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Exploring the links between agricultural biodiversity, ecosystem services and human well-being. Evidence from the Yucatán, Mexico.

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“Conocer de nuevo lo que hemos dejado que se perdiera” Doña Rosy

Abstract

This study hypothesises that the application of an integrated and multidimensional human well-being - ecosystem approach can improve our understanding of agricultural biodiversity and the ecosystem services it provides in terms that are meaningful to the people that depend on them, allowing us to draw relevant policy implications. We develop an Extended-Capability-Ecosystem-Approach based on Duraiappah (2004) to analyze the relationship between the conservation and use of agricultural biodiversity and different aspects of the well-being of households, including their conversion factors, capabilities and endowments. The empirical focus is on farming households of the Yucatán, Mexico, where Mayan descendants depend on agricultural biodiversity and the ecosystem services it provides for their subsistence, food security, and culture, often within marginal economic and agronomic conditions. The possible expansion of opportunities open to people through education and employment appears coupled with a process of ageing of the population working in agriculture and rural out-migration. The latter seems related to the use of higher crop diversity on farm and the conservation of local varieties, posing issues of future loss of genetic resources, associated knowledge and cultural values. Geographical isolation also appears to contribute to a higher level of crop diversity and a more intensive use of off farm ecosystem goods. Finally, the work of women on farm is significantly associated with conservation of local varieties and higher crop diversity for consumption, indicating that conservation strategies should take into account the gender dimension of associated knowledge and preferred characteristics of varieties. It emerges that agrobiodiversity and related ecosystem services represent fundamental safety nets, the basis for consumption stability and a risk diversification strategy, often linked to cultural and social practices, but the difficult condition of life in rural areas cannot be overlooked. The relationship between socio-economic characteristics of households and agrobiodiversity calls for a more coherent and concerted conservation strategy linking the action of development and environmental agencies. The recognition of the needs and aspirations of different groups in the population might favour the creation of appropriate incentives for the conservation of crop genetic resources on farm and the sustainable use of off farm ecosystem goods, expanding the real opportunities that people enjoy.

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List of Acronyms and Abbreviations

CA Capability Approach

CBD Convention on Biological Diversity

CEA Capability Ecosystem Approach

CONAFOR National Forestry Commission

CONAPO National Council of Population

CONEVAL National Council of Evaluation of Social Development Policy

ICDD International Center for Development and Decent Work

INEGI National Institute of Statistics and Geography

MEA Millennium Ecosystem Assessment

NAFTA North America Free Trade Agreement

PROCAMPO Program for Direct Support to Agriculture

PROGAN Program for Sustainable Livestock Production and Management of Livestock Production and Beekeeping

SAGARPA Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food

SEMARNAT Secretariat of Environment and Natural Resources

UADY Universidad Autonoma de Yucatán

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Introduction

Today there is growing international recognition of the contribution of biodiversity and the ecosystem services it supports to human well-being. The UN General Assembly declared that "preserving biodiversity is inseparable from the fight against poverty" (UN General Assembly, 2010), while EU leaders endorsed a long-term vision: "By 2050, European Union biodiversity and the ecosystem services it provides — its natural capital — are protected, valued and appropriately restored for biodiversity's intrinsic value and for their essential contribution to human well-being and economic prosperity" (European Commission, 2010). There is therefore a call for researchers from different disciplines to improve the understanding of the relationship between human well-being and the ecosystems on which it relies (Carpenter et al., 2009; Chan et al., 2012; Balvanera et al., 2014). The reason for this resides in the assumption that human well-being is intimately tied to biodiversity and ecosystem services (Jones and Vincent, 1998; Duraiappah and Naeem, 2005; Gowdy et al., 2009; Ring, 2010; Roe, 2010; TEEB, 2010). There are however few studies describing the multidimensional synergies and trade-offs between biodiversity, ecosystem services and human well-being, while evaluation of assumptions, policy instruments and practices is badly needed (Comim, 2004; Duraiappah, 2004; Carpenter et al., 2009; Barrett et al., 2011).

Biodiversity in agroecosystems and the well-being of rural households are intimately tied in a multiple-provisioning/multiple-use relationship. Diverse crop, livestock, tree and wild species sustain diets, food security, income, employment, shelter, and cultural practices, also representing a coping mechanism and safety net especially for poor people in rural areas. Centuries of local management of biodiversity have created invaluable knowledge shaping landscapes, diets, social habits and cultures (Altieri et al., 1987; Rhoades and Nazarea, 1999; Altieri, 2004; Brush, 2004; Bellon, 2009). Agricultural biodiversity is important as it conduces to human well-being directly and indirectly through its contribution to material well-being, security, health, social relations, resiliency and ultimately contributing to what people value doing and being (Dasgupta, 2001; Tilman, 1997; Perrings et al., 1995; Duraiappah and Naeem, 2005; Roe, 2010). On the other side, human actions impact ecosystems and biodiversity directly through the use of natural resources and indirectly through demographic, economic, socio-political, and cultural drivers. These processes

determine for instance direct changes in local land use and cover, resources consumption, or species introduction, which in turn determine changes in human well-being (Young et al. 2005; Millennium Ecosystem Assessment, 2005; TEEB, 2010; Barrett et al., 2011). On the other side there is strong evidence that poor people rely more heavily than others on ecosystem services and biodiversity for different reasons such as lack of other alternatives, for risk management, or to diversify livelihood options during bad times (Duraiappah and Naeem, 2005; Ring, 2010; Roe et al., 2011).

We argue that biodiversity and ecosystem services should be understood in an integrated socio–ecological framework that takes into account the real opportunities open to individuals. Identifying how ecosystems contribute to human well-being and how in turn they are influenced by well-being outcomes also depends on how we define human well-being. This research proposes an extension to the Capability-Ecosystem Approach developed by Duraiappah (2004) to explore multidimensional links between human well-being and agricultural biodiversity, which are influenced among other thing by the conversion factors and capabilities of households. Accounting for conversion factors and drivers of change we look at households within the social, economic, political and cultural characteristics of the society in which they operate, which also affect their availability and access to natural resources. Through the application of a Capability-Ecosystem Approach we can better understand the constraints and opportunities individuals face and how these contribute to shape their choices affecting agricultural biodiversity. Targeting different stakeholders affected by diverse socio-economic and environmental drivers, focussing on the real opportunities available to them can provide guidance for better-directed conservation and development programmes.

We analyse the relationship between agricultural biodiversity, ecosystem services and human well-being in rural areas of the Yucatán, Mexico, where farmers are among the poorest inhabitants of the total Mexican population. The Yucatán area is of particular interest as Mayan farmers use and depend from a wide variety of natural resources, especially agrobiodiversity, which represents a fundamental element of their culture, traditional knowledge, food security and stability. Agrobiodiversity is a relevant part of the agricultural strategy of Mayan farmers and therefore strongly linked to their culture (Durán et al., 2010).

Mayan farmers know the value of biodiversity in that it protects them and supports their well-being so that its depletion is a threat both in material and cultural terms. Indigenous farmers of the South and Southeast region of Mexico are *de facto* conserving crop genetic resources and are therefore potential candidates for on farm conservation interventions (Perales et al., 2005; Smale, 2005). We embed our analysis within the drivers that are affecting the way rural Mayan people interact with their environment.

Through the development of an Extended Capability-Ecosystem Approach we aim to contribute to the growing literature on capabilities and ecosystems by originally introducing the focus on biodiversity in agricultural landscapes. We also aim to contribute to understand what influences the conservation of agrobiodiversity on farm through the application of a multidimensional framework to define well-being. Thirdly, by studying communities located in partly different social and environmental contexts but subject to similar drivers of change we aim at unveiling the vulnerabilities and opportunities of the human well-being - biodiversity relationship in rural areas of the Yucatán.

We find that an Extended-Capability-Ecosystem-Approach allows us to recognize the dependence of different farming households from ecosystem services in agricultural landscapes by embedding the choices they make on the environment within the opportunities that are open to them, and that agrobiodiversity and ecosystem services can also represent part of the opportunities they can choose from.

Structure of the thesis

A literature review is provided in Chapter 1, which details how well-being is defined in the analysis and outlines the literature on human well-being, ecosystem services and biodiversity, with a focus on agricultural biodiversity. In Chapter 2 we review the literature on links between the Capability Approach and ecosystem ervices and develop an Extended-Capability-Ecosystem-Approach for the analysis of agrobiodivesity. Chapter 3 contextualizes the research within the area of study, focussing on the use of agroecosystems by Yucatec Mayan farmers and reviewing the socio-economic drivers that affect rural areas under study. In Chapter 4 a detailed analysis of the multiple use of agrobiodiversity by households interviewed is carried out through the lens of the Extended Capability-Ecosystem Approach.

A closer analysis of the factors influencing conservation of crop diversity is provided in Chapter 5 through the development of an econometric model. Finally, Chapter 6 draws conclusions and policy implications.

CHAPTER 1. Literature Review: human well-being, agrobiodiversity and ecosystem services

Introduction

This research hypothesises that the application of an integrated and multidimensional human wellbeing – ecosystem approach can improve our understanding of agricultural biodiversity and the ecosystem services it provides in a meaningful way for people that depend on them. We argue that biodiversity and ecosystem services should be understood in an integrated socio–ecological context that takes into account opportunities open to individuals; and that identifying how ecosystems contribute to human well-being and how in turn are influenced by well-being outcomes depends also on how we define human well-being.

We focus on biodiversity in agroecosystems and the well-being of farming households, which are intimately tied through a multiple-provisioning and multiple-use relationship. Diverse crop, livestock, tree and wild species sustain diets, food security, income, employment, shelter, and cultural practices, often representing buffering and coping mechanisms in times of distress. However, the *State of the World's Plant Genetic Resources for Food and Agriculture (PGRFA)* in 1997 described as 'substantial' the loss of plant genetic resources for agriculture, and in 2010 it indicated land clearing, population pressures, overgrazing, environmental degradation and changing agricultural practices as major drivers of this loss, and yet few specific strategies for conserving and managing crop diversity on farm involving communities have been developed (FAO, 1997; 2010).

The past decade has therefore seen a growing consensus on the importance of understanding socio–ecological contexts when studying biodiversity influence on human well-being and the drivers that affect its loss, including ethical, equity, distribution and spiritual issues that have been marginalized in conventional economic analysis of natural resources (Costanza et al., 1997; Dasgupta, 2001; Comim, 2004; Duraiappah, 2004; Duraiappah and Naeem, 2005; Millennium Ecosystem Assessment, 2005; Brown et al., 2008; Carpenter et al., 2009; TEEB, 2010; Raudsepp-Hearne et al., 2011; Reddy and Pogge, 2009; Barrett et al., 2011, Daw et al., 2011; Nelson, 2011). Recent works on ecosystem services in particular argue that in order to develop appropriate responses and development strategies it is fundamental to

examine who benefits or is constrained in the use and access to ecosystem services and how changes in these services affect livelihoods, particularly in poor countries (Brown et al., 2008; TEEB, 2010; Daw et al., 2011; Nelson, 2011). The Millennium Ecosystem Assessment (MA) was pivotal in introducing a framework for analyzing socio–ecological systems and has been used largely in research and the science-policy interface, but also criticized (Millennium Ecosystem Assessment, 2003). The lack of integration in studying ecosystems and poverty was one of the main gaps identified by the MA, that stated that '*the failure to incorporate considerations of ecosystem management in the strategies being pursued to achieve many of the eight Millennium Development Goals will undermine the sustainability of progress that is made toward the goals and targets associated with poverty, hunger, disease, child mortality and access to water, in particular'* (Millennium Ecosystem Assessment, 2005).

The link between well-being, economic growth and the environment has received less attention than other themes in the literature referring to Amartya Sen's seminal work on human development and freedoms (Sen, 1992, 1999; Sen and Anand, 1996; Anand and Sen, 2000; Sen, 2000; Sen, 2004). Recently a bulk of authors has been addressing environmental sustainability and degradation through the Capability Approach (CA) in a more systematic way (Duraiappah, 2002, 2004; Lehtonen, 2004; Pelenc, 2010; Pascual. et al. 2010; Ballet, 2011; Polishchuk and Rauschmayer, 2012; Lessmann and Rauschmayer, 2013). The definition of well-being provided by the CA is particularly attractive for understanding its links with the environment by focussing on the actual and potential opportunities available to individuals, including those linked to availability and access to natural resources. *Substantial* freedom of choice between alternatives, a fundamental concept in the CA, can be seen as the underlying link between the rate at which natural resources are used, the opportunities open to people that determine different levels of use, and actual well-being achievements in part linked to the environment.

Biodiversity, including agricultural diversity, and ecosystem services can be analysed adapting the theoretical framework of the CA. Following Ballet et al. (2011) '*what matters is our understanding of the constraints that affect individuals and induce them to make certain choices, including how they use natural resources. The efficient use of natural resources depends to a great extent on the opportunities that individuals have'*. In this research we

focus in particular on agricultural biodiversity and human well-being through the lens of the Capability Ecosystem Approach (Duraiappah, 2004), which links ecosystem services to human well-being as defined in the CA. The theoretical categories of the CA, capabilities, conversion factors and endowments are applied to understand their potential links with conservation of agrobiodiversity.

1.1. Defining human well-being

The definition of well-being depends on the informational basis that underlies it: welfare, quality of life, living standard, utility, life satisfaction, human development, capability expansion and so on. In reality these different meanings are not clearly distinct but have many points in common, sometimes overlapping. Lack of human well-being is often associated with lack of goods and services or unsatisfied basic needs, overlooking the fact that it is also a synthesis of political, economic and social rights. In fact, the utilitarian approach remains the most common theoretical framework adopted for the analysis of well-being, where an absolute 'poverty line' measure based on income or consumption levels is developed and the welfare function ranks alternative social states based on utility maximization (Ravallion 1994, 2008; Deaton 1997, 2005). Income is an important and necessary mean to expand the opportunities of people to live the kind of life they value, but it should be regarded as a fundamental instrument and not an end for human life itself, while the relationship between well-being and income is hardly linear. A common example is that what two persons can achieve through the same commodity bundle differs depending on their physical condition, the cultural, social, political and geographical context they live in or the resources and services they have access to, their so-called conversion factors (Sen, 1992, 1999). Moreover, while poverty is often measured through the use of monetary poverty lines, some have demonstrated that there is no perfect correlation between income poverty and unsatisfied basic needs (for reviews see Alkire, 2002a, 2002b; Boltvinik, 2001; Gasper, 2007). There can be in fact many households above official income poverty lines that lack health, water, sewage and other services, not counting social and political capabilities that are not considered basic needs[1].

[1] Indicators presently used to measure well-being are mainly based on direct measures of current material wealth, such as the gross national product (GNP) per capita but also the Human Development Index (HDI), which includes indicators of education and health but has been criticized for the implicit assumption of perfect substitutability of its components. The HDI combines PPP GDP per capita in US dollars, life expectancy at

In the past thirty years the conceptualization of wellbeing as a multi-dimensional concept has flourished. Among common multi-dimensional measurement approaches there are the capability approach (Sen, 1985, 1992, 1999), the intermediate needs approach (Doyal and Gough, 1991), the dimensions of wellbeing approach (Narayan et al., 2000), the human capabilities approach (Nussbaum, 2000), and the sustainable livelihoods approach (Chambers and Conway, 1991; Scoones, 1998; Adato and Meizen-Dick, 2002). The dimensions characterizing wellbeing identified by these and other approaches are numerous: affiliation, bodily integrity, health, freedom, self-esteem, economic security and so on. Gasper (2007) provides a review of current human development theorists.

In particular, a large bulk of literature has spanned from Amartya Sen's critique of the accepted similarity of concepts such as self-interest, preference, choice, satisfaction and wellbeing, conflated in the term 'utility' (Sen, 1999). Drawing from a multi-disciplinary perspective including sociology, anthropology and philosophy, Sen has emphasized the need to introduce qualitative and multi-dimensional information in the assessment of wellbeing and poverty. He argues that the utilitarian approach focuses on the achievement of a mental state by measuring how much one is satisfied and happy with the basket of goods he is entitled to. Such an aggregative approach looks at the amount of total utility rather than at how it is distributed. On one side Sen argues that the utilitarian approach has the merit of concentrating on the results of social arrangements: for instance, if law protects property rights but the majority people are poor because they don't have access to land, total utility is low. On the other side, the utilitarian approach is indifferent to distribution when total utility is maximized and is unfair to those who are permanently deprived. The ability of people to

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birth, adult literacy and the combined primary, secondary and tertiary education enrolment ratio. Some, like Fukuda Parr argue that the success of the HDI has somehow narrowed the debate over human development to some basic issues, obscuring other relevant meanings of the concept. Ending absolute poverty has become a synonym for meeting basic needs rather than promoting development as freedom. The accepted simplification of the HDI mostly in terms of education and health has excluded other human capabilities: participation, cultural liberty and security (Fukuda Parr, 2003). The new UNDP Multidimensional Poverty Index (MPI), which was published for the first time in the 2010 Report, addresses some of these criticisms complementing money-based measures through multiple deprivations and allowing their overlap (HDR, 2010). The inclusive wealth indicator developed by Arrow and Dasgupta used in the Inclusive Wealth Report of 2012 could be the basis of a promising indicator for measuring nation's development by including the depletion of natural capital. The report looks at the productive base of economies, based on capital assets – produced or manufactured capital; human capital; and natural capital. A key finding shows that inclusive wealth has declined in many countries and this reduction can be traced back to the decline in ecosystem services (UNU-IHDP and UNEP, 2012).

feel satisfaction, their desires and ambitions may be adaptive to circumstances because one might appreciate only what one knows and has the freedom and ability to choose. When the real alternatives open to people expand, their desires, satisfaction and utility increase: expanding real alternatives open to people means expanding their freedoms, therefore the focus of development should be in Sen's view the expansion of freedoms rather than utility, (Sen, 1999). Freedom expansion is central for an evaluative reason as it helps us assess development as the process of enlarging people's choices, and for an effectiveness reason that takes into account the interconnections between freedoms that are enhanced through the agency of people. Sen points out that economic unfreedom can make a person a helpless prey in the violation of other kinds of freedom, which might provoke social unfreedom, while political unfreedom can on the other side result in economic unfreedom (Sen, 1999). In light of this the approach suggested by Sen is one of integrated processes that give birth to intertwined outcomes contributing to a life worth living.

As Sen states: '*What people can positively achieve is influenced by economic opportunities, political liberties, social power, and the enabling conditions of good health, basic education and the encouragement and cultivation of initiatives*' (Sen, 1999, p. 5). Central figure is the agent and his achievements in terms of his own values and objectives. Agency represents the pursuit of a life goal, which can be achieved only if social arrangements give one the opportunity to make choices. As an agent the person is active and is the primary reason of changes in her life. Choice and participation to social, economic and political life are thus essential *functionings* that capture the real freedom and complex deprivation status of people better than commodities. In such a framework the allocation of resources and the role of markets are to be viewed in terms of culmination outcomes, such as the final results in terms of income, and comprehensive outcomes, or what represents the process that leads to those culmination outcomes. It is an open-ended and intentionally incomplete approach, which values social arrangements that expand the freedom to achieve valued objectives (Alkire, 2002a).

1.1.1. Capabilities and functionings

Sen's approach is based on functionings (achievements of a person) and capabilities (what a person values doing or being) meaning a person's ability and opportunity to activate and

achieve a given functioning. Functionings reflect the various things a person may value doing or being and '*they may vary from elementary ones, such as being adequately nourished and being free from avoidable disease, to very complex activities or personal states, such as being able to take part in the life of the community and having self-respect*' (Sen 1999, p 75). The activation of these functionings depends on the person's choices (she chooses to attend school) or not (if she is illiterate she cannot chose to read or write). It also depends on the person's preferences, as she will activate the functionings that she prefers. Capabilities refer to the alternative combinations of functionings that one is able to achieve, therefore represent the opportunities, the substantive freedoms to achieve alternative functioning combinations. Someone's capabilities only include functionings that are, or can be, activated through choice while it excludes the ones that the person cannot activate herself. This definition focuses on the 'ends', or the kind of life actually lived, rather than on the 'means' to escape poverty, such as income. The extent to which each functioning is enjoyed may be represented by a real number, so that a person's actual achievement can be seen as a functioning vector. While the combination of functionings reflects actual achievements, the capability set represents the freedom to achieve: the alternative functioning combinations from which this person can choose (Sen 1999, p 75).

Prioritization of functionings and therefore capabilities is not made by Sen at a theoretical level but he argues for a participatory approaches and context-based assessment. Participation is an essential component of the process aimed at increasing the wellbeing of people because public awareness and understanding of problems and remedies cannot be disjoined by the value judgements a society makes in a specific context and time. Sen thus avoids and refuses the drawing of a predefined list of fundamental capabilities. The capability approach is not intended to build an ordering of states that is general and valid in all circumstances but rather to focus on various aspects of the process of development, diversely relevant depending on the context[2].

