sexo 1…Hombre 2…Mujer	**1.11** Relación con el jefe cabeza de hogar	**1.12** Ayuda en las actividades agrícolas? 1… Si 2… No	**1.13** Como ayuda?	**1.14** Cuál es el nivel educativo más alto que ha obtenido?
1	**Jefe Cabeza Hogar**	**Ver arriba**	**Ver arriba**	**N/A**			
2							
3							
4							
5							
6							
7							
8							
9							
10							

SECCION 2 – ACTIVIDADES AGRICOLAS

MILPA

Cuadro 2. Con respecto a la milpa por favor responda las siguientes preguntas:

Año Pasado:			
2.1 Cuantas parcelas de milpa tuvo?	*Tonamil* 2010	2.1a Parcela 1:	2.1b Parcela 2:
	Temporal 2010	2.1c Parcela 1:	2.1d Parcela 2:
2.2 Cuanto tiempo le tomaba llegar	*Tonamil* 2010	2.2a Parcela 1:	2.2b Parcela 2:
	Temporal 2010	2.2c Parcela 1:	2.2d Parcela 2:
La parcela…… estuvo sembrada donde antes había:			
2.3 Helecho, Copetate, Camalote?	*Tonamil* 2010	2.3a Parcela 1:	2.3b Parcela 2:
	Temporal 2010	2.3c Parcela 1:	2.3d Parcela 2:
2.4 Milpa de Temporal?	*Tonamil* 2010	2.4a Parcela 1:	2.4b Parcela 2:
2.5 Acahual – de que edad?	*Tonamil* 2010	2.5a Parcela 1:	2.5b Parcela 2:
	Temporal 2010	2.5c Parcela 1:	2.5d Parcela 2:

Si alguna(s) parcela(s) de milpa fue sembrada donde antes había invasión de HECOCA, entonces hacer las siguientes preguntas. Si la respuesta es NO, entonces ir a Cafetal, pregunta 2.14:

2.6 Por qué decidió sembrar su milpa en una zona con HECOCA? _____

2.7 Como fue su cosecha el año pasado (2010), en el sitio de HECOCA? Buena__ Regular ___ Mala __
Si fue mala o regular, preguntar si fue por:
a) Causa de dañeros: Si _____ No _____ Cuales: _____
b) El terreno no era bueno: Si _____ No _____
c) Algún otro factor: Si _____ No _____ Cual: _____

CAFETAL

2.8 Tiene usted actualmente cafetal(es)? Si ____ No ____ **2.9** Cuantas parcelas de cafetal tiene? _____
2.10 Que tantas hectáreas (en total) tiene de cafetales)? _____

2.11 Alguna de estas parcelas de cafetal está dentro del área de conservación? Si _____ No _____
2.12 Alguna de estas parcelas de cafetal está sembrada donde antes había HECOCA? Si _____ No _____

Si alguna(s) parcela(s) de cafetal fue sembrada donde antes había invasión de HECOCA, entonces hacer las siguientes preguntas. Si la respuesta es NO entonces ir a Yuca, pregunta 2.16:

2.13 Por qué decidió sembrar su cafetal donde había HECOCA? _____

2.14 Como fue su última cosecha de café en el área de HECOCA? Buena__ Regular ___ Mala __
Si fue mala o regular, preguntar si fue por:
a) Causa de dañeros: Si _____ No _____ Cuales? _____
b) El terreno no era bueno: Si _____ No _____
c) Algún otro factor: Si _____ No _____ Cual? _____

2.15 En que año abrió esta parcela de cafetal en el área que tenía HECOCA? P1_____ P2 _____

YUCA
2.16 Usted actualmente cultiva yuca? Si _____ No _____ **2.17** Cuantas parcelas tiene? P1 _____ P2 _____
2.18 Que tamaño tiene en hectáreas? P1 _____ P2_____
2.19 Alguna de estas parcelas de yuca está sembrada donde antes había HECOCA? SI: P1___ P2 ___ NO: P1___ P2 ___

Si alguna(s) parcela(s) de yuca fue sembrada donde antes había invasión de HECOCA, entonces hacer las siguientes preguntas, si responde NO, entonces ir a la Pina, pregunta 2.25:

2.20 Por qué decidió sembrar la yuca donde había HECOCA? _____
2.21 Como fue su última cosecha de yuca el año pasado donde había HECOCA? Buena_____ Regular _____ Mala _____
Si fue mala o regular, preguntar si fue por:
a) Causa de dañeros: Si _____ No _____ Cuales?_____
b) El terreno no era bueno: Si _____ No _____
c) Algún otro factor: Si _____ No _____ Cual? _____

2.22 En qué año abrió esta parcela de yuca donde antes había HECOCA? P1_____ P2 _____

2.23 Cuanto tiempo le toma llegar hasta esta(s) parcela(s) de yuca? P1_____ P2 _____
2.24 De la yuca que cosecho en el área que tenía HECOCA, se vendió algo? Si _____ No _____

PINA
2.25 Usted actualmente cultiva piña? Si _____ No _____ **2.26** Cuantas parcelas tiene? P1 _____ P2 _____
2.27 Que tamaño en hectáreas tiene? P1 _____ P2_____
2.28 Alguna de estas parcelas de piña está sembrada donde antes había HECOCA? Si _____ No _____

Si alguna(s) parcela(s) de piña fue sembrada donde antes había invasión de HECOCA, entonces hacer las siguientes preguntas. Si la respuesta es NO, entonces ir a GANADO, pregunta 2.35:

2.29 Por qué decidió sembrar la piña donde había copetate y/o camalote? _____
2.30 Como fue su última cosecha de piña el año pasado donde antes había HECOCA? Buena _____ Regular _____ Mala ___
Si fue mala o regular, preguntar si fue por:
a) Causa de dañeros: Si _____ No _____ Cuales?_____
b) El terreno no era bueno: Si _____ No _____
c) Algún otro factor: Si _____ No _____ Cual?_____

2.31 En qué año abrió esta parcela de piña donde antes había HECOCA? P1_____ P2 _____
2.32 Cuanto tiempo le toma llegar hasta esta(s) parcela(s) de yuca? P1_____ P2 _____
2.33 De la piña que cosecho en el área que tenía HECOCA, se vendió algo? Si _____ No _____

GANADO
2.34 Usted tiene? Vacas _____ Borregos _____ Mulas _____ Otro _____
2.35 Cuantos? Vacas _____ Borregos _____ Mulas _____ Otro _____
2.36 Donde los tiene? Potrero _____ Amarrado en la Casa_____ En la orilla de Rio_____ Otro _____

Si responde que en POTRERO, entonces hacer las siguientes dos preguntas. Si la respuesta es Amarrado en la Casa o En la Orilla del Rio, entonces ir a la Sección 3, pregunta 3.1:

2.37 De qué tamaño es el potrero donde tiene estos animales? _____
2.38 Los potreros donde tiene estos animales, eran áreas que antes tenían HECOCA? Si _____ No _____

Si la respuesta es SÍ hacer las siguientes preguntas:
2.39 Que animales puso ahí? Vacas _____ Borregos _____ Mulas _____ Otro _____
2.40 En qué año puso los animales ahí? _____
2.41 Por que decidió poner estos animales en la zona de helecho y/o copetate? _____
2.42 Que plantas hay en esos potreros ahora? Pasto _____ HECOCA _____ Arboles _____ Que tipo _____

Si hay PASTO y ARBOLES, entonces preguntar:
2.43 Usted sembró el pasto y/o los arboles ahí? Si ____No____

Si ya no predomina el HECOCA, entonces preguntar:
2.44 Usted quito el HECOCA? Si____ No_____
Si la respuesta es NO, entonces preguntar:
2.45 Que paso con el HECOCA? _____

SECCION 3 – HELECHO (co'mah'na), COPETATE Y CAMALOTE (co'mah'ju)