[2] Nussbaum for instance develops a list of dimensions relevant to the definition of wellbeing, isolating those human capabilities that can be argued to be of central importance in any human life, whatever the person pursues or chooses (2000). Others, such as Stewart, advocate that the capabilities approach should include the valuation that priority should be given to achieving basic capabilities. Doyal and Gough, for instance, argue that human beings have basic needs for physical health and autonomy, which they define as 'the ability to make informed choices about what should be done and how to go about doing it' (Doyal and Gough, 1991). From these two basic needs they derive a range of so called intermediate needs connected to goods that are deemed essential to satisfy the basic needs. Finally, the sustainable livelihoods approach recognizes that the building blocks of livelihoods are assets and that they can be categorized as natural, social, human, physical, and

1.1.2. Instrumental freedoms

With the capability approach one moves forward from the space of determinants of wellbeing, such as commodities and income, to include also the constituents of wellbeing such as social relations, security, health, freedoms and choices (Reddy and Pogge, 2009; Dasgupta, 2001; Sen, 1999). Sen defines two aspects of freedom: a process aspect, the ability to be agents and affect the process, and an opportunity aspect, the ability to achieve valued functionings given social and personal circumstances. These two aspects make freedom expansion both an end - constitutive role of freedom - and a mean of development - instrumental role. As an end, strengthening freedoms reduces deprivation, which should be the aim of the development process. Such 'ends' of human life can be elementary (escaping morbidity, undernourishment) or complex (feel self-respect, participation to the community), general (have the capability to be nourished) or specific (the capability to eat a certain food). The intrinsic importance of human freedom as the preeminent objective of development has to be distinguished from its instrumental effectiveness in promoting human well-being (Sen, 1999). '*The instrumental role of freedom concerns the way different kinds of rights, opportunities, and entitlements contribute to the expansion of human freedom in general, and thus to promoting development*' (Sen, 1999, p 37). Sen defines five instrumental freedoms:

1. Political freedoms that attain to the democratic control sphere: who controls the process of development and how can people influence or criticize them, determining how they want to be ruled.
2. Economic facilities: the economic resources to which one is entitled and which give one different means of choice.
3. Social opportunities such as education, health care and related entitlements that are available to people and influence their private lives and their participation to the development process. When people lack basic entitlements related to education, such as literacy and primary education, this represents a major barrier to social participation and capability expansion. To concentrate on the education of people means allowing them to grab the opportunities offered by the expansion of their resources and entitlements, something that the sole increase of income is not able to induce.

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financial assets. These assets are combined in the pursuit of different livelihood strategies, for instance agricultural intensification and livelihood diversification. Alkire (2002b) and Gasper (2007) provide reviews of different lines of thought in the human development paradigm.

4. Transparency guarantees: the basis for openness and disclosure, which make contracts enforceable and are necessary against corruption, financial recklessness and violation of commitments.
5. Protective security: attains to the availability of social safety nets that protect people from deprivation in times of crisis or emergency and are of utmost importance to avoid the reversal of improvements achieved.

With these instruments in mind, growth would translate not only in income and commodities increase but also in an improvement in quality of life. The quality of growth thus depends on freedoms and choices available to and made by society through participation and value judgements. Value judgements are a central point of the CA. One gives different weights to different freedoms, because they are heterogeneous and context-based. The matter concerns not only ethical and moral instances, but also the way in which value judgements are formulated. Sen argues that many choices made by governments affecting populations depend on a choice on the importance of values that is not discussed publicly and doesn't involve participation. Several choices concerning the environment take up this form when decisions over the access for instance to environmental goods is centralized or based on market prices.

1.1.3. Heterogeneity and conversion factors

The approach that Sen envisions is a 'goal-rights approach' where the satisfaction one can obtain from a given level of income depends on social and personal circumstances. This stems from the recognition that people differ through a series of characteristics, their conversion factors, which allow them to convert resources into well-being achievements at different rates. These characteristics include:

- Personal heterogeneities: benefits and disadvantages are different within people because of physical differences
- Environmental diversities: education, health or pollution influence what one can gain from different levels of income
- Variations in social climate: social issues like violence and crime that affect the quality of life
- Differences in relational perspectives: cultural conventions or relative poverty within a

community entail different requirements for the well-being of people

- Distribution within the family: gender inequalities, quality and quantity of what is distributed within the family affect the well-being of its members

By distinguishing between income and achievements, commodities and capabilities, economic wealth and ability to live the kind of lives one has reason to value, the CA focuses on the opportunities open to people, their access to resources, their ability to convert them into meaningful outcomes, and their choice to do so.

In this thesis we focus on capabilities of people in terms of opportunities to choose among different alternatives, for instance by having access to employment off farm or education opportunities among the forces shaping the use of agrobiodiversity. While the sum of all the substantial freedoms available to people, their capability set, is infinite, we concentrate on some proxies of capabilities that are relevant for the analysis of agrobiodiversity and human well-being according to the literature and the developing country and rural context that we study. In this view, we follow Sen's suggestion to concentrate on the actual living that people manage to achieve rather than focussing only on the means (Sen, 1999, p 73). As Sen notes, sometimes the lack of substantive freedoms relates directly to economic poverty or the inability to be adequately nourished, being adequately sheltered etc., but also on institutional failures such as the lack of access to employment opportunities, public facilities and social care, or other instruments that concur to the ability of people to convert resources into meaningful wellbeing achievements.

1.2. Ecosystem services, biodiversity and human well-being

We enter the discussion of links between agrobiodiversity, ecosystem services and human well-being trying to define the complex relationship between human and ecosystems. These complex linkages are strongly dynamic and context-specific: drivers that affect biodiversity have direct effects on ecosystem services, and changes in ecosystem services may then evoke feedbacks through human responses (Barrett et al., 2011; Carpenter et al., 2009). Because of their complexity, there are no operational and simple definitions, single measures or a definitive approach to measure biodiversity and ecosystem services. Biological diversity or biodiversity can be expressed as the variety of all forms of life on earth, while ecosystem

services can be broadly seen as the benefits humans derive from ecosystems (Wilson, 1992; Daily, 1997; Duraiappah and Naeem, 2005). While biodiversity often entails a biocentric valuation as life can be assigned an intrinsic value in all its forms, ecosystem services are often associated with an anthropocentric view that gives natural resources an instrumental value in supporting human well-being (Reyers et al., 2012). Some authors argue for analyses that acknowledge biodiversity and ecosystem services through both their intrinsic and instrumental value in order to better tackle the issue of biodiversity loss, acknowledging ends and means for conservation, in a similar way as the debate on ends and means within the CA (Reyers et al., 2012). Moreover, different groups in the population, in diverse contexts, rely on different benefits from ecosystems and biodiversity therefore it is important to understand issues they face in availability, access and opportunities (Daw et al., 2011; Ribot and Peluso, 2003). Changes in access and changes in the socio-economic context might in fact determine changes in the benefits that are derived from ecosystems even if actual changes in the ecosystem are not in place.

Our analysis focuses on who derives different benefits from ecosystems based on the opportunities open to them. With this aim we take into account the conversion factors of different households, their capabilities and their endowments, acknowledging their role in shaping the relationship between agrobiodiversity and human well-being.

1.2.1. Multiple benefits derived from ecosystems

Ecosystem services are defined as the processes and conditions of natural ecosystems that support human activity and sustain human life (Daily, 1997). They are the benefits people derive both directly and indirectly from ecosystem functions, which are the habitat, biological and system properties or processes of ecosystems. This definition can be expanded to represent ecosystem services as the aspects of ecosystems utilized to produce human well-being (Fisher and Turner, 2008). Elrich and Mooney (1983) were among the first to use the concept in order to demonstrate the effects of biodiversity loss on ecosystem functioning and consequently on human well-being. The most commonly used definition, following the Millennium Ecosystem Assessment (MEA, 2005), defines ecosystem services as:

- Provisioning services: e.g. food, fiber, fuels, fresh water, genetic material, biochemicals;
- Regulating services: e.g. purification of air and water, mitigation of droughts and floods, renewal of soil and soil fertility, maintenance of biodiversity, partial stabilization of

climate;

- Cultural services: e.g. social relations and values, aesthetic values, spiritual values

Underpinning all of the above are supporting services such as soil formation, primary production, photosynthesis, nutrient and water cycling, and biodiversity, which supports their functioning (Chapin et al., 2000).

In economic terms there are many sectors and activities dependent on these services. Agriculture, forestry, fisheries, pharmaceuticals, and hunting depend for instance on provisioning services; while regulating services potentially include a large variety of economic activity; and cultural services-related economic activities include tourism, recreation, and education. Regulating and supporting services in particular are essential for the steady delivery of provisioning services to humans and to sustain life on Earth, while cultural services are important for many people especially in developing countries where nature is often valued as a living entity supporting spiritual guidance and social relations (Duraiappah and Naeem, 2005; Duraiappah, 2004).

A thorough review of the concept of ecosystem services especially in the context of poverty alleviation and prevention is provided by Daw et al. (2011). The authors stress the need for disaggregation of well-being and ecosystem services in order to understand synergies and trade-offs of the relationship for different groups in a society, which implies different interventions according to policy objectives. The need for disaggregation is accounted for in this dissertation, acknowledging the distribution of benefits and their availability and access to different people. The authors take the discourse further by suggesting the integration of income and employment as indirect benefits derived by ecosystems in order to understand who benefits from them and whether ecosystem services are important for instance through nutrition, cultural practices or income generation. They also argue that at least in terms of poverty prevention or alleviation direct benefits from ecosystem services such as food, shelter, and protection from extreme climatic events may be more immediately relevant. For instance, through an assessment of marine ecosystem services Brown et al. (2008) find that services that appear of most immediate relevance to the poor are dominated by provisioning services, especially generating economic opportunities and adequate nourishment. A view of biodiversity and ecosystem services based on accounting for different groups, access

mechanisms, individual contexts and characteristics to determine how well-being is improved by ecosystem services, is especially apt to be analyzed through the lens of the Capability Approach, which is the objective of this dissertation. This is particularly important in a developing country context such as Mexico, where income inequality is very high: as Daw and colleagues suggest '*the greater the inequality within a system, the more fundamental are the issues around the unequal distribution of benefits and the marginal utility of income, and thus there is a greater need to disaggregate and account for this*' (Daw et al., 2011). Brown et al. (2008) also take a critical view on the analysis of ecosystem benefits on poverty alleviation due to the existence of only few concrete analyses that also look at conflicts. These may arise for instance when income generation alleviating poverty in the short-term impairs long-term sustainability and maintenance of the flow of services or biodiversity. From an ecological perspective they point to the knowledge gaps in how flows of services and stocks of ecosystems are linked, their non-linear relationships, responses, and their impacts.

Given the rural context where direct benefits from agroecosystems are particularly important and given the socio-economic nature of this research, we focus on provisioning services, mainly crop diversity and off farm ecosystem goods used by people in agricultural landscapes, and in part on the cultural value of agriculture and biodiversity in farmer's perceptions.

1.2.2. Biodiversity and ecosystem functioning

It is useful to go into some detail over the issues involving biodiversity and ecosystem services on a more general scale and then take a narrower look at agricultural biodiversity.

Biodiversity is defined by the UN Convention on Biological Diversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems". Biodiversity plays a fundamental role for ecosystem functions that provide supporting, provisioning, regulating, and cultural services. These services are essential for human wellbeing and for this function biodiversity has been defined as 'the insurance policy for life itself—something especially

needed in this time of fast-paced global change' (WEHAB Working Group 2002). What is emphasized in this notion, which has been gaining importance in recent decades over the utilitarian value of biodiversity in terms of genetic resources in the future or for pharmaceutical purposes, is its value as a source of ecosystem resilience. Resilience represents the functional stability of an ecosystem due to the existence of species 'waiting in the shadow' for the eventual moment when they will have to supply functions typical of other species that have been depleted or that disappeared (Perrings et al., 1995).

While this concept might remind one of factor substitutability in economics, the foundation for the resilience of an ecosystem is that species 'waiting in the shadow' must actually exist in order to be able to supply the functions of lost species. Moreover, there are species or ecological processes which are complementary to each other and not substitutable, so that an economic valuation in terms of substitutability would not be feasible (Balmford et al., 2002). The concept of resilience thus implies that when a natural-resource base is depleted, it affects not only the volume and quality of ecosystem services it provides but also its capacity to absorb disturbances without undergoing fundamental changes in its functional characteristics (Dasgupta, 2001). Biodiversity loss can affect the self-organizing ability of the system, or the resilience of this self-organization that determines the system's ability to cope with external stresses (Perrings et al., 1995). This is the critical concept underlying resilience: biodiversity has primary importance for its role in supporting the functioning of ecosystems when environmental conditions vary. Holling's definition of resilience in fact is "*the capacity of a system to absorb and utilise or even benefit from perturbations and changes that attain it, and so to persist without a qualitative change in the system*" (Holling, 1973).

The way in which resilience of a system depends on biodiversity varies and is not necessarily linked to the number of species present in the system, but also to the mix of species that constitute it, creating a complex web of interactions. What is at stake therefore when natural resources are exploited over their regeneration or conservation level is the productive ability of the ecosystem that generated these resources (Perrings et al., 1995). While the biomass of an ecosystem is a flow concept deriving from the available stock, the value of this stock depends on its productive ability, which in turn depends on its adaptability to environmental changes. Because this adaptability is a function of the system's resilience it is fundamental for ecological economics to assess the value of resilience (Folke, 2006)[3].

[3] Another critical concept involving biodiversity loss and resilience is the presence of ecological thresholds, related to the fact that damage to ecosystems can be irreversible. Two types of resilience exist in ecological

Biodiversity therefore plays a fundamental role for ecosystem functions that provide supporting, provisioning, regulating, and cultural services. The economics of biodiversity is a complex, evolving and rather recent field including the determination of a set of state variables that characterize a complex ecosystem but also understanding the function of biodiversity within the ecosystem as a source of ecosystem productivity and health, for instance through its support to stability and resilience (Tilman, 1997; Perrings et al., 1995; Holling, 1973; Holling et al., 1994, 1996; Dasgupta, 2001; Carpenter et al., 2009; TEEB, 2012). Despite strong synergies have been found in systems with high provision of ecosystem services paired with high levels of biodiversity the functioning of this relationship is still foggy and trade-offs may arise in their conservation (Kareiva et al., 2007; Balvanera et al., 2006; Nelson, 2011).

1.2.3. Biodiversity loss, the decline of ecosystem services and human well-being

A recent study linking biodiversity, ecosystem services and employment illustrates through case studies how overlooking and underestimating the dependence of the poor on ecosystem services can lead to negative outcomes in terms of livelihoods and ecosystems (Nunes et al., 2011). The authors found for instance that there is a strong link between employment and biodiversity through the ecosystem services it provides, especially in primary sectors and in developing countries, but not at all confined to these, and the degree of importance of this link depends partly on the substitutability with man-made goods and services. While there is evidence of synergies between ecosystem services, human well-being and biodiversity, some apparent conflicts emerged with the so called 'environmentalist's paradox': in recent decades improvement in wellbeing has occurred despite decreases in certain ecosystem services, as the Millennium Ecosystem Assessment reported (Millennium Ecosystem Assessment, 2005). Raudsepp-Hearne et al. (2010) formulate four hypotheses on the reasons behind this paradox: critical dimensions of declining human well-being are not captured adequately (which enters Alkire and Sen's debates on measuring human well-being); provisioning services (access to more food) are the most important services for human well-being (following Evenson and

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literature: first kind resilience is resilience to perturbations and speed of return to a globally stable equilibrium. Second kind resilience is the magnitude of disturbance that can be absorbed before flipping from a locally stable equilibrium to another (Holling et al., 1995). These are features of ecosystem stability which are difficult to formalize in economic terms and have been often overlooked by economists focused on valuing biodiversity for the provisioning services it delivers and on its supposed inner substitutability.

Gollin, 2003); technological innovations allow to overcome environmental problems (following Boserup, 1976); ecosystem degradation affects human well-being with a time lag (Meadows et al., 1972). The authors support the second hypothesis based on the empirical strong evidence for the importance of food and the lack of data to address importance of other ecosystem services; they also support evidence suggesting that technological innovation can partially decouple human well-being from the use of ecosystem services trough technology substitution, but innovation tend to dominance of ecosystems rather than complete substitution; and they find mixed evidence for the lagged effects hypothesis which is based on theory and modelling and cannot be rejected due to the lack of counterevidence and a precautionary principle. Instead, they reject the first view that we are measuring the wrong variables on the basis that most well-being indicators, such as health-adjusted life expectancy, adult and youth literacy, gender equality, strongly correlated with the HDI, have been, on average, growing at national levels. They however exclude indicators that include the depletion or growth of natural capital and avoid the issue that the relationship between ecosystems and human well-being is strongly context dependent and might not arise at national level, but be dramatic in specific localities, in pockets of poverty and ecosystem degradation. According to other authors in fact accounting for other dimensions would show an actual decrease of human wellbeing linked to decreasing ecosystem services (Sen, 1985; Reddy and Pogge, 2009; UNU-IHDP and UNEP, 2012). Moreover, most of the services found to be declining are regulating and supporting services, which have been largely overlooked in studying ecosystem links to human wellbeing, while provisioning services have been expanding. These declines are of particular concern because of the vital role of regulating and supporting services in underpinning provisioning services, which are the direct benefits to well-being.

An explanation for the decline of ecosystem services is that their true values are not taken into consideration in standard economic decision making, which in ultimate analysis is based on the aforementioned global indicators of wellbeing (Balmford, 2002; TEEB, 2010). Bateman et al. (2011) clearly summarize the economics of ecosystem services arguing that the level of ecosystem services harvested at each period represents the flow of products extracted from a stock of ecosystem assets. This rate can be unsustainable when the asset is depleted to the point that the flow of services is reduced or stopped. However, not all benefits

derived from ecosystem can be valued in monetary terms as they might be related to spiritual and cultural values, social norms or other aspects[4]. In order to address the distributional dimension of the provision of ecosystem services and livelihood dependence upon them there is a need for improved instruments to measure economic welfare and human wellbeing (TEEB, 2008). Issues of valuation are beyond the scope of this dissertation, the interested reader is referred to Barbier et al. (1990), Barbier (2009), Bateman et al. (2011) and TEEB (2010) for a synthesis.

1.2.4. Feedback loops and instrumental freedoms

Barrett et al. (2011) describe the many interlinkages between biodiversity and human wellbeing in terms of the apparent feedback loops between biodiversity loss and poverty traps. The authors define four classes of inter-linkages between (tropical) biodiversity and poverty traps:

1. Dependence on inherently limited natural resources: the growing conversion of forest and lands or overharvesting to satisfy consumption determines feedback loops between environmental degradation and deterioration of human wellbeing. This is accentuated by the complementary relationship of the rural poor with nature, the quantity and quality of which determines returns to labor (poverty-environment trap). Moreover, the non-linearity that characterizes natural processes increases the possibility of coupled collapse or abundance in human wellbeing and biophysical resources. Recalling the Capability Approach, overharvesting of natural resources can be a direct consequence of lack of alternative opportunities and economic facilities when degradation is directly provoked by the poor; but it can be the result of lack of democratic processes and value formation to allow individuals to decide on issues related to well-being and ecosystem management when agricultural and pastoral encroachment or commercial timber interests are involved, often incentivized by government subsidies.
2. Shared vulnerabilities: large-scale processes and consumptive tendencies heavily influence the choice of response of households to different pressures as well as biodiversity dynamics independent of household behaviour. Where natural shocks such as drought or flood are regular, the feedback loops between poverty, population

[4] An influential and largely criticized study by Costanza (1997) estimated the value of the world' ecosystem services, boosting discussion and research on the matter.

growth, migration, and environmental degradation are reinforced. In such cases, lack of protective security in the form of formal or informal safety nets that automatically provide benefits during times of stress coupled with absence of adequate prevention strategies aggravates feedback loops.

3. Failure of social institutions: market, political and institutional failures, which often happen simultaneously, can lead to poverty traps and ecosystem collapse if formal property rights or informal social norms and cultural practices are not aimed at controlling self-interested individual behaviour. In this case a mix of lack of instrumental freedoms deepns the feedback loops due to lack of transparency guarantees that improve the efficiency of bureaucracy, polity and judiciary, or low social opportunities for specific groups in the society, or lack of economic facilities in the form of clear ownership and easy access to ecosystems and ecosystem services.
4. Unintended consequences and lack of informed adaptive management: there might be imperfect informational feedback due the difficulty in anticipating the outcomes of decisions affecting the environment, such as downstream changes that become visible after a period of time, making response more costly. In this case, the notion of ecological security introduced by Duraiappah (2004) as the conservation of a critical mass of ecosystems in order to ensure that vital ecosystem services are kept intact would represent a sixth instrumnetal freedom linked to the environment, which is explored in Chapter 2.

Finally, biodiversity services are non-exclusive and biodiversity stocks are difficult to monitor. On the other side property rights to biodiversity may be difficult to establish, therefore effective biodiversity protection requires strong enforcement institutions. Many natural resources are 'open access' and not covered by property rights or effective national laws and international treaties, which leads to their constant depletion. This substantial free-riding happens through overuse without concern for negative externalities, and a lack of contributed resources for conserving and improving common-pool resources (Ostrom et al., 1999). For example, open access and a perverse system of subsidies have left two-thirds of fish stocks across the globe over-exploited, and have damaged coastal ecosystems (Sukhdev, 2009). On the other side, high biodiversity is often rich in marginal lands, where private and public sector investments remain low, though they are critical for sustainable management of

natural resources (Jha and Bawa, 2006).

1.3. The relevance of agricultural biodiversity

Agricultural biodiversity, or agrobiodiversity, is the variety and variability of living organisms within agroecosystems. Agroecosystems are systems originated by the action of men with the objective to produce crops and livestock for consumption (Hernández-Xolocotzi, 1985). The living organisms that inhabit them are all the forms of life that contribute to food and agriculture including 'crops and livestock, wild relatives, pollinators, and the species that interact with and support these species: symbionts, pests, parasites, predators, and competitors' (Qualset et al., 1995; Jackson et al., 2007; Wood and Lenné, 1999). From an anthropocentric point of view we can say that biodiversity, and specifically agrobiodiversity, has instrumental value because it provides services that contribute to human well-being (Reyers et al., 2012). Something that has instrumental value is a means to a valuable end, a concept common in Sen's differentiation between means and ends. The goods provided by agrobiodiversity represent means to achieve valuable outcomes, therefore there is an instrumental value to agrobiodiversity. Cultural and economic reasons underlie the conservation of agrobiodiversity, which helps farmers address the risk of fluctuations in the markets and climate-related changes (Lipper and Cooper, 2009). The use of genetically diverse varieties and species is often a risk management strategy: through diversification of the production 'portfolio' when crop fails or external stresses occur risk is reduced and production stability increased (Roe, 2011). Genetic resources for instance allow farmers and plant breeders to cope with heterogeneous and changing environments, an issue particularly important under the pressures of climate change (Fowler and Hodgkin, 2004). Small farmers cope with climate change often through the use of agroforestry, soil conservation practices, and local varieties that are more resistant to drought and other adverse climatic events (Altieri and Koohafkan 2008). However, farmer's decisions to adopt agrobiodiversity-based practices may depend on instrumental and non utilitarian values, which are difficult to assess and often used only for legitimizing conservation when the instrumental value is not deemed sufficient, an anthropocentric view strongly opposed by many conservation biologists (Stanley, 1995, Agar, 2001).

The benefits that people derive from agroecosystems are varied: direct such as food, medicines, and even cultural heritage, but also indirect such as income, employment, and sense of belonging. The rural poor especially depend on agricultural biodiversity for food, shelter, medicines and many other aspects of their lives (Jones and Vincent, 1998). The importance of agrobiodiversity is clear for the provisioning services it provides, but it is also fundamental for supporting, regulating and cultural services. Agrobiodiversity is in fact key to fertilizing soil, controlling erosion, pollinating many crops and trees, providing decomposers, natural enemies of pests and diseases, and genetic material (Wood et al., 2000; Swinton et al., 2007; Hajjar et al., 2008; Kremen, 2012). However, because these services are provided outside markets their price and therefore their loss is not appropriately valued.

The knowledge and cultural diversity associated with agricultural biodiversity can also be intended as integral parts of the concept of agrobiodiversity (Altieri, 2004; Jackson et al., 2007; Toledo and Barrera-Bassols, 2008). Altieri stresses the necessity of recognizing and conserving cultural diversity as part of biodiversity management and conservation efforts (Altieri, 2004). The farmer plans what crops and livestock are to be managed, while the associated biota depends on the local management and environment. In this view, traditional agricultural systems are a continuum of agricultural units and natural ecosystems where the collection and production of plants are part of the same strategy and depend from the management of human groupings. Following Harwood, Altieri concludes that the farmer strategy of risk minimization through cultivation of different species and varieties stabilizes yields in the long term, promoting diet diversity and maximizing returns even with limited resources and technology. Cultural traditions, religious beliefs and the identity of communities around the world are often intimately tied to food and spiritual practices connected to biodiversity. Therefore, biodiversity loss can be detrimental to local identity and good social relations, particularly in marginal areas (Posey, 1999). Many populations have developed invaluable knowledge linked to centuries of local management of biodiversity, shaping landscapes, diets, social habits and cultures (Altieri et al., 1987; Rhoades and Nazarea, 1999; Altieri, 2004; Brush, 2004; Bellon, 2009). Policy and technological advancement should support and help improve these practices and knowledge in order to improve the real opportunities of people in rural areas.

Global industrialization, poverty, population increase, infective diseases and climate change have disrupted local practices endangering livelihoods and biodiversity. Poor rural people are often hit hardest by biodiversity loss because they depend more directly and more heavily on biodiversity and ecosystem services (Gowdy et al., 2009; Sukhdev, 2009). There is in fact an intimate relationship between poverty, inequality and rapid loss of biodiversity, especially in those geographical hot spots where rural livelihoods depend strongly on nature (Barrett et al., 2011). Unnumbered crop varieties and domestic animal breeds have disappeared, while fishing grounds are exploited at or above their sustainable limits. Introduction of exotic species, climate change, harvesting, habitat loss and fragmentation, conversion of forests to pasturelands and urbanization, all contribute to endangering. This genetic erosion[5] implies lower adaptability to marginal and fragile ecosystems and to low-input agriculture (Bellon, 2006).

Dietary diversity and appropriate nutritional intake are also often dependent on genetic resources. Diversification of human diets through consumption of different fruits, seeds and vegetables, is essential for maintaining a healthy nutritional status, for instance improving children's nutrition, and consequently enhancing human wellbeing (MEA, 2005). The diet simplification that results from genetic erosion can have negative impacts on food security and health (Love and Spanner, 2007). Low-caste, tribal, and poor rural women are especially dependent on the environment for water, fuel, fodder and food, and they are the first to be adversely affected by environmental degradation, biodiversity loss and climate change (Bellon, 2006). The lack of social opportunities and economic facilities of these particularly vulnerable groups impedes their access to fundamental resources because of their household or community social status (Roy and Venema, 2002).

Duraiappah (2004) defines the crucial role of institutions and organizations in helping individuals earn a sustainable income from the provisioning services offered by ecosystems: in particular clear ownership of and easy access to a variety of resources is needed to make the conversion of natural resources into economic activities successful. Many of the natural resources upon which rural people depend for income generation traditionally under common

[5] Gnetic erosion means a loss of variability and thus a loss of flexibility, defined as "the loss of individual genes and the loss of particular combinations of genes (i.e. of gene complexes) such as those maintained in locally adapted landraces. The term 'genetic erosion' is sometimes used in a narrow sense, i.e. the loss of genes or alleles, as well as more broadly, referring to the loss of varieties" (FAO, 1998).

property regimes governed by informal institutions, have often been deprived of access by the emergence of formal private property right regimes (Rutten, 1992; Leach et al., 1999). Distributive inequality and access to information and knowledge that allows the poor to manage their resources in the most economically efficient and ecologically sustainable manner is also linked to institutional settings and failure. The lack of information on prices, markets, opportunities, and sustainable technologies is considered one of the driving forces for the poor to use natural resources unsustainably (Amman et al., 2001).
Moreover, conventional resource management often fails to manage biological resources and diversity sustainably, especially in areas where local communities achieved long-term successful management of common pool resources (Holling and Meffe, 1996). Approaches have been studied and developed to recognize the role of collective action and social mechanisms in regulating such open access resources. Most notably, Ostrom (1990) reviewed and analysed similarities and differences in cases where communities have developed advanced context-dependent mechanisms to manage common property. The issue of information on, and access to, agricultural biodiversity and the ecosystem services it provides therefore is extremely relevant.

Jackson and colleagues (2007) provide a useful review of the relationship between agrobiodiversity and ecosystem goods and services, and scenarios to promote sustainable agriculture. Functions of agrobiodiversity are better understood for provisioning services than supporting and regulating, and the economic analysis of the insurance value has been overlooked in practical studies. The authors stress the importance of institutional change for aligning private and social values of agrobiodiversity, the conservation of which ultimately depends on farmers' decisions, while the consequences of its loss accrue to society as a whole.

Hajjar et al. (2008) argue that the contribution of agrobiodiversity to ecosystem functioning is variable but can be substantial both at genetic and species level in farming systems. They hypothesize that crop genetic diversity has a direct maintenance effect on ecosystems by increasing the number of functional traits and facilitating above and below ground interactions; and that increasing long-term stability of the ecosystem promotes the maintenance of biomass and ecosystem services it provides. They find, for instance, that loss

of biodiversity in agroecosystems due to intensification and habitat degradation has negatively affected pollination systems causing the loss of pollinators worldwide; and that varietal and species diversity planted, and landscape heterogeneity, are very useful in pest and disease management. They advocate for the use of a holistic approach to stress the direct and indirect effects of crop genetic diversity that can improve multiple ecosystem functions and analyze their trade-offs and synergies.

Overall, as Jackson and colleagues suggest, the potential for use and conservation of agricultural biodiversity should not be tackled by single disciplines, but involve cooperation among agriculturalists, ecologists, economists, anthropologists, biologists and so on, in order to create frameworks that search biodiversity-based solutions for sustainable agricultural production (Jackson et al., 2007).

1.3.1. On farm management and loss of agricultural biodiversity

In the 1920s, the Russian biologist and geneticist, Nikolaj Vavilov, through the study of botanic collections, literature review and fieldwork, identified so called geographical centres of crop diversity, mainly located in the Global South, in areas where ancient civilization had flourished: the Andes, Mesoamerica, the Mediterranean, Etiopia, the Middle-East, India and China. In these centres, farmers domesticated local genetic resources for thousands of years, and they still share many characteristics: they practice small-scale subsistence production in harsh environments, belong to cultural minorities, and are often the poorest and more marginalized groups in the society, at the margins of economic growth (Hernández-Xolocotzi, 1993; Brush, 2000; Altieri, 2004). In the last two decades, interest has grown in the use and management of traditional varieties (landraces) in farmers' fields and in the wild, so called on-farm and in situ conservation, as a complementary strategy to ex-situ conservation in gene-banks, where genes are stored (Brush, 2004). The basic principle of on-farm conservation is to enable farmers to capture more benefits from the diversity they maintain. On-farm conservation is based on farmers' cultivation and management of a diverse set of crop populations within their original ecosystem or in specific centres. Brush (2004), has summarized the principal advantages of in-situ conservation: fundamental ecological interactions and evolution cannot be stored off site, instead they should be observed and understood in the field; gene-bank collections miss the co-evolutionary

dimension as they are fixed in a point in time; in situ conservation represents a potential store for future recollection; and they represent an effective policy for agricultural development. In-situ conservation has the further advantage of allowing farmers to experiment with their seed favouring crop evolution and adaptation to changing environments. In fact, the process of domestication, changing landscapes and complementing or replacing existing wild species and varieties has favoured the creation of thousands of new species, varieties and breeds (Toledo and Barrera-Bassols, 2008). The appeal of in situ conservation finally lies in its focus on the people-nature relationship as a co-evolutionary process that implies experimentation, trial, error and success. However, conserving crop diversity on farm can be costly to farmers without support, and they have strong incentives to abandon this managed diversity (Bellon, 2004). On-farm biodiversity conservation does not attract many investments because hot spots are often located in poor marginal areas, demand is low and market size and infrastructure insufficient for linking it to commercialization. Moreover, high rates of poverty may impede the creation of a demand profitable enough to justify investment in complementary inputs and institutions to support the poor and ecosystems. However, some research shows that with diminishing returns in favoured areas, higher returns can be sought in marginal areas, particularly on poverty reduction and environmental protection (Bellon, 2006). On the other side, crop genetic resources and more extensively agricultural biodiversity can provide benefits to people so long as their agronomic, nutritional, culinary, cultural and medicinal attributes are known: the shift to on farm and in-situ conservation, within the natural habitat of species, acknowledged this feature, opposite to the isolation of genetic material in gene-banks.

1.3.2. Determinants of crop diversity on farm

The extent of genetic erosion and conservation efforts have been documented systematically by the U.N. Food and Agriculture Organization (FAO) since the 90's, following concerns and studies on the economics of diversity loss by early researchers (Yeatman et al., 1981; Altieri et al., 1987; FAO, 1998; Fowler and Mooney, 1990). Because the loss of genetic resources is a threat to global food security and ecosystems health, and not just limited to local contexts, the public good value of on farm conservation carried out by farmers should be properly accounted. However, the local and global benefits produced by conservationist farmers are not rewarded through the market, which pushes farmers to grow less diversity than is socially

optimal, while corrective policies are not in place (Heal et al., 2004; Pascual and Perrings, 2007). Recognizing the causes of agricultural biodiversity loss and facilitating appropriate institutions to accounting for its true value is therefore of paramount importance. Applied studies have found diverse determinants that influence the maintenance of crop biodiversity in developing countries, including agroecological and environmental heterogeneity, cultural identity and cohesion, aeasthetic value, farmer's need and preferences, government support to high yielding varieties, missing markets and market isolation (Altieri et al., 1987; Zimmerer, 1991; Brush, 2000; Bellon, 1996; Di Falco and Perrings, 2003; Benin et al., 2004; Smale and Drucker, 2007; Kontoleon et al., 2009). Brush (1992) points out that 'Environmental heterogeneity creates the opportunity for selection and isolation of different crops and varieties that are more suited to one set of circumstances'.

Determinants of rural livelihoods strategies that influence land uses and crop diversity have therefore been studied under different angles and include demographic factors, assets and endowments, property rights, education, and other (Radel et al., 2010). Some authors in the past thirty years have focused on the economics of crop diversity to understand how household characteristics and their socio-environmental context contribute to shape its costs and benefits, and who are the potential targets for conservation strategies as they are conserving genetic resources *de facto* (Altieri et al., 1987; Zimmmerer, 1991; Brush et al., 1992; Bellon, 1996; Meng, 1997; Brush, 2000; Van Dusen, 2000; Jarvis et al., 2000; Smale et al., 2001; Di Falco and Perrings, 2003; Perales, Brush and Qualset, 2003; Benin et al., 2004; Smale and Drucker, 2007; Isakson, 2007; Kontoleon et al., 2009; Bellon and Hellin, 2011).

Economic literature on the loss of crop diversity generally adopts the notion of utility-maximizing households that choose the appropriate level of species and varieties managed based on optimal allocation of agricultural inputs given land available, often abstracting from political and cultural processes that might play a role in their decision-making. This also leads to the accepted notion that development is incompatible with conservation of traditional varieties, which become the symbol of subsistence agriculture, while improved varieties become synonym of agricultural development (Brush et al., 1998; Bellon and Taylor, 1993; Van Dusen and Taylor, 2005; Dyer, 2010). However this is very context dependent and many of these authors also find that despite adoption of modern varieties strongly reduces the area planted with landraces or traditional varieties, they maintain a predominant or relevant role in

production, as they provide desired agromorphological traits, satisfy tastes, productive and consumption needs, or retain cultural values (Bellon and Brush, 1994; Bellon, 1996; Brush, 1995, 2000, 2004; Perales, Brush and Qualset, 2003; Isakson, 2007; Jackson et al., 2007; Bellon and Hellin, 2011).

In his development of a conceptual framework at the farmer level, Bellon (1996) suggests how to analyze farmers' decisions to maintain or not infra-specific diversity and how it can affect the household's wellbeing. The framework is equally applicable to study crop inter-specific diversity, as is the case in this dissertation. Starting from the recognition that crop diversity has provided goods and services to farmers through production and consumption (but also cultural) values, Bellon groups farmers by the concern profiles they share, related to personal, environmental and market or institutional characteristics, which we can in part relate to the concept of conversion factors and capabilities. As Bellon conceptualizes, market failures, lack of access to information, and high transaction costs increase the risks associated with crop specialization and reduce satisfaction of the household consumption demands, which might favour the maintenance of higher crop diversity. This is not only true for poorer subsistence farmers, but also for relatively better off farmers, which leads to a possible grouping of farmers into three types, according to their characteristics and concerns, related to ecology, management and use.

Bellon suggests grouping farmers into subsistence, surplus, and commercial farmers. Subsistence or peasant farmers are usually small holders with low resources, without an irrigation system, characterized by a high degree of self sufficiency in their own product; low access to credit and funding; production activities are performed by family members and/or animals; and livelihood strategies are based on a combination of practices including agricultural collection, domestic livestock, handicrafts, fishing, hunting and part-time work outside the house, determining a strategy of multiple use of agricultural resources. On the other side, commercial farmers are characterized by specialized production; availability of funding and inputs; better quality soils; intensive mechanization; maximization of returns per unit of investment; high use of capital and adequate information systems on prices, markets and transport of inputs and outputs; high level of organization in the administration of the factors of production (Sepulveda, 1992). Subsistence farmers produce for self-consumption, although their production might not satisfy completely their consumption needs of specific

crops; they may cultivate on small plots, in marginal environments, with high use of family labour and might look for off farm employment to complement income needs. Their concerns may be linked with adaptation to the environmental context, input availability, employment opportunities, storage, consumption preferences and needs. Other farmers may produce a crop both for self-consumption as well as surpluses for the market therefore they might have slightly larger farms, be more concerned with yields, and combine family and hired labour. Finally, commercial farmers may be entitled to larger areas, with more or less modern inputs, hiring labour and being mainly concerned with yields and planting density. The monetary benefit, both in terms of income generation and saving, is often not the main concern of farmers as Smale, Brush and Bellon find among maize farmers in Guanajuato, Mexico, who are more interested in the consumption than marketing characteristics of their varieties (Smale et al. 2001).

Genetic erosion and adoption are determined in this literature by risk aversion, thin and incomplete markets, or specialization due to market integration. Technologies may be adopted because they supply valued traits to farmers (Smale et al., 2001; Bellon et al., 2006) or their adoption depends on the distribution of resource endowments that may constrain farmers' decisions (Feder, 1980). The latter assume uncertainty and risk aversion that explain farmers' reluctance to abandon traditional varieties and crop diversification as the result of high risk aversion due to input, infrastructure, or information constraints that causes a cautionary attitude towards improved varieties (Feder, 1980). Other authors argue that thin and incomplete markets determine high transaction costs so that isolated farmers don't find an incentive in allocating inputs to market production or to a single marketable modern variety (de Janvry et al., 1999). A combination of risk aversion and incomplete markets dominates the literature on loss of traditional varieties, particularly after studies by Van Dusen and Taylor (2005) that find that household, production, and market characteristics of households shape diversity managed on farm and that market integration and expansion produces a gradual shift from subsistence farming to a simplified agricultural system even when competition from new varieties is absent[6]. They find that an increase in the level of market integration decreases the level of total diversity in a farmer's field, as transaction

[6] They look at decreasing returns to scale implying some fixed factor of production such as time or land quality, therefore specializing in one crop might not be optimal with heterogeneous land quality or high transaction costs to reach markets. They also look at missing commodity or factor market that might determine that all household consumption demand for a crop must be satisfied entirely from own production.

costs increase prices for buyers and reduce prices for sellers, as well as the development of local markets and the level of international migration at village level. However, these substitutes might not satisfy individual preferences or represent inferior goods considering taste or other reasons, therefore the nature of the good 'diversity' will also determine the rate of substitution (Brush et al., 1992; Bellon, 1996; Bellon and Hellin, 2011).

Perales (1998) also finds that urban migration and the increasing average age of farmers are threatening the conservation of crop genetic resources. Other studies such as Perales et al. (2003) find that for maize varieties in central Mexico different levels of adoption of modern maize varieties don't derive only from marginal environmental conditions, market isolation and poor infrastructure or poor research and development system. The authors also find higher presence of traditional varieties in areas where a larger part of the harvest is sold. There is evidence that also relatively well-off farmers in areas with access to markets and modern inputs are maintaining crop specific diversity because their ecology, management and use problems cannot be satisfied uniquely by one or few varieties (Brush, 1995; Bellon, 1996; Bellon and Hellin, 2011).

The degree of diversity maintained by farmers, therefore, not only responds to strategies based on direct utilitarian value, but also to a risk management and adaptation strategy that takes into account unexpected circumstances that might arise in the future, to local and individual tastes and demand, and to availability of desirable traits. Drucker et al. (2005) for instance list five fundamental socio-economic aspects of managing crop and livestock genetic resources on farm: as a means of survival for the world's rural poor; as pests and disease management strategy; as an input into indigenous technology systems; as a biological asset with potential future value; and as a way to satisfy tastes and preferences. Fewer studies include non-agricultural market activities, cultural identity and preferences as playing an increasingly important role in rural livelihood strategies affecting crop diversity conservation (Reardon and German Escobar, 2001; Brush 2004; Deere 2005; Isakson, 2007).