3.1 Desde cuando sabe usted que existe el **helecho, copetate y camalote** en los terrenos de su comunidad?
Entre 10-50 años _____ Entre 50-100 años _____ Desde hace más de 100 años _____
Observación: _____
3.2 Desde que usted se acuerda, las áreas con HECOCA dentro de su comunidad han:
Aumentado _____ Disminuido_____ Están igual _____
3.3 Del total de hectáreas que tiene su comunidad, cuantas hectáreas cree usted que están invadida por HECOCA? _____
3.4 Cree usted que es más fácil abrir una parcela en el acahual, o es más fácil abrir una parcela donde hay HECOCA? _____
3.5 Por qué? _____
3.6 En los últimos cinco años, usted ha abandonado alguna parcela de yuca y/o piña, que antes tenía HECOCA? Si____No___

Si la respuesta es SÍ, hacer las siguientes preguntas. Si la respuesta es NO, entonces ir a la pregunta 3.9:

3.7 Que hay ahí ahora? HECOCA _____ Acahual _____ Potrero _____ Otro cultivo (cuál) _____
3.8 Por qué abandono esa parcela? _____

3.9 Usted cree que la existencia del área con HECOCA le afecta para tener áreas donde: Cultivar milpa___ Cafetal___ Sacar leña____
3.10 Usted cree que las áreas con HECOCA le traen algún beneficio (*sacar leña, sacar madera, para servir de potrero, para conseguir carne de monte*)? Sí _____cual(es) _____ No ____

3.11 Por qué? _____
3.12 Le gustaría que en lugar de las áreas con HECOCA hubiera: Milpa_____ Cafetal_____ Acahual_____ Bosque_____ Otros cultivos_____ cual(es):_____
3.13 Usted cree que es posible que **todas** las áreas con HECOCA de su comunidad puedan ser recuperadas para acahual o cultivos? Sí ____ No____
3.14 Por qué? _____
3.15 Usted cree que el helecho es un problema? Sí_____ No_____
3.16 Por qué?_____

SUELO

3.17 Sabemos que el terreno en las áreas con HECOCA no siempre es igual. Sabe usted cuantas tipos de terreno hay en las áreas con HECOCA? _____

Cuadro 3. 3.18 Me podría describir como es cada tipo?

	3.18a Color	3.18b Profundidad	3.18c Calidad del suelo suficiente para cultivar: 1..Maíz 2..Café 3..Yuca-piña 4..Frutales 5…Arboles/leña 5..Otros	3.18d Textura: 1..arenosa 2..chiclosa 3..otra	Notas
Tipo 1:					
Tipo 2:					
Tipo 3:					
Tipo 4:					

3.19 En las áreas con HECOCA cuál de estos tipos de terreno es el que más hay (abunda)? _____

TECNICAS DE CONTROL Ahora vamos a hablar de la manera en que usted quita el HECOCA:

3.20 Cuales fueron los pasos que siguió para abrir esta última parcela yuca/piña (milpa/café) que tenía HECOCA?

1._____
2._____
3._____
4._____
5._____
6._____

3.21 Cuantos días necesito para abrir esta parcela (horas)? _____

3.22 Cuantas personas trabajaron abriendo esa parcela? _____

3.23 Cuales fueron los pasos que siguió para sembrar y hacer crecer su cultivo de _____?

1._____
2._____
3._____
4._____
5._____
6._____

3.24 Cómo hizo para controlar que no creciera el HECOCA, mientras se daba la cosecha (yuca/piña)? _____
_____

3.25 Quien le enseño como rozar y sembrar en los sitios donde hay HECOCA? _____

3.26 Después que cosecho, qué hizo en la parcela? Abandono la parcela _____La dejo en descanso_____ Volvió a sembrar un cultivo _____ cuál? _____ Sembró arboles_____ cuáles? _____

Si la respuesta fue LA DEJO EN DESCANSO, hacer la siguiente pregunta. Si la respuesta es NO, entonces ir a la Sección 4, pregunta 4.1:

3.26 Usted hizo algo para que no creciera el HECOCA? Si___ No____

Si la respuesta es SI entonces preguntar:

3.27 Me podría explicar que hizo?_____

SECCION 4. ÁREA VOLUNTARIA DE CONSERVACION (ACV)

4.1 Usted cree que en su territorio hay área suficiente para que todas las personas tengan milpas? Si _____ No_____

4.2 Antes de existir el área de conservación tenia usted milpa en el área de conservación? Si _____ No _____

Si la respuesta es SI, hacer la pregunta 4.3. Si la respuesta es NO, entonces seguir a la pregunta 4.4.