In his study on livelihood diversification strategies and crop diversity managed by Mayan farmers in Guatemala, Isakson (2007) for instance takes into account economic, historical, cultural and political drivers that have contributed to shape the conservation of plant genetic

resources in the areas, acknowledging their role in influencing peasant agricultural practices. He finds that the level of agricultural biodiversity managed among small-holders is positively associated with land endowments; that households maintain diversity as a risk management strategy against environmental variability and income shocks from market activities; that diversity represents also a form of cultural belonging and recreation.

Taking into account these factors when assessing the different dimensions of human well-being influenced by agrobiodiversity is particularly interesting in the Mexican context. Smallholder farmers have been largely overlooked by government assistance, which has been directed to subsidize 'modern' commercial farming. However undervalued by public policy their role is crucial in conserving the genetic resources they domesticated through centuries, maintaining and improving selection practices and seed flow (Bellon, 2009). Peasant farmers in Mexico seemingly conserve and use a high level of biodiversity based on integration with the surrounding environment, while commercial farmers have low levels of agrobiodiversity due to monoculture, excessive application of chemicals, and depend heavily on subsidies. Moreover, small subsistence and surplus farmers depend directly on agrobiodiversity for both consumption and production.

Crop infra- and inter-specific diversity therefore plays different complementary roles in the well-being of households ranging from adaptation, risk management, providing goods for production and consumption, or even for ritual use, a particularly important feature among Mayan descendants. In this thesis we contribute to the theorization on the conservation of crop genetic resources taking into account wider drivers of change linked to population growth, the expansion of agricultural frontiers, off farm labour opportunities, migration, and social opportunities. These drivers influence households' conversion factors, endowments and capabilities that contribute to shape the level of crop diversity managed and the use of ecosystem goods.

1.4. Conclusion

There is an urgent need today for better understating who benefits from the production of goods and services in agroecosystems and beyond and how changes in their provision might

affect them. This dissertation enters the debate by understanding dependency of people on nature in a setting that is a centre of crop origin and domestication, rich in biodiversity and cultural identity, and affected by economic, social, and environmental changes that shape the way people relate to the environment and the benefits and trade-offs of this relationship that affect their ability to achieve valued well-being outcomes. By taking into account differences in availability and access to resources of different types of farmers we aim to highlight the different benefits provided by crop diversity and use of off farm ecosystem goods, and to make explicit the factors that shape their use and conservation. A view of biodiversity and ecosystem services based on accounting for different groups, access mechanisms, socio-environmental contexts and characteristics to determine how well-being is improved by agroecosystems is especially apt to be analyzed through the lens of the Capability Approach, which is the objective of this dissertation.

CHAPTER 2. Theoretical Framework - An Extended Capability Ecosystem Approach

This chapter develops an original theoretical framework based on the Capability-Ecosystem Approach (CEA) outlined by Duraiappah (2004), adapted to the analysis of the use of biodiversity in agroecosystems taking into account recent works on the links between capabilities and ecosystem services including Pelenc (2010), Ballet et al. (2011) and Polishchuk and Rauschmayer (2012). In fact, some relevant literature for this thesis came out while it was being written, given the importance that the theme has acquired recently. The conceptual framework developed provides a guide for a capability-ecosystem approach applied to agricultural landscapes.

Following from the overarching hypothesis that the application of an integrated and multidimensional human wellbeing – ecosystem approach can improve our understanding of agricultural biodiversity and the ecosystem services it provides in a meaningful way for people that rely on them, an extended CEA helps us define the intimate ties between human well-being and agrobiodiversity, and the synergies, trade-offs and vulnerabilities involved in this relationship. By applying theoretical categories of the Capability Approach we take into account the fact that the intensity of this relationship varies across individuals and/or groups depending on the opportunities available to them, their characteristics and their choices. We also take a step further in the theorization of a Capability-Ecosystem Approach by adding a link from the activation of certain capabilities to the use of agrobiodiversity and ecosystem services.

2.1. Linking the Capability Approach to ecosystems

There is less literature referring to the environment compared to other themes within the Capability Approach and this is mainly based on analyzing sustainable human development on a theoretical level (Sen and Anand, 1994; Anand and Sen, 2000; Sen, 2004). There is fewer literature on the relationship between biodiversity, ecosystem services and capabilities, and part of this literature came out while this thesis was being developed. Even through a superficial Google search for literature on biodiversity and the Capability Approach, less than

a handful of results can be found, mainly with references in publications from TEEB and Polischuck. This literature has focused on ecosystem services mainly on a theoretical level (Duraiappah, A.K., 2002, 2004; Ballet et al., 2003; Lehtonen, 2004; Canova et al., 2009; Pascual et al., 2010; Ballet, 2011; Polishchuk and Rauschmayer, 2012; Scerri, 2012; Lessmann and Rauschmayer, 2013)[7]. Here we provide a brief review of this literature, in order to introduce the framework to which we refer in our analysis.

Lehtonen (2004) looks at preliminary ideas on frameworks for analyzing the environmental–social interface: starting from neoinstitutional and ecological economics he looks at the role of the Capability and Social Capital approaches to address the social dimension of sustainability. Concerning the CA he focuses on early works by Ballet et al. (2003) who argue that individual and societal capabilities are the result of an adaptation to external constraints: when a change for instance in distribution occurs, this may increase vulnerability reducing resilience (similarly to resilience in ecological processes). Therefore different combinations of capabilities determine different levels of resilience to external shocks. Lethonen notes the conceptual similarity of the CA with the Critical Natural Capital debate (De Groot, 1994) that acknowledge that ecosystems provide critical functions for societies such as production, habitat but also pleasure and cultural meaning that are affected by policy design. Similarly, changes in individual and social capabilities determine critical functions for people in different ways and therefore policies that affect capabilities should be designed by taking into account all affected parties and develop common scenarios.

Pascual et al. (2010) argue that in analyzing social welfare outcomes of different stakeholders related to natural resources it is necessary to clearly define the evaluative space of outcomes, and the type of indicators used to evaluate impacts on human well-being. Specifically, they refer to consequences of payments for ecosystem/environmental services (PES)[8], which cannot be fully captured in terms of income as its translation in increased well-being is not

[7] In the Human Development Report 2007/2008 Sen argues that the contribution of the human development approach to the debate on environmental sustainability lies in seeing development as the expansion of substantive human freedom (UNDP, 2007). The first issue on sustainability of the Journal of Human Development and Capabilities was published in 2013, with a contribution from Amartya Sen on sustainability.

[8] 'Payments for ecosystem services (PES) policies compensate individuals or communities for undertaking actions that increase the provision of ecosystem services such as water purification, flood mitigation, or carbon sequestration. PES schemes rely on incentives to induce behavioral change and can thus be considered part of the broader class of incentive- or market-based mechanisms for environmental policy. By recognizing that PES programs are incentive-based, policymakers can draw on insights from the substantial body of accumulated knowledge about this class of instruments' (Jack et al., 2008).

obvious or linear. For instance, reducing arable land for reforestation through a PES scheme might adversely affect food provisioning in the affected area and related functionings, increasing the vulnerability of households. On the other side, increased income through the PES scheme could open education or employment opportunities, increasing other functionings. The authors argue that the Capability Approach could provide a valid alternative for understanding synergies and trade-offs between human well-being and the environment by taking into account social and environmental conditions and opportunities on which the relationship depends.

Pelenc (2010) follows Lethonen's suggestion to cross Critical Natural Capital with the Capability Approach by highlighting the role of critical services for human well-being. These are ecosystem services, from life supporting and biophisycal functions to creation of opportunities of learning, recreation and spiritual well-being, providing ecological foundations for many functionings. Pelenc goes to define the important role of the CA into issues of critical natural capital by arguing that the critical level per se is not enough to understand for 'what' and for 'whom' that capital is critical. In order to be able to understand for whom it is critical we need to understand if ecosystem services are accessible through information, entitlements (property rights), conversion factors (infrastructure, services, availability of parks etc.), resources (income, mean of transportation etc.), and functionings (education, health etc.). Given information, functionings, and enabling or constraining factors and conditions, the last step is the choice of the agent that decides if her use of a resource will be sustainable or not.

Ballet et al. (2011), focus on capabilities as actual and potential opportunities for individuals that contribute to determine their efficient or inefficient use of resources. This leads to envision the environment as an opportunity or a constraint compared to alternative opportunities and constraints (for instance the cost of using alternative resources, or the opportunity provided by a river for fishing, or the threat it provides when it overflows). They also point out the value of the idea of justice in Sen's framework not as mere distributional justice but as substantial freedom. The anthropocentrism of this approach, as well as in the ecosystem services approach, is a limitation but also an advantage as it draws the focus to the economic, social and ecological aspects of the relationship between human well-being and

the environment. Ballet et al. also argue that opportunities and constraints are better understood under the combination of functionings that individuals can choose to activate within their available capability set which determines their ability to adjust to constraints. For instance the ability to cook and heat is a basic functioning that can incentivize deforestation when families use firewood due to their inability to choose alternative options. Policies aimed at conservation cannot therefore be implemented in isolation and ignore the reason why a resource is being harvested unsustainably and by whom, but they have to look at the capability structure of the households that depend on that resource. Ballet et al. find that the limitation of the CA lies in its static analysis and the overlooking of uncertainty, whereas environmental systems are characterized by dynamic processes involving a certain level of risk and uncertainty when changes occur. However, they advocate the use of the CA in analyzing the human wellbeing-environment nexus as it offers an explanation of the use of resources as a choice between different types of opportunities, or freedoms, available to the individual.

Finally, Polishchuk and Rauschmayer (2012) advocate for the use of the CA in order to overcome the utilitarian framing of ecosystem services as benefits. In light of the debate on the role of biodiversity in strengthening ecosystems and supporting service provisioning they argue that the reconciliation of its intrinsic value with the 'commodification' of nature partly implicit in the concepts of ecosystem services can be achieved through the CA. In Duraiappah (2004) they find a first step in going beyond the monetization context by showing the diversity of contributions of ecosystem services to well-being and the particular dependence of the poor on these contributions. The authors start from the idea that the way ecosystem services translate into well-being depends on the personal, social and environmental conversion factors of different stakeholders in specific contexts. Moreover, people's choices within their capability set, resources and entitlements directly affect the state of ecosystem services and biodiversity, which is the missing link in the Millennium Ecosystem Assessment (which somehow makes this link indirectly through the notion of drivers). The conversion of ecosystem services into well-being happens through mediation of education, health, cultural beliefs, social status, and through availability of other services and assets or infrastructure. Apart from provisioning services which are tangible goods, regulating services can also be seen as environmental conversion factors that influence how

people can convert resources (including provisioning services) into well-being for instance through regulation of air and water quality. The authors also view cultural services as environmental conversion factors as they provide spaces for socialization or environment related activities. The contribution to capability formation therefore can be both direct and indirect.

From this literature review we can argue that the Capability Approach offers an articulated framework for the analysis of links between well-being and the environment by taking into account the opportunities, as well as the constraints, that the environment offers to individuals. Specifically, we embrace Duraiappah's theorizing on the relationship between ecosystems and human well-being and adjust it to understand the role of agrobiodiversity in rural well-being. We also take a step further in the theorization of a Capability-Ecosystem Approach by adding a link from achieved functionings, the results of capability set and choice, to the provision of ecosystem services and biodiversity.

2.2. The Capability-Ecosystem Approach as an overarching framework

One can argue that the overall value of the environment does not lie only in what is available, but also in the opportunities it offers. By focusing on opportunities the Capability-Ecosystem Approach can provide a particularly fitting framework for the analysis of the relationship between human well-being and the environment. The CEA framework was developed by Duraiappah to analyze links between poverty and the environment, having in mind a developing country context (Duraiappah, 2003; Duraiappah, 2004). He uses a categorization of ecosystem services close to that proposed by the *Millennium Ecosystem Assessment*, while human welfare is defined by being able to be and to do, that is to say not only real opportunities, but also potential opportunities open to individuals. Duraiappah defines poverty as the pronounced deprivation of wellbeing (Chopra et al., 2005) drawing on Sen's concept of five freedoms, which implies that a person possesses political capabilities (empowerment, rights, freedom of choice), economic capabilities (the ability to earn an income, access to land and resources, decent work), human capabilities (health, education, nutrition), socio-cultural capabilities (status, dignity) and protective capabilities (to address security, risk and vulnerability). These capabilities are determined by the enabling conditions

provided by instrumental freedoms, defined in Chapter 1: participative freedom, economic facilities, social opportunities, transparency guarantees, and protective security.

Duraiappah takes a step further by defining a sixth instrumental freedom, ecological security, a concept that recalls environmental sustainability: '*setting aside a critical mass of an ecosystem that will ensure that vital ecosystem services are kept intact; and the processes by which communities make decisions to arrive at this critical mass*' (Duraiappah, 2003; Duraiappah, 2004; Duraiappah and Roy, 2007). He argues that a critical element of current and future human well-being is to ensure that vital ecosystem services are kept intact to provide safety nets to individuals who depend on them. For instance, because biodiversity provides many goods and services, changes in its levels and stability determine changes in the ability of the ecosystem to provide these services, making it a fundamental constituent of ecological security. Going beyond provisioning services, biodiversity, regulating and enriching services can be seen as '*constitutive elements and a human right to which all individuals are entitled*' (Duraiappah, 2004) and should have guaranteed access, both for the present and future generations (Canova et al., 2009).

The CEA aims to address three objectives: to demonstrate how human wellbeing is dependent on ecosystems and ecosystem services; to identify barriers and drivers that prevent the poor from using ecosystem services; and to identify policy response options to remove the barriers, re-design or even introduce new intervention strategies to allow the poor to improve their wellbeing through an ecosystem approach (Duraiappah, 2004). In order to conceptualize the natural environment this approach does not focus on a single environmental issue or species and recognizes that the ability of ecosystems to provide products for consumption and absorb human waste is declining (Duraiappah and Roy, 2007). Duraiappah uses a categorization of ecosystem services close to that proposed by the Millennium Ecosystem Assessment (MEA), but human welfare is defined by capabilities to be and to do, including potential opportunities that should be allowed or provided to individuals[9]. To define the components of well-being Duraiappah moves from the recognition that all people

[9] We have seen in Chapter 1 that the MEA identified five components of well-being: basic material for a good life, such as adequate livelihoods, food, shelter, income; health, including personal and environmental health; good social relations, such as good gender relations, respect, cohesion; security of access to environmental and other resources, personal and environmental security; and freedom of choice and action as underlying the other components (MEA, 2003).

depend on services provided by ecological systems and '*yet, the poor are more heavily dependent on these services than the rich, since the rich can buy clean water or air-cleaners or build appropriate shelters to isolate themselves from environmental degradation. Ecosystems do affect well-being*.' (Duraiappah, 2002). Based on an extensive review of the poverty-environment literature, Duraiappah suggests ten fundamental constituents and determinants of well-being directly related to ecosystems and their services, which are both an expression of capabilities (opportunities) and functioning (achieved outcomes through choice):

1. Being able to be adequately nourished.
2. Being able to be free from avoidable disease.
3. Being able to live in an environmentally clean and safe shelter.
4. Being able to have adequate and clean drinking water.
5. Being able to have clean air.
6. Being able to have energy to keep warm and cook.
7. Being able to use traditional medicine.
8. Being able to continue using natural elements found in ecosystems for traditional cultural and spiritual practices.
9. Being able to cope against extreme natural events like floods, tropical storms and landslides.
10. Being able to make sustainable management decisions that respect natural resources and enable the achievement of a sustainable income.

The list is not meant to be complete: the final selection of well-being constituents and their relevance must be determined by the communities or individuals concerned, ideally through a participatory process. Following Alkire (2002a), a key aspect is that the set of dimensions of well-being chosen should not be derived by a metaphysical standpoint, and should not be overspecified or too prescriptive. Failure to include participatory processes that tackle the importance of traditional knowledge, innovation, practices and institutions that make community-based conservation efficient, would exacerbate uneven wealth creation and unsustainable rent-seeking behaviour (Duraiappah and Abraham 2004). There is complementarity and synergy among these ten constituents in determining levels of well-being: being able to be free from avoidable disease is connected to being able to be adequately nourished and have adequate drinking water for instance. Moreover, not only

these ten basic constituents often depend on ecosystems, but can also affect ecosystems by influencing direct and indirect drivers of change, for instance influencing demographic and economic processes that cause land use and land cover change, or species introduction. In this thesis we take this point further by adding a direct link from constituents of well-being or achieved functionings to ecosystem services.

Roughly, the links between ecosystem services and the ten constituents of well-being can be summarized as follows (Chapter 1 provides a more general overview). Provisioning services play an instrumental role in improving diets and providing relief during times of famine, crop failure, pest attack and drought. They include the provision of fresh water as most poor people depend on rivers and streams for their daily requirements. Also, a large part of the world's population cooks with biomass derived by firewood, crop residues and animal dung; while traditional medicine is an integral part of the health care system of the poor in many developing countries. While unsustainable activities cause ecosystem degradation, natural resources are also among the main sources of income and employment for the poor: not only cultivated and wild crops, wood, medicinal plants and other ecosystem goods are sold for marketing, but they represent a source of permanent or seasonal employment. While the inclusion of income and employment as ecosystem services is uncommon, it does make sense from the perspective of the poor when considering these services as benefits they derive from the environment (Brown et al., 2008). As mentioned in Chapter 1, Brown et al. (2008) find that the poor prioritise provisioning services, especially cash, food and employment, however they also value especially the protective role of regulating and supporting services that allow the continued supply of provisioning services and secure environment.

Regulating services are also fundamental for human well-being. Purification of air and water for instance is directly linked to being able to be free from avoidable disease: many illnesses are linked to ecological conditions such as air and water pollution. Changes in ecosystem can also alter the concentration of disease vectors such as mosquitoes. The regulation of floods, landslides and the impacts of storms have evident consequences for people's ability to live in a safe environment, and can be strongly influenced by changes in land and vegetation cover. Different stakeholders also perceive these services differently: carbon sequestration from tropical rainforests may be valued for climate regulation at the global level, but locally the

forest may have its ain value for the provisioning of firewood.

Finally, many rural communities worship and attach spiritual or religious value to the natural environment, while many social activities and traditions revolve around local biodiversity. Duraiappah cites an enlightening example of the value of sacred groves in India, which for some communities not only have cultural and spiritual value, but as a repository of seed and for water conservation. While many sacred groves are preserved for religious or spiritual reasons, their preservation directly influences other fundamental services these groves provide.

There are many linkages between ecosystem services and constituents of human wellbeing and through this interdependency many of them could improve by addressing some of the others. However, the relationship between ecosystem services and human well-being cannot only be thought of under a positive angle. As we have seen, there can be constraints and trade-offs between services and functionings, such as unsustainable harvesting of natural resources when other options are not available, for instance for heating and cooking. Deforestation can in turn reduce regulating services such as carbon storage and flood protection, but also cultural services if groups in the society put a specific spiritual or cultural value on the forest. Trade-offs often occur at regulating and cultural level as provisioning services are favoured at the expense of other services (Millennium Ecosystem Assessment, 2005). In order to understand these synergies and trade-offs the CEA approach takes into account direct and indirect drivers that impact ecosystems as well as the poor's access to, and use of ecosystem services: economic, governance-related, social and ecological drivers. The MEA unpacked these drivers into demographic, economic, socio-political, science and technology, cultural and religious, and physical, biological and chemical drivers. The four categories devised by Duraiappah can be argued to include these drivers, however cultural drivers are more difficult to interpret. Cultural drivers can refer to changes in consumption habits linked to religious beliefs and precepts, for instance through designation of sacred species or places.

2.2.1. Instrumental freedoms in the CEA

In Duraiappah's framework these drivers can be addressed by highlighting the instrumental freedoms earlier defined. Governance-related drivers for instance include inefficient government agencies and policy instruments, and lack of participation and involvement by groups dependent on ecosystems in decision-making. Institutional failure or inefficiency can be caused by the power of specific groups or by the absence of distributive instruments that improve equality in access and use. They are linked to participative freedom as it allows value formation through public discussion, which has direct influence on whether resources are managed, conserved and used sustainably to enable their continuous supply. Public debate and information support the creation of an environmental ethic and a recognized space to present views on ecosystem management for people who depend on the environment for their well-being. Economic facilities provide the means to earn a sustainable income from provisioning services through clear ownership and low transaction costs. The lack of financial resources or access to resources necessary to undertake economic activity such as land, but also information on prices, markets, inputs, economically efficient and ecologically sustainable production are serious constraints for the poor. Transaction costs incurred by the poor are classified in Duraiappah's framework as 'process' and 'marketing' transaction costs. Process transaction costs occur when natural resources are converted into economic goods, including costs to install water and energy sources, to obtain permits, or time costs due to red tape. Marketing transaction costs occur when people try to sell goods through the markets, looking for information on 'appropriate' markets and prices, having to recur to intermediaries, or filling out costly forms. On the other side economic drivers for instance linked to liquidation of natural assets to finance current consumption can contribute to increased short-term well-being without taking into account the adverse effect on nature's ability to support economic, ecological, social, and cultural benefits in the future. A combination of instruments (property rights), institutions (formal acts) and organizations (formal spaces) are deemed necessary to address economic drivers. Economic and governance-related drivers can also conflict with cultural drivers such as the defence of sacred places or the conservation of certain species for spiritual and religious purposes. Participative freedom, information, and involvement of all interested parties in decisions over the environment would expand the ability of people to make choices over the ecosystem on which they depend for their well-being. Among social opportunities Duraiappah puts special

emphasis on the dependency of poor women and children on ecosystem services, for instance as they are dedicated to collecting firewood and subsistence farming. Informal institutions, but also social practices, can constrain their opportunities to access these services so that interventions in this area must take them into account. Potential corrections of these drivers might lie in promoting women's agency but also providing access to adequate services, such as clean water, decent shelter, and education on links between ecosystems and well-being. Transparency guarantees relate especially to openness and trust: corruption mines the social fabric creating perverse cycles of bribery and poverty in constraining access to resources, and inefficiency in bureaucracy and the private sector adversely impact ecosystem management. Inefficiency arises also when lack of knowledge impedes the development of environmental policies or conflicting rules are set by government agencies, for instance promoting agricultural intensification on one side and environmental protection on the other in the same context. Protective security lies in the existence of formal or informal safety nets to deal with times of stress. While formal safety nets are often absent in developing countries or inaccessible for the poor, informal ones have often collapsed with commercialization and migratory movements, reducing the ability to share common resources. Duraiappah suggests for instance restoration of ecosystems as a source of employment during times of extreme distress. One could also devise programmes linking remittances to sustainable agricultural practices or conservation programmes, access to credit or other facilities that link people staying behind with migrants[10]. Finally, ecological security as a freedom gives ecosystem services the status of human rights as they represent safety nets for people who depend on them for their well-being. However the process of self-determination of the critical mass level of an ecosystem that should be kept intact is strongly linked to participative freedom. Suggested actions include increasing participative freedom for sustainable management of ecosystems, establishment of formal institutions to protect ecological safety nets and for the fair distribution and use of these nets by local communities.

The Capability-Ecosystem approach can provide a comprehensive framework to analyse the relationship between ecosystem services and human well-being. The approach recognizes that different stakeholders use ecosystem services in different ways with diverse degrees of

[10] The 3x1 Program for Migrants in Mexico for instance, links remittances from Mexicans abroad to works of social impact in their home communities. For every dollar brought by migrants, the Federal, State and Municipal governments add 3 pesos.

dependency, therefore analysis at the local scale is best fitted to explore the links between ecosystem services and human well being. This is even more relevant in view of the fact that the relationship between human wellbeing and the environment can only be understood within particular sets of institutions (Duraiappah and Roy, 2007).

2.2.2. Limits of the CEA

Some limits of Duraiappah's framework should be highlighted. As abovementioned, the framework is quite open and general and leaves out some concepts that are building blocks of the Capability Approach. The generality is justified by the fact that it serves as a policy guide and that specific indicators are context specific, which helps flexible policy options but makes comparisons more difficult. This feature of the framework comes from its recognition that the poverty (or more generally well-being) environment nexus is context specific and should be studied within a set of specific institutions. Also, the framework was devised for a developing country context, which puts an emphasis on achieved well-being outcomes and opportunities but is limited in making explicit the choice of individuals and their agency in choosing alternative options. A justification of this generality over concepts is given in the use of the lexicon 'being able to' before each constituent and determinant of well-being that would automatically imply agency, value and choice. However, making these three characteristics explicit could improve the framework's ability to explain the benefits and constrains involved in the conversion of ecosystem goods and services into well-being.

On the other side, it also puts strong emphasis on the enabling conditions, the drivers, external opportunities and constraints that determine people's use of natural resources, but less relevance is given to an important part of the analysis of the CA, which is the concept of conversion factors. Individual, social and environmental conversion factors influence the way people convert resources into well-being but also the way people use resources, and is therefore a fundamental link in the human-environment relationship. Taking it further, regulatory, supporting ecosystem services and biodiversity could also be devised as environmental conversion factors that allow people to convert the resource available (a specific ecosystem per se for instance) into well-being achievements, whether by supporting quantity and quality of provisioning services, or by cultural, spiritual well-being or inspiration.

The CEA focuses largely on the benefit side of ecosystem services and looks at vulnerability more in the absence of alternative options and less as an outcome of ecosystem processes. Rainfall is fundamental for crop development in seasonal farming but at the same time excessive rainfall can destroy the harvest.

Also, the cultural aspect linked to ecosystem services is less investigated in Duraiappah's framework, partly because of its focus on a developing country context where the cultural aspect can be more limited compared to basic capabilities and more related to spiritual values and identity rather than other cultural-related values such as recreation or sport.

The main constraint in operationalizing such a framework is the lack of other applications related to agricultural biodiversity, but also the lack of empirical studies to use for comparison and guidance, which has proved a strong empirical effort. In our final conclusions we will comment on the difficulties encountered and possible limitations of the study.

2.3. Extended Capability-Ecosystem Approach for Agrobiodiversity

Capabilities and ecosystem services are multidimensional and dynamic concepts, but can be studied in a specific point in time to provide a picture of dependencies and vulnerabilities that can guide policy actions. The CEA was chosen because it allows to highlight inequalities between individuals, households or groups in their conversion factors, entitlements and resources that concur to determine the opportunities they can draw from ecosystems. Our framework tries to contribute to the operationalization of a complex model that includes capabilities in the analysis of agrobiodiversity and the goods it provides. The original contribution lies in the addition to the framework of agrobiodiversity as a specific domain that can be seen under different lights based on the point of view that is taken: as a resource when looking at its role in consumption or as an instrumental freedom in its role as a safety net. We name therefore our framework an Extended Capability-Ecosystem Approach.
While biodiversity and ecosystem services are the goods that people can use, their availability and quality represents a real freedom enjoyed by people, actual opportunities

available to them. Within this logic, the existence of agrobiodiversity and ecosystems services represents opportunities, therefore a form of freedom, but their conservation can impose constraints on their use. Therefore they have an important instrumental value in enlarging opportunities to achieve valued outcomes. Their conservation also provides a safety net: these values can be captured in the notion of ecological security. While this is the underlying theoretical construct of this thesis, our empirical focus is on the direct benefits provided by agroecosystems and how they are used for and affected by well-being outcomes, applying the theoretical categories of a Capability-Ecosystem Approach. Despite the need to narrow down the focus for empirical purposes, the framework can be applied to the analysis of other services and can be used in both a static and dynamic analysis. Through the integration of the Capability Approach within an Ecosystem Approach we take into account the fact that households differ in endowments, access and availability, and that conversion factors and capabilities influence the benefits they derive from ecosystems, but also their vulnerabilities.

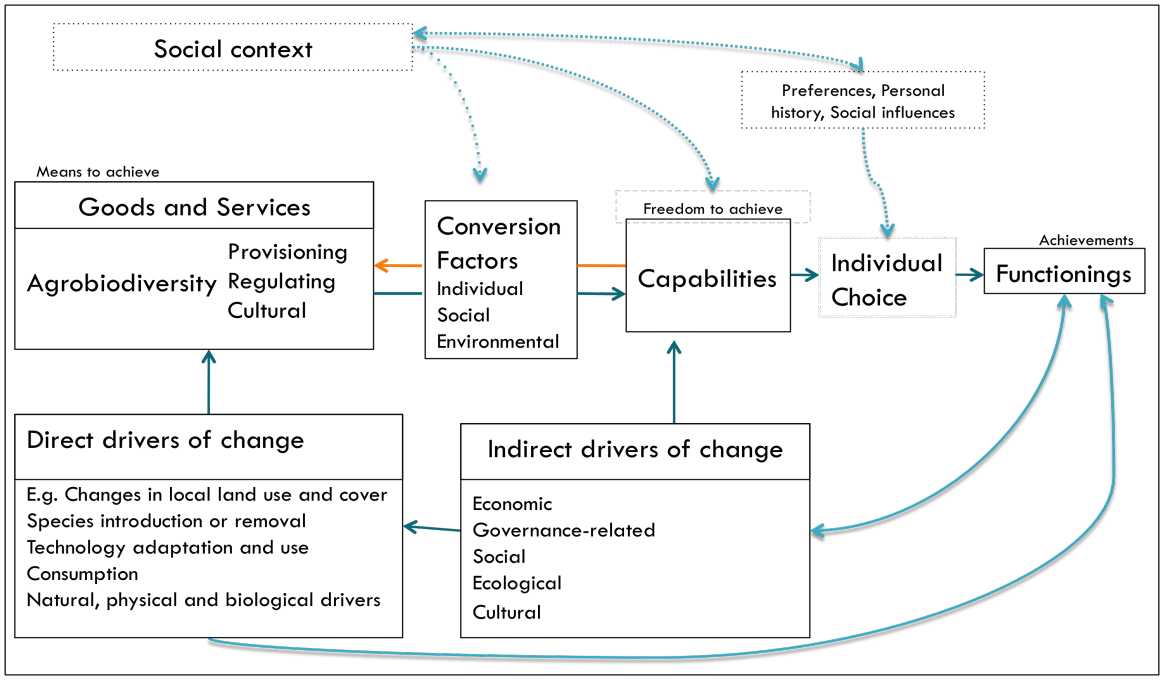
The theoretical framework is depicted in Figure 2.1: it shows the static and dynamic features of the relationship between goods and services provided by agrobiodiversity and human well-being. The lower part depicting drivers of change represents the dynamic part of the model as the impacts of indirect drivers are lagged in time, while the impacts of direct drivers can be both immediate (e.g. adoption of monoculture) or happen in a second moment (e.g. changes in consumption habits; also the adoption of monoculture can have lagged effects, for instance on soil erosion and fertility). The central part of the framework represents the static picture of the relationship linking agrobiodiversity and achieved well-being, but also the effects of the conversion factors, the capability set and chosen functionings on agrobiodiversity. Crop diversity for instance provides goods that can be converted through experience and skills into consumption, medicinal, marketing goods etc. They represent an opportunity to achieve a certain level of well-being in the dimension of adequate nourishment, health or income.

They contribute to the creation of the person's capability set, which may also include the ability to go to the market and buy those goods instead of producing them oneself, given income, transport to or availability of a close market. The choice of producing them oneself, given other opportunities and constraints and the social context that influences preferences and other mechanisms that affect choice, translate into a certain level of achieved

nourishment thanks to crop diversity. On the other side, the opportunity to buy substitutes in the market may have a direct influence on agrobiodiversity if linked with a reduction of crops cultivated or switching to monocrops for marketing and substitution through income.

Conversion factors of households such as age, education, or availability of different soils, can also directly influence the level of crop diversity managed or the use of associated off farm ecosystem goods. The model is therefore complex and involves feedback loops that reverberate through the system.

Figure 2.1: Theoretical Framework of the Extended Capability-Ecosystem Approach



Source: Author. Adapted from Duraiappah (2004), MEA (2005), Robeyns (2005), Pelenc (2010), Polishuck and Rauschmayer (2012)

Drivers

Several factors affect ecosystems directly through natural processes or human intervention: these can include changes in local land use and cover for agriculture, urbanization, infrastructure; introduction of species that affect other composition of other species; adoption of technologies and innovations that influence species diversity or ecosystem functioning; changes in consumption habits that favour area increases for specific crops or conversion of land to pasture, etc. Economic, demographic, social, institutional, cultural or ecological

drivers determine these factors. For instance, population growth demanding increases in agricultural land or staple crops; lack of property rights that limit overharvesting of resources; corruption of government agencies that allow illegal logging activities and so on. There are also feedback loops in the system: for instance increased deforestation due to conversion to pasturelands can increase well-being of livestock owners, but reduces well-being of people dependent on the forest for food, tools, construction resources, medicinal plants etc, directly affecting their functionings. They also affect their functionings indirectly by reducing the capability set through a reduction of provisioning, cultural and regulating services offered by the forest or by the use of land for traditional agriculture rather than cash crop plantations or pasture. As we have argued in the previous paragraphs instrumental freedoms can be used to overcome these drivers and canalize them to more equitable outcomes.

Endowments

Small-scale farmers are usually considered the keepers of crop diversity, not only in marginal areas, but even when they produce for the market and have access to different inputs, as we have seen in Chapter 1 (Bellon and Taylor 1993; Brush 1995). Their resource endowments concur with conversion and other factors to determine the level of crop diversity managed. We look in particular at two assets relevant for the empirical context, irrigation and land area, which might contribute to determine the level of agrobiodiversity managed. As mentioned in Chapter 1, the comparison between farmers producing at different scales is interesting when assessing the different dimensions of human well-being linked to agrobiodiversity. Peasant farmers in Mexico seemingly conserve and use a high level of biodiversity based on integration with the surrounding environment, while commercial farmers have low levels of agrobiodiversity due to monoculture, more intensive application of chemicals, and partly dependency on subsidies. Moreover, small peasant farmers depend directly on agrobiodiversity for both consumption and production.

Conversion factors

In Chapter 1 we defined conversion factors as the individual, environmental and social conditions that influence the conversion of a good or a resource into achieved states of being and doing (Sen, 1993; Robeyns, 2005). A typical example is the bike metaphor: the bike is useful to achieve beings and doings only if the person is able to use it because she is not

impaired by body constraints, or lack of infrastructure or cultural norms. The degree of usefulness of a good therefore depends on if and how it can be used to achieve a well-being outcome. Factors that are specific of a person, or in our analysis a household, are termed individual conversion factors: they attain to age, health, gender, intellectual ability and so on. In farming households age can be an advantage because linked to a higher level of experience, associated knowledge and ability to react to problems linked to agriculture, but can also be a constraint in terms of health and withstanding fatigue. Social conversion factors are the public policies, social norms, discriminating practises, gender roles, societal hierarchies, power relations that influence what well-being outcomes a person or household in the community is able to achieve. Policies that exclude access to certain resources reduce the ability of a person to convert those resources into well-being outcomes, despite their availability. Environmental conversion factors attain to the built and natural environment. Conversion factors from the built environment are roads, transport, infrastructure, access to services, while geographical location, climate, and type of lands available represent factors from the natural environment. For instance, the availability of different types of soils or altitudes can be a determinant of different levels of crop diversity and production systems. On the other side, the availability of roads and market infrastructure can influence farmer's choices in production but also collection of off farm ecosystem goods. Another example is that the benefit derived from a plant or animal species can only contribute to well-being to the extent that people have access to that resource and have knowledge and skills to be able use it. A medicinal plant gathered from the wild can be meaningful to the person only to the extent that she knows how and for what purpose to use it (or because she takes pleasure by knowing that the plant exists, which is a different level of value). The process of conversion of available resources into well-being is therefore mediated by these individual, social and environmental characteristics. Chiappero-Martinetti (2000) for instance compares the conversion process to a production function that transforms inputs into outputs, where the level of output depends on the amount of inputs but also on other factors, such as technology, that determine the conversion rate.

Capabilities

We have largely talked about capabilities and their role as substantial freedoms for people to choose a life they value. They represent real opportunities of choice given the social,

political, economic, institutional, and cultural context in which people operate. For instance, the availability of off farm employment opportunities potentially increases a household's capability set for instance allowing children to go to school. On the other side, it can have direct consequences on the level of crop diversity managed through reduced time for agriculture. This has consequences for conservation of valuable crop genetic resources, but it can also affect the household's well-being if the choice of off farm employment is driven by vulnerability to harvest fail and food insecurity.

Instrumental freedoms have therefore a crucial role in shaping the capability set. Indirect drivers of change, which can be corrected or reinforced by changes in instrumental freedoms also affect the capability set of individuals through the same mechanisms that we have already detailed. For instance, women are fundamental in ensuring diet quality and appropriate quantity for the family and often play an active role in the management of agricultural biodiversity, which can become a mean of empowerment and at the same time increase ecosystem resilience. However, social drivers in the form of social pressure excluding women who work the land from land use decisions or possession determine a reduction of the opportunities open to them and at the same time affect agrobiodiversity if land is converted into other uses without taking into account women's view and dependence on it. Moreover, this would reinforce the process by reducing for instance crop diversity on which the ability to be adequately nourished depended, further reducing the capability set.

Therefore, different stakeholders use ecosystem services in different ways and have different degrees of dependency on these services. Some can have clear substitutes while others have more limited options. We need to adopt strategies that respect these differences and make sure that no stakeholder group is marginalized in the process. The heterogeneity and diversity of people is taken into account in the capability approach through the focus on opportunities, conversion factors and how direct and indirect drivers of change affect this process (Robeyns, 2005).

Availability and access

Agrobiodiversity and ecosystem services can be instrumental for people to achieve valued outcomes and can be devised instrumental freedoms in their role of ecological safety nets. They are also part of the environmental context, and affected by the level of realized well-

being achievements or functionings. Adjusting the CEA to the analysis of agricultural biodiversity we hypothesize that opportunities and conversion factors not only affect how these resources are converted into well-being outcomes, but also that the level of utilization of these resources depends on the opportunities available to people, their conversion factors, and their choices. Different agroecosystems determine different ability of households to derive ecosystem goods and services. On the other side, it also represents the level and quality of opportunities open to people in their use of the environment, contributing to their capability set from which they can choose the states they want to activate.

Availability depends on indirect and direct drivers, which can be social, political, environmental etc. For instance availability of different types of soils enables farmers to cultivate certain crops rather than others, influencing their decision to adopt different technologies, convert land into pasture or other uses. On the other side, availability of mature forests in the surrounding area provides an opportunity for people to hunt, collect medicinal plants, fruits, gather wood or place their beehives to obtain a specific honey taste. This availability is an opportunity only for those people who have the resources (transport, tools), the entitlement (access to the forest and permission to do these activities), and the conversion factors (the knowledge and skills necessary to carry out these actions, but also health). The analysis of availability of agrobiodiversity and ecosystem goods is the basis for the anaysis in Chapter 4, which details the socio-economic and environmental context and the ecosystem goods upon which rural Mayan farmers depend.

Given availability, access to crop diversification can depend on resources (input availability, land etc.), characteristics inherent to households (age, education, health etc.) and opportunities or constraints they face in using diverse resources. Some conversion factors and other exogenous variables influence the access through knowledge and agricultural expertise, availability of household labour, access to land, restriction on the use of certain resources, public policies, and other factors that influence the diversity of resources managed by households. The analysis of what influences crop diversity managed on farmer's plots, carried out in Chapter 5, falls in part into the notion of availability and mostly in that of access. We specifically look at two aspects of crop diversity relevant from the point of view of ecosystem services and that of the conservation of crop genetic resources. We analyze the

determinants of crop diversification for consumption and for marketing, which can be generalized as two types of provisioning services directly (food) and indirectly (income) provided by crop diversity. Because this study is based on a centre of origin and domestication of maize, bean and squash, we also look at the determinants of their *de facto* conservation on farmers' fields, as they entail nutritional, ecological and cultural values. The choice of focussing on farmer's choices to diversify for consumption and for marketing follows Brown et al. (2008) who consider income and employment benefits as part of provisioning services, beyond food. These types of services are not explicitly considered in other frameworks such as the Millennium Ecosystem Assessment because they gain higher relevance at a disaggregated micro level, for instance when analyzing the benefits derived from ecosystems by poor people in a specific context.