4.3 Después del área de conservación, usted ha podido encontrar una parcela adecuada para sus necesidades de producir maíz? Sí _____ No _____

4.4 Usted cree que por culpa de las áreas con HECOCA, no hay suficientes áreas para que todos en su comunidad tengan donde hacer su milpa? Sí _____ No _____

4.5 Usted piensa que lo que recibe su comunidad por pagos de servicios hidrológicos compensa por no poder meter milpa en el área de conservación? Si _____ No _____

4.6 Por qué? _____

4.7 Su comunidad ha puesto prohibiciones sobre la caza de animales no dañeros, usted está de acuerdo con estas restricciones? Si_____ No _____

4.8 Por qué? _____

4.9 Usted piensa que el área de conservación ha hecho que en los últimos años hayan aumentado los animales dañeros? Si_____ No _____

4.10 Usted sabe si hay animales dañeros que se refugian en el área de HECOCA? Si ____ No ____

Cuadro 4.

4.10a Cuáles?	4.10b Que cultivo se come más?	4.10c Lo ha visto en el HECOCA?

4.11 Usted cree que el área de HECOCA aumenta el número de animales dañeros? Si ____ No ____

4.12 Usted ha visto alguno de los siguientes animales en el área de HECOCA?
Mirar ilustraciones de Beletzky (1999): Paginas 395, 403, 405, 407, 409, 413, 415.

Cuadro 5.

4.12 a Animal - mamíferos	4.12b Dañero / No Dañero	4.12c Lo ha visto en el HECOCA?	4.12d Que actividades lo ha visto haciendo?

4.13 Usted cree que el área de HECOCA aumenta el número de animales silvestres (no dañeros)? Si___ No ____

FIN DE LA ENTREVISTA!! MUCHAS GRACIAS POR LA INFORMACION Y POR SU TIEMPO!!!!!!!

APPENDIX 3 - LOCAL TECHNIQUES TO CONTROL BRACKEN FERN

To learn about the bracken fern control methods, informants were asked to list and describe in detail the steps involved in three different processes: 1) clearing land invaded by bracken fern for agricultural cultivation; 2) planting process; and 3) keeping bracken under control while the crop was growing. In the conception of the questionnaire, it was important to specifically ask each informant about details of these processes to be able to determine whether or not there were differences in the bracken agricultural control techniques utilized between individuals and communities. It was found, however, that the agricultural control techniques are pretty much the same in the studied communities, with just minor differences in, for example utilized tools. On the basis of the information gathered in the interviews, and with the aim of documenting the traditional knowledge, I below I present the generalized steps for the three processes mentioned above for yucca and pineapple plots, as these are the crops that are mainly cultivated in bracken invaded areas.

The first process is clearing the land invaded by bracken fern for agricultural cultivation. As is typical of swidden agriculture, slashing and burning are the two steps involved here. First, bracken fern and other vegetation are physically slashed or cut down. To accomplish this, there are three different practices in the study site: 1) slashing only with the help of a machete (sometimes other tools such as a sickle (*gancho*) are utilized in addition to the machete); 2) slashing bracken with the machete and pulling it up by hand; and 3) pulling bracken up only by hand (no tools utilized). The first two practices are the most commonones, and although the third method is less often used

because its laborious nature, is worth mentioning it because when pulling up by hand, bracken's roots get extirpated, minimizing considerably its re-growth. After slashing, bracken and other vegetation are left to dry out for as little as two days and up to 30 days, but in general 15 days is the average drying time reported. The second and last step is the burning of the dried out vegetation, which is a generalized practice. However, there were a few informants who do not burn because they were concerned that the fire would extend to forest areas or other agricultural areas with active crops.