2.4. Conclusion

The underlying assumption of this research is that an integrated approach is needed to understand biodiversity and ecosystem services in terms that are meaningful to the people that depend on them. This study aims to contribute to the development of an integrated approach and to bring new understanding on how human dynamics intersect with nature in a multifaceted and complex way. It follows the path stressed by the Convention on Biological Diversity of stopping to separate environmental sustainability from development, and does so by understanding the links that make the conservation of agrobiodiversity and of ecosystem services potential instruments of development. In this view both human well-being and sustainable resource use can be promoted by highlighting the synergies between them. From a theoretical point of view it contributes to integrate the literature on ecosystem services and biodiversity with the capability approach. This research also contributes to understand what influences agrobiodiversity use and conservation in an area that has been defined a promising candidate for on farm conservation, taking into account the embeddedness of people in diverse socio-environmental contexts along with their resource endowment. By exploring and assessing the socio-economic implications of agrobiodiversity use and conservation we also aim at informing concrete policies and public management decisions relevant to the Mayan communities that depend on local agrobiodiversity and ecosystem services it provide in the Yucatán rural areas. Our focus is therefore in line with the growing agreement that there is a

strong need for more research on the local scale on the way ecosystem services influence human well-being, especially in terms of regulating and cultural services (Duraiappah 2011; Raudsepp-Hearne, 2010, 2011; Nelson 2011). By applying a level of analysis focused on the local scale this research gives insights on the form and relevance of the relationship between agrobiodiversity and human well-being in the study area. This deepens our knowledge of the direct and indirect drivers of change at the local level and to derive relevant policy implications. Moreover, by understanding what ecosystem services are relevant to human well-being important lessons can be derived to improve policy sustainability and its ability to address local problems in a way significant to the people affected, considering their culture and traditional knowledge. Finally, understanding the use and relative value of ecosystem services and biodiversity to different groups in society can help improve the design of incentive mechanisms for the efficient provision and use of these ecosystem services, instead of ignoring the reason why a resource is being harvested unsustainably and by whom.

CHAPTER 3. Agrobiodiversity, agriculture and drivers of change in the Yucatán

Introduction

Mexico is an important centre of crop domestication and diversity, due to biological events and the interaction between human populations and the natural environment for hundreds of generations (Bellon, 2009). The needs, interests, practices and knowledge of these human populations have been forming and maintaining this diversity, and they continue to maintain and develop it even under increasingly difficult conditions. The geography of Mexico, its variety of climates, topography and geological history concurred to the creation of one of the richest countries in the world, biologically and culturally, making it a megadiverse country[11]. Estimates indicate that Mexico maintains about 10% of all living organisms on earth (Toledo, 1988; Ramamoorthy et al., 1993). The total number of *described* species in the country is about 65 million, very well below the *estimated* 200 million (Groombridge and Jenkins, 2002). Fauna is about 171 million invertebrates and 5 million vertebrates, mainly fish and birds. Mexican flora has about 23 million species, with an endemism level above 40%. In terms of habitats or eco-regions, Mexico is the most diverse country of Latin America (Dinerstein et al., 1995). Biodiversity is also closely linked to cultural diversity, as indigenous communities have collectively tried, selected, exchanged seed, and used plants, insects and animals for food, medicine, shelter, clothing and spiritual practices for generations (Brush, 2007). Biodiversity is therefore also the result of a large and continuous process of selection and crossing, spontaneous or provoked by people.

About two thirds of current inhabitant in the Yucatán Peninsula are Maya descendants and this heritage is reflected in the multiple use of natural resources practiced by many rural households. This is partly a heritage of the Maya civilization, whose greatness lied in technological advancement, close relationship with nature, scientific knowledge and ability to create majestic architecture in unwelcoming environments, but also and most strikingly in their ability to feed a population probably larger than today in those areas, despite challenging tropical soils and climatic conditions (Gomez Pompa, 2003). This advanced civilization however collapsed under the weight of concurrent causes and consequences: reduction of ecosystem services due to overexploitation of natural resources for agriculture,

[11] Conservation International forged this concept in order to give priority to conservation goals in 17 countries, which possess as much as 70% of the biological diversity of the planet.

wood extraction, game hunting, water pollution and soil erosion; climate change that brought droughts and unpredictable rainfall; social conflict over resources for a growing population; and political unrest among kings and nobles that unset food shortages, famine and more rebellions (Faust, 2001; Diamond, 2003). On the other side, the heritage of the ancient Maya has endured and is today still tangible in the worldview of Maya descendants and in their multiple-use strategy, associated with spiritual practices, beliefs and sense of community.

Despite the large interest and availability of research over the Yucatec Maya, only few studies try to understand and explain how contemporary Maya farmers perceive, know, use and manage their landscapes as a whole, often focusing on specific communities, farming systems, or on the southern Yucatán peninsula (Toledo et al., 2003; Arias et al., 2004; Barrera-Bassols and Toledo, 2005; Roy Chowdury and Turner, 2006; García-Frapolli et al., 2008; Schmook and Radel, 2008; Schmook, 2009; Wyman et al., 2008; Radel et al., 2010; Busch and Vance, 2011). This dissertation provides further evidence on how modern Mayas manage their landscape in the Yucatán state, studying this complex strategy through the lens of a Capability-Ecosystem Approach. Recognizing that indigenous practices related to biodiversity and resource management can only be understood within their environmental and cultural context (Faust, 2001), this chapter describes the importance of agroecosystems and the multiple-use strategy in the well-being of Mayan households, followed by a review of the historical and political evolution of the agricultural sector.

3.1 Contextualization of the study area

Mexico is a constitutional federal republic comprising thirty-one sovereign states and a federal district, the capital. Mexican population amounted to about 120 million people in 2012, and according to the latest census (2010) about 26 million live in rural areas, defined as localities with less than 2500 inhabitants (INEGI, 2011). GDP per capita was 15,600 PPP dollars in 2012 and income inequality high with a Gini index of 47,16 in 2010. Mexico is also one of the first countries to have officially adopted a multidimensional measure of poverty, referring to Alkire and Foster's measures (Alkire and Foster, 2009)[12], which is applied by the

[12] An interesting debate about the appropriateness of Alkire and Foster's measure has stemmed in Mexico, based on Boltvinik's critique of the identification and intersection issue. Alkire and Foster sent a Memo to CONEVAL in 2009, which was used for the official measure of poverty, criticized by Boltvinik as strongly underestimating poverty. Some of the documents in this debate can be found at:

National Council of Evaluation of Social Development Policy, the CONEVAL (Corona, 2007). According to this measure, 45.5% of Mexican population was multidimensionally poor in 2012, with 9.8% extremely poor (CONEVAL, Website). The values are very similar for the Yucatán state (48.9% poor and 9.8% extremely poor), while other states such as Chiapas and Guerrero have as much as one third of the population in extreme poverty. Scott (2010) argues that between 2006 and 2008 rural poverty in Mexico has augmented due to the global increase in food prices and the onset of the financial crisis, bringing extreme poverty to 31%, just a little above 1992 levels. Inequalities between the rural and urban sector persist especially in education and health, which are the main objectives of social development programmes. Compared to urban households, rural households obtain a smaller share of their income from the labor market (41%), and are more dependent on transfers (18%) and self-employment (18%). Scott calculates that among households that do not own land, non-agricultural workers are better off than agricultural workers, who also report lower social security coverage levels. However, poorest households are not those without land in rural areas but smallholders, especially households with less than 2 hectares. These households are more frequently of indigenous descent and over 70% of them reports farm labor as their main occupation.

The Yucatán state mirrors several national trends but has local peculiarities that differentiate it from the federation panorama. The state is located in the south east of Mexico, in the northern part of the Yucatán Peninsula. It has a population of 2 million in 106 municipalities, 16% in rural areas. Life expectancy is 75 years and the state Human Development Index is 0.72, moderately high, but both indices are lower than national average (UNDP, 2010). The state has among the highest levels of educational backwardness and marginalization in the federation. About 9.2% of the population is illiterate, with illiteracy higher among women than men (10.6% against 7.8%), according to the latest Census (INEGI, 2010). The state index of marginalization is high, except in the capital where 40% of the state's population is concentrated. The marginalization index is calculated on four socioeconomic dimensions: education, household assets, population distribution, and income (CONAPO, 2010). Based on these data, the index is ordered from very low to very high and an ancillary index is drawn to define priority areas for development. Highest levels of marginalization are found in the

http://www.jornada.unam.mx/2011/03/11/opinion/031o1eco;
http://www.ophi.org.uk/wp-content/uploads/OPHI-RP-21a.pdf;
http://www.ophi.org.uk/wp-content/uploads/Respuesta-a-Julio-Boltvinik.pdf?79d835

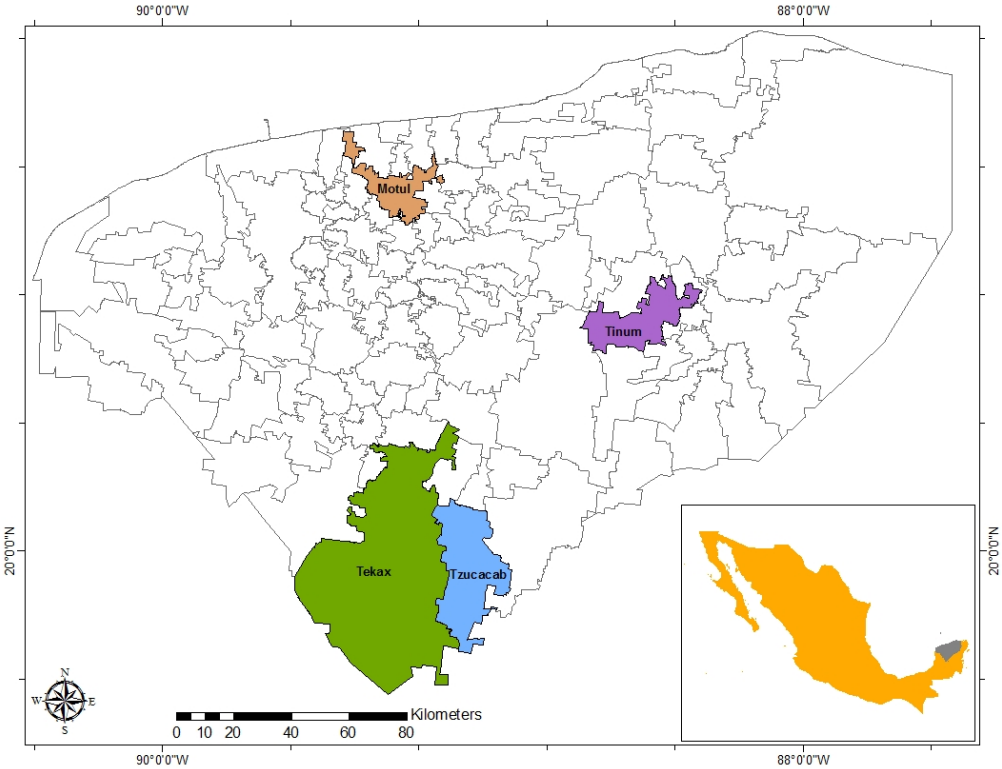
southeastern and central eastern part of the Yucatán, but pockets of population high marginalization are also common within municipalities. This index is further discussed in Chapter 4. Yucatán is the second Mexican state with the largest proportion of the population speaking an indigenous language (one third of the population speaks Maya). Only the metropolitan region of the capital, Merida, and the coastline are not considered indigenous, as less than 40% of the population is Maya. The agave (*henequen*) and fruit producing regions, where the communities of Motul, Tekax and Tzucacab analyzed in this study are located have average indigenous incidence (40% to 60%), while the *milpera* (maiz producing) region, where Tinum community is located, has high incidence (more than 70%). Following national trends, communities with higher indigenous presence face higher marginalization in terms of basic services, infrastructure and housing conditions. This mirrors the type of health problems faced in areas with different indigenous presence: malnutrition and infectious diseases affect more areas where a higher percentage of the population is indigenous, while chronic and degenerative diseases are principal health problems in areas with fewer indigenous population (Durán, 2010). According to researchers of the Yucatán public research centre (CICY), these differences are one of the effects of the development model adopted, which deteriorates the environment and reduces biodiversity whilst increasing social inequality[13]. Also, low population density characterizes rural areas, with many communities lacking basic services and facing high transport costs and marginalization. Serious lack of formal employment, access to health services, water treatment, provision of sewage and waste collection, often due to the high dispersion and remoteness of communities, are among the most serious challenges facing the state (OECD, 2007).

The Yucatán can be virtually divided in two parts: the west-northeast region centered by the capital, Merida, historically more open to external influence; and the southeast region, more isolated and with a higher concentration of indigenous communities (Durán et al., 2010). The agricultural production system in the Yucatán peninsula is characterized by a predominant crop, maize, complemented by a set of secondary but nonetheless important crops such as beans, tomatoes, chili peppers and so on, and also by the use of wild biodiversity, especially

[13] Loss of biodiversity is linked especially with infectious diseases as it increases the level of exposure to pathogenous and infectious agents and reduced regulation of their population levels. The researchers also point out to changing dietary habits of the population linked to commercialization and specialization of agriculture: a study by Murguia in the 90s showed for instance higher denutrition in cattle breeding and costal areas with high biodiversity loss.

forest resources. The Yucatán can be classified into seven productive regions that differ in vegetation and agricultural development levels: the metropolitan, coastal, livestock, agave (henequenera), south, maize (milpera), and western region (Durán et al., 2010). In this study we focused on three areas of particular interest for agrobiodiversity and ecosystem services, which are the henequenera, milpera and southern regions (Figure 3.1). We briefly outline their characteristics here, but will go in more depth in Chapter 4.

Figure 3.1: Map of the study area



Source: Own elaboration on data from CONABIO (2014)

The centre-north henequenera region surrounding Motul municipality experienced strong economic growth during the nineteenth century, thanks to the cultivation of a native fiber, the sisal or henequen (*Agave sisalana*), which dramatically declined with the development of synthetic fibers in the 1960s, and has partially regained growth with *maquiladora* industries. The metropolitan henequera subregion around Motul concentrates 36% of the area planted with henequen in the state, pasturelands have been increasing to an area equivalent to 60% of that occupied by henequen, while maize only occupies a fourth of the area. Other activities include poultry and pig-farming (10% and 12% of units in the state) (Durán et al., 2010).

The central maize-producing region, so called milpera as the *milpa* is the traditional slash and burn maize cultivation, is characterized by traditional farming communities such as the municipality of Tinum, which is also interesting as it includes the state's main tourism site, Chichén Itzá. Tourism-induced benefits in the area are mainly concentrated in the urban area surrounding it (Pisté), while other municipalities are characterized by demographic stagnation, with 7% of land dedicated to agriculture. About 15% of the area cultivated with maize in the Yucatán is concentrated in this area, along with 15% of the states' apiaries and growing horticulture.

The southern agricultural region is characterized by agricultural mechanization and citrus cultivation, introduced as a commercial crop in the 1970s. The municipalities of Tekax and Tzucacab, analyzed in this study, are located in the so called Cono Sur (Southern Cone) which occupies 13.7% of the state area but concentrates only 4.9% of the population, with two main urban areas and other sparse, isolated villages. About 10% of the area is cultivated with mechanized maize and pastures, followed by vegetables, citrus and traditional *milpa*s. About 16% of apiaries in the state can be found in this area (Durán et al., 2010). A large textile *maquiladora*[14] is present in the municipality of Tekax, employing more than 1000 people, and a large US agro-industry dedicated to vegetables export employs about 500 workers based on seasonal need. According to the 2007 OECD outlook FDI and *maquiladora* activities made the Yucatán one of the fastest regional economies per economic growth within OECD countries. *Maquiladoras*' export activities were implemented in two stages: between 1984 and 1994 industrial hubs in the capital were created through foreign investment; then the Henequenera Regional Development Program established *maquiladoras* in rural areas, while trade liberalization was also implemented through the North America Free Trade Agreement (Becerril et al., 2012). At the peak of their activities, in 2000-2001, *maquiladoras* accounted for one third of total manufacturing employment and more than two thirds of total exports in the state (OECD, 2007). While production, urban and rural income distribution have improved, as *maquiladoras* are located both near the capital and in rural areas, the export-oriented industrialization strategy failed to promote significant structural change in the state to foster growth in different economic sectors (Biles, 2004). One of the

[14] Maquiladoras are foreign owned labour-intensive assembly plants manufacturing duty free imported components for export, under a special treatment for tariff and fiscal exemption.

main limits for the *maquiladora* industry to act as a motor or catalyst for local economic development would therefore be the low level of connection with the local productive structure, as it employes mainly imported goods (Becerril et al., 2012). Between 2004 and 2009 more than 40% of *maquiladoras* have either closed or left the state, conciding with economic downturn in the US and Asiatic competition, desplacing more than a quarter of *maquiladora* employees (OECD, 2007; Castilla-Ramos and Torres, 2010). Biles (2004) already argued that regional policy makers have foregone a chance to foster sustainable regional development by focusing on a single market based on foreign capital, risking a similar fate to that of the henequen industry.

3.2 A complex multiple-use of agroecosystems

Tropical small-scale agroecosystems are made up of agricultural fields, fallow lands, homegardens and agroforestry plots that usually contain more than 100 plant species, which provide a variety of different uses from food and fodder to contsruction materials, wood, tools, and medicines (Altieri, 1999). The Yucatec Maya make no exception to this strategy. Over 3000 years, they have developed a complex cosmovision around the natural environment on which their sustainance depended, involving management strategies, perceptions and cognitive systems over the landscape and ecosystem goods and services it provides (Terán and Rasmussen, 1994; Terán et al., 1998; Dunning and Beach 2004; Barrera-Bassols and Toledo, 2005; Toledo et al., 2008). Mayan farmers have developed a management system that integrates different landscapes through home-gardens, slash and burn systems, agroforestry, commercial activities, and successional vegetation (Hernández-Xolocotzi, 1959; Ewell 1984; Terán and Rasmussen, 1995; Berkes et al., 2000; Gómez-Pompa et al., 2003; Toledo and Barrera-Bassols, 2008). They depend on a multiple-use strategy of species conservation, resource rotation, landscape-patch management, and succession management characterized by high adaptability to socioeconomic and ecological conditions as local ecological knowledge is constantly adjusted and adapted to environmental, demographic, cultural, technological, informational, and economic changes (Hostettler 1996; Berkes et al., 2000; Jimenez Osornio et al., 2003; Toledo et al., 2003). Knowledge, cosmology and social institutions are therefore closely linked to the management of natural resources and determine the perception and level of exploitation of the natural environment by rural households. Pool Novelo (1980) describes the relationship with soils:

'*As a sacred domain, Lu'um symbolizes the following principles: (1) a life supporter (nature); (2) a home (sense of place); (3) an agricultural parcel or milpa (sense of abundance), (4) a territory (a primordial identity value); (5) a womb (sense of fertility), and (5) a graveyard (sense of destiny)*'. Contemporary Maya households still maintain some traditional practices in a fragile environment, which poses important issues on pathways to conserve biodiversity in tropical areas, systems of communal management of resources in a fragile environment, and the associated indigenous knowledge (Faust, 2001).

The Yucatán Peninsula is charaterized by shallow soils with poor dranage, savannas affected by periodic flooding, limestone with vertical cracks, and lack of surface groundwater (Faust, 2001). Seasonal farming follows the cycle of the 6-month dry and wet seasons, with seasonal droughts and hurricane periods that can affect plant growth. Climate in the Yucatán is in fact tropical, characterized by distinct wet (May-October) and dry season (November-April) with high annual mean temperature (26 C°). Rainfall irregularity and increasing unpredictability, combined with shallow soils and scarcity of water resources, are the main constraints for agriculture in the region (Ewell, 1984; Hernández-Xolocotzi et al. 1990; Barrera-Bassols, 2005). The dry north and North-East areas of the region are characterized by a prevalence of secondary vegetation (lower woody vegetation growing on land which was previously cleared), while tall mature forests can be found in the humid South-East. The distribution is patch-like as a result of shifting cultivation and maize plots along with with cash crop plantations and pastures. Strong seasonality often leads rural families to look for off-farm employment opportunities or temporal waged agricultural labour. In other cases, it can also determine temporal waves of migration after the end of the productive season. In discussion with key informants it was mentioned that this kind of migration is often domestic as individuals move to turistic or urban areas after the harvest, however there is no source of substantial data on this phenomenon.

Agrobiodiversity is a fundamental element of the agricultural strategy of Mayan farmers and therefore strongly linked to their culture. Following the traditional knowledge and beliefs of Mayan farmers, the natural environment and its components have a high value due to their perception of plants, animals, and rocks as 'beings' with something similar to a soul (Durán et al., 2010). Traditional practices such as the *milpa* system of slash and burn agriculture (roza-

tumba-quema) have also a moral meaning as they affect and deeply change the natural environment. As a productive system, the *milpa* involves different activities from husbandry, beekeeping, home gardens, hunting, wood collection from the forest and small commerce (Durán et al., 2010). It is a polyculture system that can involve the use of various fields (1st, 2nd, or 3rd year, after which they are normally abandoned to fallow) with as much as 32 different species over a production cycle, with annual legumes like beans, squashes and pumkpins, and other crops. Mayan farmers value biodiversity for its pest control strategy, consumption diversification, risk mitigation, and cultural significance, so that its depletion is a loss both in material and cultural terms.

Mayan households utilize their environment through different combinations of landscapes and land uses, providing a variety of goods and services during the year. These resources are used with varying intensity in space and time, mainly for subsistence purposes, and often complemented by commercial activities. Historically, the *milpa*, the traditional maize-bean-squash plot, not only provides different benefits, including nutrional quality, food security, cultural and spiritual values, but also defines issues of land ownership, reciprocity and participation to life in the community (Garcia-Frapolli et al., 2008). It is therefore the pivotal element of the farmer production strategy, but it represents only the centre of a compex strategy involving beekeeping, hunting, extractive activities, and gardening in homegardens (Terán and Rasmussen 1994; Barrera-Bassols and Toledo, 2005). This multidimensional strategy minimizes the risks associated with external socioeconomic or ecological events guaranteeing food security and subsistence during the year (Faust, 1998; Barrera-Bassols and Toledo, 2005; Garcia-Frapolli et al., 2008). It can be therefore seen as a resilience strategy where all available landscape units are managed with different intensity (Barrera-Bassols and Toledo, 2005). Following Berkes et al. (2000), the authors point out that this multiple use of species, resource rotation, landscape-patch management, and succession management is an adaptive strategy to face changes in demographic, cultural, technological, informational, and economic conditions. Moreover, they often manage several land units in the same year, usually with different crops according to the type of soil, and allocate labour with varying intensity depending on the plots' characteristics. Land heterogeneity seems to favour diversity, but determines more intensive labour input and larger land areas, and reciprocal community organization and effort are in place in order to distribute labour efficiently (Terán

and Rasmussen 1994; Faust 1998; Barrera-Bassols, 2005).

Crop diversity

As we have seen in Chapter 1, given biophysical conditions, farmers pay attention to a large range of characteristics when deciding what to cultivate: market and own consumption preferences, nutritional attributes and productivity, but also ancestral and cultural value, and sense of belonging (Bellon and Brush, 1994; Bellon, 1996; Brush and Meng, 1998; Pascual and Barbier, 2005; Perales et al., 2005; Bellon et al., 2006; Smale, 2006; Brush and Perales, 2007). The *milpa* system in the Yucatán has received wide attention since the early 80s when a 10 years research on dynamics of production to understand lower *milpa* productivity was started by Hernández-Xolocotzi. Researchers have studied the ecological, technological, historical and socio-economic features of the *milpa* system (Hernández-Xolocotzi, 1959; Terán and Rasmussen, 1994, Arias et al. 1994; Arias et al., 2000; Tuxill et al., 2010). Traditional *milpas* are polyagricultural fields where maize (*Zea mays L.*), squash (*Cucurbita spp.*) and beans (*Phaseolus spp.*) are intercalated in shifting cultivation in order to benefit from their interaction and growth and to guarantee risk management and diversity of diet for the family (Terán and Rasmussen, 1995). They can include annual and perennial crops: as much as 87 different crops and trees can be found within one village, including native and introduced domesticated plants (Terán and Rasmussen, 1994).

In pre-Colombian Mesoamerica, the *milpa* was the predominant farming system and sustained a large population even in times of distress and during half a century of colonization (Terán and Rasmussen, 1995; Hernández-Xolocotzi, 1959). The farmer clears an area of forest usually between 1 and 3 ha through the slash-and-burn method as burning the vegetation releases nutrients held in the organic matter. The plot is cultivated for no more than 2 or 3 consecutive years due to rapid growth of weeds and drop in soil fertility, followed by a fallow period for soil recovery (Terán & Rassmusen 1994). Soil fertility management constitutes the key factor for the Yucatec Maya *milpa* production (Sanabria 1986; Zizumbo and Sima 1988; Terán and Rasmussen 1994). In the last three decades, due to a mixture of drivers including population growth, urbanization, reduction of land for agriculture, cheap maize imports from the US, the henequen crisis, the emphasis on cattle production, and other land-use intensification projects, the traditional fifteen year fallow cycle needed for adequate

soil nutrient recovery has been reduced to an average five year fallow cycle (Brannon and Baklanoff, 1987; Turner et al., 2003; Wyman et al., 2008).

There is no doubt that maize is the single most important crop in Mayan farming, entailing a range of values so wide that according to the Maya sacred book, the *Popol Vuh*, humans were created by gods from maize. As Stephen Brush writes, maize 'is one of the few crops that is so dominant in the regional culture and society of its origin that it might be perceived as having domesticated humans as much as humans domesticated it' (Brush 2004, p.82). Mexico is one of the centres of origin and domestication of maize, which provides the main component of the Mayan family diet. It is usually the largest plantation, and traditional farmers tend to plant a large area with one or two varieties of different color, size, taste, and growth, and sometimes plant smaller areas to other maize varieties, not only limited to landraces, but also 'creolized' modern varieties crossed and selected by the farmers, or modern varieties, usually in mechanized fields (de Janvry et al., 1995; Barkin, 2002; Bellon and Berthaud, 2004; Bellon and Hellin, 2011). Maize has evolved through domestication to a form so different from its wild relative, teocintle, that it would have been difficult to imagine the potential enclosed in its wild form: its adaptability to a wide range of environemtns and its incredible variety of uses almost know no rival (Perales, 2009). The importance of cultivation spans over a wide range of values and especially non-market values are often cited to explain why subsistence farming in Mexico still exists despite monetary losses. Arslan for instance shows that indigenous identity is significant in determining high shadow prices for subsistence farmers and that production decisions are not separable from farmer's preferences and endowments (Arslan, 2007). Social identity and participation to community life as good farmers is another important non-market value (Perales et al., 2005). Research on maize has been extensive and maize was the first commercial hybrid seed, but as Brush points out its economical value is only a small part of what it represents. However, the focus on its economic value has resulted in strong subsisdizing of commercial hybrid varieties producers and impossible landrace competition against imports of cheap maize from the US, especially for small producers who are the keepers of the largest diversity of maize and are slowly but inhesorably leaving their plots in search of employment opportunities in the urban areas or abroad.

Apart from maize, three native *Fabaceae* are common and often planted by the same farmer: *frijol* (*Phaseolus vulgaris* L.), *ibes* (*Phaseolus lunatus* L.), and *xpelon* (*Vigna unguiculata* (L.) Walp.). Two native *Cucurbitaceae* accompany almost every maize field in the area: the Calabaza de pepita gruesa "xtop" wich is characterized by large seeds (*Cucurbita mixta* Pang. o *Cucurbita argyrosperma* Huber 'Xtop'), and the calabaza de pepita menuda (*Cucurbita moschata)* of smaller seed. In order to maximize their outcomes given the seasonality of production, some farmers cultivate watermelon before sowing maize, or they dedicate smaller patches to native cucumber or *pepino* (*Cucumis sativus* L.) and more seldom to introduced tubers such as manioc or yuca (*Manihot esculenta* Crantz.) and sweet potato or camote (*Ipomoea batatas* (L.) Poir.). Some farmers, especially those with an irrigation system, also grow smaller patches of horticultural species such as tomatoes (*Solanum lycopersicum* L.), and chili peppers (*Capsicum chinense* Jacq., *Capsicum frutescens* L., *Capsicum annuum* var aviculare (Dierb.) D'Arcy & Eshbaugh). Such diversity of crops is due to the fact that most native genotypes are well adapted to local soil and climate (Arias, 1994). Land fragmentation is also common and thought to promote crop and agricultural diversity as farmers match varieties to different agroecological conditions (Bellon and Taylor, 1993; Di Falco et al., 2010).

Stoniness is a main feature of calcareous Yucatec soils, and limestone (chaltun) is easily cracked and penetrated by plant roots. Mayan farmers classify soils based on their color, stoniness, permeability, depth, and vegetation (León-Arteta, 1991). Mostly, the soils are shallow and stony, with good drainage, such as the *K'an-k'ab*, *Chaclu'um*, and *Tsek'el*, which allow traditional shifting cultivations. Soils are usually too shallow and stony to allow agricultural mechanization, form which derives the choice of *milpa* shifting cultivation by Mayan farmers (Pool-Novelo, 1980)[15]. However, there are areas in the South of the region where deep red or black soils developed through erosion, allowing mechanization: there, the *K'an-k'ab* (red), a red permeable soil, deep and without stones, is combined with *Ya ax hom*, dark to yellowy soils with good drainage, and sometimes *Ak'alché*, deep greyish soils of bad

[15] Pool Novelo describes the adaptation of crops to sites like this: 'Sites with evergreen tropical forest (Ya'axk'aax) are considered most fertile for agriculture. Vegetables, fruit trees and short-cycle maize varieties are grown after clearing, cutting and burning the vegetation on the new agricultural plot. Forest sites on stony and hilly terrain (Tzekel k'aax) are suitable for long-cycle maize varieties, while stony and flat forest remains (Tzekel kancab k'aax) are considered as the low fertility sites for agricultural purposes. Soil fertility replenishment is assessed according to soil type and the speed of recovery of herbs, shrubs and trees, which may take up to 40 years. Thus the Yucatec Maya producer not only distinguishes and uses succession processes, but manipulates the speed of such processes for decision-making.

drainage and clayey texture (León-Arteta, 1991; Graefe, 2003). Lands under mechanized and or irrigated management are generally cultivated with hybrid maize seeds, as they perform better with intensive use of inputs and can be easily merketed, although they may be also used for self-consumption. Mechanized lands are less crop diverse and are cultivated mainly to maize, sometimes with small areas left for squash and, more rarely, other crops; the application of chemical inputs is considerably higher in mechanized fields, as well as yields per ha. Interestingly, in a series of studies on the corn-bean-squash polyculture in Tabasco, Mexico, it was shown that corn yields could be stimulated as much as 50% beyond monoculture yields when planted with beans and squash using techniques practiced by local farmers and planting on land that had only been managed using local traditional practices (Gliessman, 1988). The reasons for the yield increases include more active fixation and availability of nitrogen, weed control through squash leaves that block sunlight, less insects, benefits of more diverse pollen and nectar sources that attracts beneficial insects.

Some farmers, especially in the Southern region of the Yucatán, have shifted to cultivation of permanent croplands with cash crops, mainly citrus species, but they often retain the *milpa* as a source of subsistence goods. Permanent croplands have higher species richness than other croplands, except for monoculture plantations of *henequen*, a native agave species that has played an important part in the economic growth of the region since pre-Hispanic times until the 1960s when synthetic fibers displaced its use (Baños Ramírez, 2010), as discussed in this Chapter's section on drivers of change.

Multiple ecosystem goods

An important basin for crop genetic resources conservation is the homegarden, or *solar*, which is often the most crop diverse area managed by households. There is a wide field of research focusing on the astonishingly vast number of plants obtained from homegardens, including fruits, firewood, medicinal plants, fodder, and tools, domestic animals and colonies of bees, and its role in maintaining ethnic identity and traditions (Ortega, et al. 1993; Herrera-Castro 1994; Jimenez-Osornio et al., 1999; García, 2000; Mariaca Mendez, ed, 2012). An estimated 80% of the species found in Maya orchards come from the native flora and the rest are species introduced since the Spanish conquest. The *solares* are spaces from which Mayan families obtain food, spices, medicines and aromatic plants that require more attention and

watering, wood and other construction goods for self-consumption (Ruenes and Osornio, 1997; García, 2000; Mariaca Mendez, 2012). Mayan home gardens are located around the house and can range from half hectare to up to five. High trees create shadow and cover that protects the soil, but also produce litter that contributes to nutrient cycling and maintaining soil fertility. These associations have been selecting for centuries and should be considered for the design of new agroforestry systems. This agroecosystem plays a key role in the livelihoods of rural populations of the peninsula, often providing a buffer for consumption in times of distress (Jiménez- Osornio et al., 1999). Fray Diego de Landa from the XVI century mentions in its "Relación de las Cosas de Yucatán" the great role of women in the education of children in between the hard work at home and in the homegarden, with their strong breeding skills. In fact homegardens are also the space where families keep poultry for self-consumption, mainly chicken, turkeys and ducks. These animals are usually breeded for consumption, but represent a source of income in times of need or a proper commercial activity. In larger homegardens one can also find areas dedicated to larger livestock such as cattle or pigs, which are often kept for their insurance value as they can be sold for money in times of distress. Households often feed their animals with maize and squash seeds from the harvest or give them tortillas (the typical Mexican corn flatbread) and leftovers from their meals. It is more common to find households without a homegarden in urban areas where there is no space in between modern houses, but it is far more uncommon in rural areas, be it only a small patch with some orange or lemon trees and few vases for the cultivation of cilantro and chilli peppers. The homegarden in many cases also serves as lavatory or toilet, when a remote corner well hidden by vegetation or through a wooden construction serves this purpose. Other activities are also often carried out in the homegarden such as cleaning and cooking, creation of artisanal products, traditional garments and hammocks, but also recreation for children and the family to gather together and eat or chat. Another important role of the *solar*, which is slowly fading into oblivion, is the one linked to spiritual practices connected to the sow and harvest periods, when different types of ceremonies are practiced to give thanks to the gods that represent the elements or propitiate a good harvest. Researchers have studied the importance of homegardens for the economic, nutritional, cultural and ecological benefits they provide (Barrera et al., 1977; Acosta et al. 1993; Jimenez-Osornio et al., 1999; Barrera-Bassols and Toledo, 2005).

Several farmers use relatively small grazing areas for cattle or sheep, which graze on pasture, but also legume trees and shrubs. Beekeeping is quite common, especially in the Cono Sur, and is usually for marketing outside the rural areas through intermediaries that buy at relatively low prices and resell with high margins to cities, touristic spots or to the export market. In fact, the Yucatán peninsula is the home of a stingless bee (*Melipona beecheii*) called Xunancab in Mayan language, that was very important in indigenoues people's lives and ritual, both as honey and balché, an alcoholic drink. However, this tradition has largely been abandoned in favour of Africanized honeybees that yield more honey (Rosalez and Rubio, 2010). This long beekeeping tradition has been fuelled by the extensive Mayan knowledge of the great potential for honey production of the regional flora and management of bees. Some beekeepers link maize varieties to this activity, when short-cycle maize and more common long-cycle maize are planted together supplying bees with pollen in the wet season and sustain them until the next floral season (Tuxill et al., 2010).

Apart from the homegarden, cultivated plots, livestock breeding, and beekeeping many households also use the fallow and secondary forest close to the land or house to gather wood, which is the main fuel used in rural kitchens, and palm leaves (huano) to repare the traditional Mayan roofs. Firewood is the main source of energy: it is estimated that each family uses about four tons of wood per year. Mature forests are also a source of several plant and animal products, fruits and medicinal plants, extraction of precious wood and timber, and hunting of wild animals like pecaries, turkeys, and deer (León and Montel, 2008). Following ancient Mayan hunting practice, these areas are used also to hunt small mammals like budgers, that often invade their fields in search for food, so that *milpa* fields sometimes becomes a source of protein (Greenberg 1992; Jorgenson 1998; Barrera-Bassols, 2005). Estimates count that Mayan families obtain between 100 and 250 species from forest areas (Toledo, 2008).

This diversified use of agroecosystems also has a strong cultural value, in particular around maize, as most ceremonies are linked to the sowing and harvest season of seasonal *milpa*s, and they entail a strong community and social value. Mayan farmers attribute strong sacred value to the enviroment: land is a living being that needs caring and feeding, through rituals and the help of supra-natural beings (aluxes) and shamans (H'men) (Barrera-Bassols and Toledo, 2005). Even soil classes, such as the Kancab and Chak lu'um, can be used as

medicine for fever or other diseases. Most Mayan ceremonies relate to agricultural practices and many households still perform the rain-calling ceremony (Ch'a Chaak), the wind deities' thanksgiving ceremony, the curing the homegarden ceremony (Jetz lu'um), and the Wajil kool or feeding the *milpa* to propitiate a good harvest season. These ceremonies have a strong social value as they are meant to bound people in sharing and taking care of the benefits received by the land, which is only borrowing them the fields and may punish them if they treat it unrespectfully (Barrera-Bassols, 2005). The Jetz lu'um for instance is practiced in order to maintain 'world' balance, which might be disturbed when forest is cleared for agriculture, or a house will be constructed. There is a cultural respect in taking advantage of the forest and the land that comes from ancient management and helps conservation by maintaining landscape variety.

3.3 Evolution of the agricultural sector and drivers of change

Rural institutions have evolved since the reform that reallocated lands under the *ejido* in the early 20th century, prohibiting land transactions and introducing collective management of land (Bouquet, 2009). A historical view is useful to understand these transformations. By the time the Mexican Revolution started in 1910, fewer than 11,000 haciendas controlled 57% of the national territory, while 15 million peasants—95 percent of rural families—worked as salaried farmers in *haciendas* and agroexport industries, owning no land (De Ita, 2006). During the first fifteen years of the reform, between 1920 and 1934, the land was distributed in order to complement the salary of rural farmers, culminating with the creation of communal and some private smallholdings. Whilst the land was owned and managed by communities, three internal bodies and several regulations posed access and production decisions under indirect control of the state (de Janvry et al., 2001). In 1992, a new agrarian reform devolved to the communities control over management of natural resources and creation of public goods, allowing them to decide on individual or common ownership (de Janvry, 2001). In 1993, the Program for Certification of Ejidal Rights (PROCEDE) started with the aim to define secure property rights, foster land market transactions and eventually agricultural growth. Individual titles were issued and people could sell land, however many communal lands were not privatized and the ejido remains active in some areas as a collective decision forum on land sales or for water management issues. The actual results of the reform are in fact mixed, with increasing informal sales that created unsecure rights, low

administrative follow up governed by top down decisions, and emergency sales by poor ejidatarios who sell at ejidatario elites buying at low rates (Bouquet, 2009; Deininger and Bresciani, 2001; De Ita, 2006).

Overall a combination of environmental, socio-cultural, and economic phenomena concurs to explain land use change in the Yucatán region and consequences for biodiversity and environmental sustainability[16]. Historically, agriculture in the Yucatán has been dominated by traditional *milpa* agriculture and later by henequen (agave) plantations. Before colons converted it into an export business, henequen was already used as raw material for various household objects, including those used in the *milpa*. However, it was since the second half of the XIX century and until the Revolution that the Yucatán peninsula became an important world producer of this agave fiber. The strong decline started in the 1970s, when the henequen industry collapsed especially due to low fiber prices and the advent of synthetic fibers (Baños Ramírez, 2010). When the sisal industry started to decline, diversification of the primary sector by the government focused on the introduction of citrus cultivation and, more recently, vegetables. On the other side, during the second half of the 1980s, the *maquiladora* industry became the region's main economic activity (Becerril et al., 2012).

This agricultural diversification strategy considerably affected land use change. In the southern area of the state, Plan Chaac (which borrowed its name from the Mayan rain deity) was implemented in the sixties to provide a new income source to farmers. The Plan provided irrigation infrastructure to 3900 ha in 15 communities of southern Yucatán where soils were slighlty more fertile and deep and apt to cash crop cultivation, especially oranges. However, the local market was unable to absorb the increased orange production and, linked with scarce knowledge of citrus pest management, caotic institutional support, lack of transport infrastrtucture, and lowering prices, pushed many farmers out of agriculture (Eastmond,

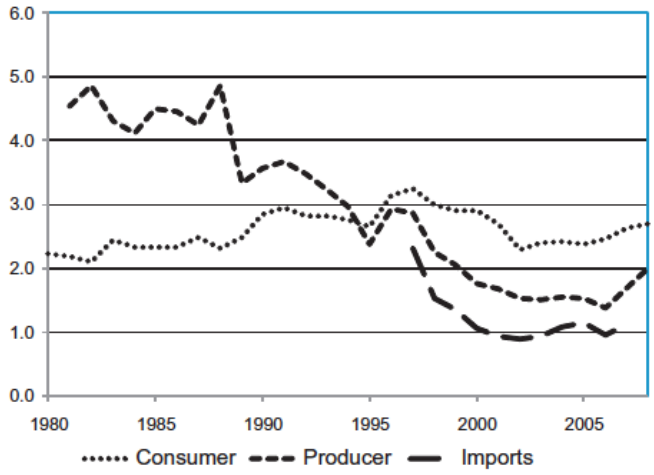
[16] In his review on land use in Mexico, Dyer (2010) provides a brief overview of microeconomic determinants of land use change: in conventional economic analysis these are linked directly to farmer's decisions for the use that provides maximum profitability, underlined by biophysical and social conditions. According to this model agricultural income decreases rapidly with distance so that there is an agricultural frontier at which forest is more profitable than conversion to agriculture. Underlying economic factors that influence profitability include prices of inputs and agricultural products, salaries, availability of credit and the level of interest rates. Other factors that can indirectly influence land use are linked to off farm employment opportunities, technological innovations, definition of property rights and infrastructure development. Even economic policies, such as trade liberalization, can indirectly influence land use change but the relationship is very context specific. There can be feedback effects of agents' decisions into the indirect and direct drivers of change.