Yucca is planted by first opening holes in the ground. Different tools are utilized to open the holes, but the most frequently used one is the *coa*. Less often used tools include the *estaca*, *pic*o, *barretón* and *bastón*. In general, distances between holes vary between 0.5 m^2 and 1 m^2. After opening the holes, yucca sticks are placed in each hole. Most commonly two yucca sticks are placed into each hole, but it was also reported that this number highly depends on the thickness of the stick. If the sticks are slim, then three sticks are placed in each hole, but if the sticks are thick then two per hole are planted. Stick sizes vary between 5 cm and 20 cm. The last step in the yucca planting is to cover the sticks with soil.

To control the growth of bracken while the yucca crops are growing, the most practiced method is to manually pull bracken up. Less commonly, the manual pulling is accompanied with the use of the machete, and in more rare cases there is no manual pulling, but growing bracken is only cut with the machete. The number of times that control is carried out depends on bracken's rate of growth. If the growth rate is rapid then control is executed every 5-10 days, and if growth is slow every 3-4 months (average is every 15-30 days). In general the control is carried out for a period of one-year, which is

when approximately yucca plants are mature. Once yucca plants reach a considerable height its shade blocks sunlight which is the limiting factor for bracken fern growth. The shade produced by the yucca plant inhibits the rapid growth of bracken. If during the second year of yucca plants' growth there is still some bracken present, it gets controlled every 2-4 months or until harvesting (less frequently than during the first year).

The first step for pineapple planting is the opening of the holes in the ground. Tools reported to be utilized to open holes included *coa*, *bastón* and *estaca*. Distances between holes vary between 0.5 m^2 and 1.5 m^2. Once the holes are opened, one pineapple stem is placed in each hole. The final step is to place soil around each stem top. The same techniques used for bracken control in yucca cultivation are utilized for pineapple cultivation: 1) manually pulling bracken up; 2) pulling up by hand and with the help of the machete; and 3) clearing bracken with machete only. Pineapple plants take at least two years to mature and thus there is not enough shade to inhibit bracken's growth, therefore control has to be carried out for approximately two years until pineapple are mature and ready to harvest. Control is done every 15-20 days is bracken's growth rate is fast, and every 2-4 months if the it is slow.

Marrs & Watt (2006) described that bracken is such a difficult plant to eradicate that usually two-stage control processes are required. I was able to confirm the need of these two mechanical control stages from the gathered information in my study. The first stage is the manual clearing of the bracken in preparation of the agricultural plot, and once the crop has been planted, a follow-up stage to maintain bracken at a low level is needed, until the crop has reached enough height to provide shade to inhibit bracken's growth or until harvesting, whichever occurs first.

In my study and in other studies, repeated cutting, both in the initial clearing phase and in the posterior maintenance phase, appears to be the most effective way of controlling bracken's spread. In this labor-intensive task, other plants, such as yucca and pineapple, are given an advantage (Schneider 2004). The method of pulling the roots up by hand appears to be effective as well, given that the rhizome system gets debilitated and re-sprouting of the fern from the roots is avoided. Although, pulling up by hand is one of the most effective ways of controlling the fern, it also demands higher labor inputs and therefore converts this method in a non-viable one for the studied communities.

Mechanical control methods require an important investment in household labor (Hartig & Beck 2003), and some households do not count with enough labor force to dedicate time to control and maintain bracken invaded areas (Edouard et al. 2004). Information gathered during informal interviews in my study shows that approximately four times more quantity of labor is needed to clear bracken fern areas, compared to the labor required to clear a fallow forest of the same size (Figure 3.2). In addition, in certain agricultural growing seasons farmers need to dedicate all their time to activities related to their subsistence crops, and to income generating activities (Edouard n.d), such as coffee fields in my study area.

Another important consideration is that burning the plots after clearing them is a generalized practice in my study site. This practice can be counterproductive for bracken control purposes, given that repeated burning of these areas in fact aggravate the problem (Hartig & Beck 2003). Basically this problem gets exacerbated because of bracken's fire ecology: 1) bracken is a fire-adapted species where its deeply buried rhizomes sprout vigorously following fires before most competing vegetation is established, and 2)

bracken's windborne spores may also establish after a fire, because fire removes competition and creates soil conditions suitable for its establishment from spores (Crane 1990).