1991; Baños Ramírez, 2001). The fate of the Plan changed at the end of the 70s when a juice plant was built in Akil to export concentrated juice, gathering produce from local farmers who sell their whole production to the plant, formally a social enterprise owned by the farmers (until 2006). However, the lack of modern agroindustrial infrastructure and years of mismanagement that even led to the plant's bankruptcy and the state overtaking its ownership, fuelled a production that hardly competes with export markets' quality, with consequent low rentability. The agricultural diversification plan also had positive results in the creation of a consolidated fruit and vegetables market in the southern city of Oxkutzcab, which receives supplies from local farmers and other Mexican states to feed the local, but mainly tourism, market. However, the prices for local producers remain extremely low and contribute to the abandonment of agriculture by the younger generation, which takes advantage of other employment opportunities. Due to the availability of better soils, the South has seen a process not only of increasing irrigation for horticulture but also mechanization for the production of basic crops, especially in the Cono Sur area. Jalapeño chili production was introduced in the 70s for rentability potential but proved risky and strongly subject to market fluctuations (Schmook and Radel, 2008). Farmers in mechanized systems, who are usually market oriented, are also facing high costs of production due to soaring agrochemicals and fuel prices, and the import of Northern American subsidized maize (Barkin, 2002). Conversion of land to pasture for cattle breeding is another activity that has been growing especially near Tzucacab and Peto areas, although it was already carried out in Spanish *haciendas* during the XVII century along with maize production (Rosales, 1980). Several studies focus especially on Southern Yucatán, a hotspot of deforestation, which is experiencing a switch from swidden agriculture to grass pasture and cash crops, partly as a result of out-migration that has incentivized switching to less labor-intensive activities (Turner et al., 2003; Klepeis and Vance, 2003; Schmook and Radel, 2008; Carte et al., 2010). In the deep south of the Peninsula around Calakmul area, a biosphere reserve, different authors find a contraction of maize production to the gain of pasturelands, especially since the 90s, and even when farmers don't yet own cattle, they sometimes keep pasture foreseeing a future purchase or simply to access higher Procampo subsidies, which are based on area (Klepeis and Vance, 2003; Dyer et al., 2006; Schmook and Radel, 2008; Schmook et al., 2013).

Recently, the primary sector has faced several problems linked to seasonality, increased unpredictability of climate, shorter fallow periods that have deteriorated forest resources; high costs of production due to high prices of fuels and agrochemicals; low marketing prices of agricultural products, particularly maize; and social and cultural change led by modernization, urbanization and migration to touristy or urban areas. The relationship between rural areas and the main urban centers in the region (Merida, Valladolid, and Cancun) is unbalanced and inequality is increasing following different degrees of technological and cultural transformation (Barrera-Bassols, 2005). Economic restructuring has been linked to urbanization of areas with touristic potential and marginalization of traditional agriculture in the rural areas, which are poorly supported (Carte et al., 2010). Yet migrants often maintain social, cultural and economic ties to their communities of origin (Re Cruz, 2003; Torres and Momsen, 2005; Wilson, 2008). Because ties are kept with the communities of origin at several levels, the 'success' of migrants can reinforce the perception of agriculture as a bad livelihood that doesn't allow people to escape poverty (Carte et al., 2010). On the other side, permanent domestic migration also determines labour shortages in agriculture in rural areas. Several authors argue that neoliberal restructuring of the agricultural sector has played a major role in determining these changes, similarly to other experiences in the Mayan influence area (de Janvry et al., 1995; Taylor et al., 1999; Dyer et al., 2006; Nadal & Wise, 2004; Yúnez Naude, 2006; Wise, 2007; Isakson, 2009). The introduction of the free trade agreement with Northern America (NAFTA) was expected to boost economic growth, but also to hit the agricultural sector through increased competition from the United States and through domestic agricultural reforms. At the same time of trade liberalization the government strongly reduced subsidized agricultural credit and inputs and changed the collective property rights system that had regulated the ownership of land since the 1920s. Many feared a steep decline of maize cultivation in the country and the displacement of small producers. Maize prices dropped as much as 50% in real terms between 1994 and 2000, with similar dramatic falls in bean and coffee prices (Wise, 2007). Figure 3.2 shows the trend for maize[17]. Not only prices, but also the expansion of the multinational Mexican maize flour producer, Maseca, providing cheap maize flour all year round thanks to access to cheap imports, heavily reduced the ability of seasonal farmers to participate in the market.

[17] After a long period of declining prices received by maize farmers in Mexico, producer maize prices have started increasing since 2008. See Dyer and Taylor, 2011, for an analysis.

Figure 3.2: Evolution of maize prices in Mexico between 1980 and 2005



Source: Dyer and Taylor, 2011

While the shock to the rural sector has been dramatic, predicted economic adjustments did not take place as expected: more than a million farmers left the agricultural sector, and while agriculture remains important, rural poverty is dramatic and migration has quickly increased (Wise, 2007). Other authors argue that the combination of trade liberalization, State transfers, remittances, and structural change in Mexico's workforce education and experience composition contributed anyway to the reduction in income inequality, subverting the steep increase in inequality after the first wave of liberalization in the 80s (Esquivel, 2008).

In fact, in order to smooth the potential shock at the time of liberalization, the government set up an impressive system of direct compensation to farmers between 1994 and 2010, with several subsidies still active today. The most important among many rural support programmes has been the Programa de Apoyo Directo al Campo (PROCAMPO) or Direct Rural Support Program, which provides payments for agricultural intensification of the area devoted to agricultural land use in 1994. Since 1995 the subsidy lifted restrictions of types of cultivation, and later included area for livestock, forestry or ecological projects. Alianza para el campo (Alliance for the rural sector) was also created to support restructuring of the agricultural sector so that the agricultural producers could face international competition. Publics support programmes were introduced on the basis that, given market liberalization, smallholder farmers would not be competitive and would need direct income to improve production strategies. However, the result has been cash transfer that are not invested

for productive activities (Yúnez Naude, 2010). In a recent volume on the problems of rural Mexican economy, Yúnez Naude argues that in the analysis of land use and cover changes it is impossible to separate the effects of NAFTA from those of public policies for the rural sector. Within the volume, Dyer shows that maize production has not dramatically dropped as forseen at the inception of the free trade agreement, quite the opposite (Dyer, 2010). Morever, Procampo programme did not promote a more efficient land use but rather the survival of maize in marginal areas of Southeastern Mexico along with the proliferation of pasturelands and, consequently, deforestation. Dyer argues that while the cultural value of maize influenced the persistence of maize production, lower grain production prices since the 90s promoted the reduction of commercial production and the increase of subsistence farming. On the other side, it represented a forgone chance to induce a forest transition, maintaining deforestation pressure strong. In fact, the reduction of market prices after trade liberalization caused adjustments in the demand of land and labor by commercial farmers, downward pressuring salaries and rent (Dyer et al., 2006). This induced subsistence farmers to increase their demand of these factors, which would explain the persistence of subsistence agriculture. However, in the southeastern part of Mexico, while the area under maize cultivation decreased significantly, it did not promote reforestation, but conversion to pasturelands, partially to maintain subsidy collection.

Some authors find that another fundamental problem of rural Mexico is that support programmes benefit for the greatest part large-scale farmers. Yúnez Naude reports calculations by Scott that during the reform period, 10% of farmers owning large parts of the land received between 50% and 80% of subsidies to the rural sector, including Alianza para el Campo which was focused on marginal areas and Procampo. According to several authors this regressive feature of subsidies channeled to the agricultural sector has increased inequality, overriding the distributional impact of social programs such as PROGRESA/Oportunidades, a conditional cash transfer programme targeted at poor families conditional on their children attending school and obtaining health care and nutrition supplementation. The programme has been running since 1997 and was the object of several famous studies and evaluations[18]. A volume titled 'Subsidies for Inequality' (Subsidios a la

[18] Well known references include: 1) Schultz, T.P. 2004. School Subsidies for the Poor: Evaluating the Mexican Progresa Program. Journal of Development Economics 74(1): 199-250. 2) Diaz, J.J. and S. Handa. 2004. Propensity Score Matching as a Non-Experimental Impact Estimator: Evidence from Mexico's PROGRESA." Mimeo, UNC-CH, Department of Public Policy (forthcoming in JHR). 3) Hoddinott, J., Skoufias, E. (2004).

Disegualdad) details in particular some of the results of twenty years of public support (Fox and Haight, coord, 2010). In the volume Scott shows that rural income inequality increased significantly between 1994 and 2000, while it returned to 1994 levels by 2006. Remittances and public transfers have helped reduce rural inequality and moderate the trend over the period, especially considering programmes to combat poverty such as Oportunidades. Programmes like Procampo had a double effect: a progressive impact in relative terms, helping reduce inequality, but regressive in absolute terms, increasing inequality. Scott shows that based on programme information producers with less than 5 ha represent 75% of the beneficiaries of Procampo, but receive only 37% of the transfers of the program, in line with their relative share of land area covered by the program. Producers with 5 to 20 ha represent 22% of the beneficiaries and receive 41% of the subsidy, while producers with more than 20 ha (3% of beneficiaries) obtain 23% of the transfers. Taylor and Yunez-Naude (2012) also find that less than 75% of the official amount of Procampo subsidy reaches the beneficiaries, with large differences between localities and socioeconomic characteristics, including political affiliation. Their worry is that this could be an indicator of irregularities, especially considering that those most affected are vulnerable rural households with few ha and low education level.

Government support to conservation is based on the creation of protected areas and since 2003 on payments for ecosystem services (PES) implemented by the national forest committee (CONAFOR). PES schemes were launched under two initiatives: the Programme for Hydrological Environmental Services (Programa de Servicios Ambientales Hidrologicas - PSAH) in 2003, and the Payments for Carbon, Biodiversity and Agroforestry Services (Programa para el Desarrollo de los Mercados de Servicios Ambientales de Captura de Carbono y los Derivados de la Biodiversidad y para Fomentar el Establecimiento y Mejoramiento de los Sistemas Agroforestales - PSA-CABSA) in 2004. In 2006, these two programmes were merged and in 2007 integrated within a new overarching programme, ProÁrbol. Today they include five categories: hydrological services, biodiversity, agroforestry systems, carbon capture, and project creation. ProÁrbol has the double aim of maintaining ecosystem services while alleviating poverty, favoring projects in ejidos and communities, particularly in highly marginalised regions. Authors note that there is no

The impact of PROGRESA on food consumption. Economic Development and Cultural Change 53 (1), 37–61.
4) Skoufias, E. (2005). PROGRESA and its impact on the welfare of rural households in Mexico. Research report 139. International Food Research Institute, Washington, DC

evidence that these payments for ecosystem services have the desired impact on the conservation of forest ecosystems, mainly due to how the payments are provided to eligible population, on which information is mainly inexistent (Muñoz et al., 2007; Dyer, 2010).

During the 80s, the Mexican government promoted the substitution of native maize with improved crops to achieve grain self-sufficiency: while this contributed to reduce the area planted with traditional maize it did not lead to the dramatic displacement of native maize feared by many and predicted by economic theory (Dyer, 2010). This can be explained by a combination of better performance of native maize in specific environments and other factors, such as characteristics and local preferences (see Chapter 1). Also, failures of market subsidized productions in the 80s and a return to subsistence production when producer prices fell, led the state to invest in tourism development, which created incentives for off farm employment and migration to the Riviera Maya in particular, where the construction and tourism industries are still experiencing continous growth (Schmook and Radel, 2008). Dyer (2010) prospects a new increase of pressures on forest resources in the recent increase of maize prices, economic contraction during the global crisis and increasing unemployment, which might favor the expansion of the agricultural frontier especially in southeastern Mexico, exacerbating deforestation and degrading ecosystems. Policy makers are being called upon to implemenet coherent strategies of sustainable development, which until now have been carried out without integration by multiple agencies with often contrasting instruments and consequences.

Environmental factors, such as extreme climatic events, unstable prices for cash crops, the end of state-guaranteed prices for maize linked to import of cheap maize and thin local labor markets are cited among the causes of the recent waive of migration, however this is largely undocumented for the Yucatán, unlike for other parts of Mexico. Rudel et al. (2005) argue that rural poverty in some parts of Central America and the Caribbean has led to the search for better employment opportunities out of agriculture, with consequent field abandonment and forest recovery. Schmook and Radel argue that the case of the southern Yucatán peninsula, an agricultural frontier at the border of Mexico's largest biosphere reserve, is one of rural poverty-led migration and smallholder reactive adjustment to changing economic opportunities and policies: it is the area's position as a development frontier that fuels

migration. Citing other authors, they argue that remittances are primarily used for household expenditures and consumption rather than investment, therefore eventual impacts on land use and cover may only come indirectly by stimulating local economic activity. For instance, while they find that remittances are substituting agricultural income and contributing to reduce land under cultivation, which improves forest recovery, many are seemingly converting their lands to pasture. This result links to Dyer's view that abandonment of cultivated fields is not improving reforestation because many are being converted to pasture. They also find that especially when the household head has migrated households are less likely to plant traditional crops and switch to monocultures: migration is leading to withdrawal from crop cultivation. All and all, they find that the migration wave has helped forest recovery, but that investment in pasture should be monitored to understand potential future threats. On a similar note, Turner et al. find that government intervention in the agricultural sector and the creation of the largest archeological eco-tourism project in the world, El Mundo Maya, is excacerbating pressure on forests in the area (Turner et al., 2001). Again they find that Procampo subsidies seemingly incentivized farmers to clear forest for pasture, in order to be able to keep receiving subsidies.

Radel et al. (2010) also show interesting data on the relatively slow changes that characterize rural households strategies in the southern Yucatán region by analyzing land use change of households interviewed in 1997 and 2003. They argue that two divergent adjustment paths are taking place: one based on slow withdrawal from agriculture and one based on intensification and commercialization. The authors look at the way households are adjusting to transformations that incorporate them in the global economy, particularly following the neoliberal transition that influenced their ability to satisfy needs through traditional *milpa* cultivation (Foley; 1995). During the 1990s households have partially responded by switching to cash crop cultivation, for instance chili peppers, which as aforementioned didn't substitute *milpa* agriculture due to risk aversion; others have recurred to international and regional migration in search of employment opportunities; and many rely heavily on government subsidies for production, conservation, or social opportunities, usually in the form of cash transfer programmes. The dual adjustment strategy Radel and colleagues describe is shaped by shifting to off farm work and migration on one side, and market oriented production, especially cattle breeding, on the other. This dual strategy has the

potential for conflicting land use change with a forest transition driven by abandonment of marginal agricultural lands contrasted by forest clearing for pasturelands and grazing, with implications for carbon sequestration and other ecosystem services.

Schmook et al. (2013) take a closer look at the area around Calakmul to document the persistence of swidden agriculture through panel data. They find that environmental factors such as drought and hurricanes have negatively onfluenced area under *milpa* cultivation, along with remittances, subsidies and off farm employment opportunities, which are associated with smaller *milpa* plots. They argue that in some cases, remittances are actually making it possible to maintain *milpa* production through investment. An interesting result is that *milpa*s persist for subsistence purpose and cultural continuation as fulfilling a cultural role in maintaining the *milpa* system and its related values. The authors state that *milpa* cultivation could be seen as part of an adaptation strategy to external changes and is therefore a response to political, economic and environmental conditions and opportunities.

A useful analysis comes from research on maize diversity and rural development policy in Chiapas suggesting that modernization of agriculture, education and market liberalization have concurred in changing livelihood strategies (Keleman et al., 2009). Keleman et al. focus on the influence of government policies on agrobiodiversity since the beginning of neoliberal restructuring. First, buffering mechanisms to international markets were introduced for farmers, especially through Procampo. Then, mechanisms to control domestic prices and markets, such as the CONASUPO, which purchased maize from farmers to sell it to maize-processing industry, substituted by ASERCA which only intervened when market price was below local production costs. This was followed by agricultural credit, government-sponsored seed and fertilizer sale linked to technology trasfer; and finally by nutrition and education policy, through infrastructure provisioning and with the Oportunidades programme. They argue that pre-liberalization policies aimed at supporting the leading role of the sector, while post-liberalization ones focused on modern producers, somehow supporting other farmers's transition to other crops. In their study area, commercial maize production has decreased due to low returns given high costs of production, while animal husbandry, poultry and pig production have increased, as well as pasturelands. Livestock transition was also sponsored through government programmes, such as PROGAN

(Programa de Estímulos a la Productividad Ganadera). Keleman and colleagues argue that the integration with the cash-based economy is having clear negative effects on the conservation of landraces, but that these still have special qualities that the producers' cherish. Culinary quality is one of them, however focus group discussions point to the time investment in preparing one's own *nixtamal* (the traditional dough to make tortillas) and that several women preferred to buy the dough and employ that time in other activities. Finally, Bellon and Hellin (2011) find in the same study area that without government interventions, farmers would tend to plant more area to landraces and that transaction costs and missing markets contribute to explain landrace persistance. They point out that the challenge is to modernize agriculture keeping in mind the complementarity of modern and traditional varieties in improving farmer's livelihoods rather than on substitution, which would contribute to their well-being but also to conservation of local agrobiodiversity (Bellon and Hellin, 2011).

3.4 Conclusion

In conclusion, the literature shows that social, economic, environmental and political drivers create opportunities and constraints that influence rural households' capabilities and choices, with consequences for ecosystem services and agrobiodiversity. This is important when taking into account the whole range of services that they provide: for instance, we see that maize cultivation has persisted independently of agricultural policies due to its importance in subsistence agriculture and in local culture, as the benefits that it provides are both tangible and intangible, including employment, food security and cultural value, which increase their value highly above market level (Perales et al., 2005; Arslan and Taylor, 2008; Keleman et al., 2009; Dyer, 2010; Bellon and Hellin, 2011).

The maintenance of the *milpa* system, activities such as beekeeping, and the self regulation of the use of forest resources through *ejidal* permits have helped partially conserve mature vegetation in the state, despite the growth of livestock breeding and commercial agriculture, as Moya-Garcia and colleagues stress (Moya-Garcia et al., 2003). They identify one of the main threats to the sustainability of the *milpa* system in the reduction of the fallow period to less than 7 years, combined with lower inter-specific diversity. These factors, linked with higher rainfall unpredictability contributing to crop failures, public policies aimed at modernization through higher input intensity and institutional change, and in part the effects

of economic restructuring have deteriorated the socio-cultural sustainability of the *milpa* system. The main beneficiaries of agrobiodiversity and the vulnerability of this relationship in the region will be investigated in the following chapters.

Chapter 4. Description of Field Site and Multiple Uses of Agrobiodiversity

Introduction

In the previous Chapter we have seen that several studies focus on traditional *milpa* agriculture and maize diversity. We take a step further by looking at the level of agrobiodiversity managed and used within a variety of socio-economic and agro-environmental conditions. Because we apply an Extended-Capability-Ecosystem Approach, we analyze the use of these goods under the theoretical umbrella of conversion factors, endowments and capabilities. To recall our framework, conversion factors are the personal, social and environmental characteristics that influence the ability of people to achieve well-being outcomes from the resources they are entitled to, while capabilities are the actual opportunities open to people on which they make a choice that determines a certain level of achieved well-being. As an example, demographic characteristics such as age and gender would fall under the first category, specific farming inputs under endowments, while education and employment opportunities are part of the capability set available to households. In order to be able to understand different regional dynamics, four areas have been studied, characterized by different degrees of economic and human development, partially different farming systems and ecosystems, but affected by similar drivers of change in terms of institutions, policy and climatic events.

4.1 Description of Field site and Survey Administration

The present analysis is based on original data collected between January - July 2012 and January – February 2013 with the support of the project 'Agrodiversity, labour migration, decent work, and agricultural development in Yucatán, Mexico'[19]. The data were generated through in depth key informants' interviews, focus groups and a semi-structured household survey. Relevant dimensions and indicators for the analysis of capabilities and environment were defined through interviews with academics and key informants from the communities such as farmer leaders and practitioners from rural government agencies. There was no collection of plant samples or counting of plant and animal individuals in the fields as this

[19] The project was funded by the International Center for Development and Decent Work (ICDD) of the University of Kassel and carried out by the Faculty of Medicine, Veterinary studies and Animal Husbandry of the Universidad Autónoma de Yucatán, which financed the fieldwork activities for this research.

was not the main scope of the study: instead, we used farmer's recall and their own characterization of species and varieties on-farm and off- farm to understand the richness of resources they depend on. Before detailing the household survey and the sampling strategy we introduce the population from which the sample was drawn.

4.1.1 A brief overview of the four municipalities

As described in Chapter 3 the four communities are characterized by different productive activities and natural resources: while they share many similarities, the social and ecological systems in which they live contribute to determine different farming systems and use of ecosystem benefits. The following description of the four municipalities is based on a series of documents including Census data from 2010, a participatory diagnostic analysis carried out by the local government in 2005 (OEIDRUS, 2005 a, b, c, d), and discussions with key informants from the communities, private sector and public agencies[20]. The four municipalities are located in three different rural development districts, as defined by the SAGARPA (Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food).

The *henequenera* area: Motul

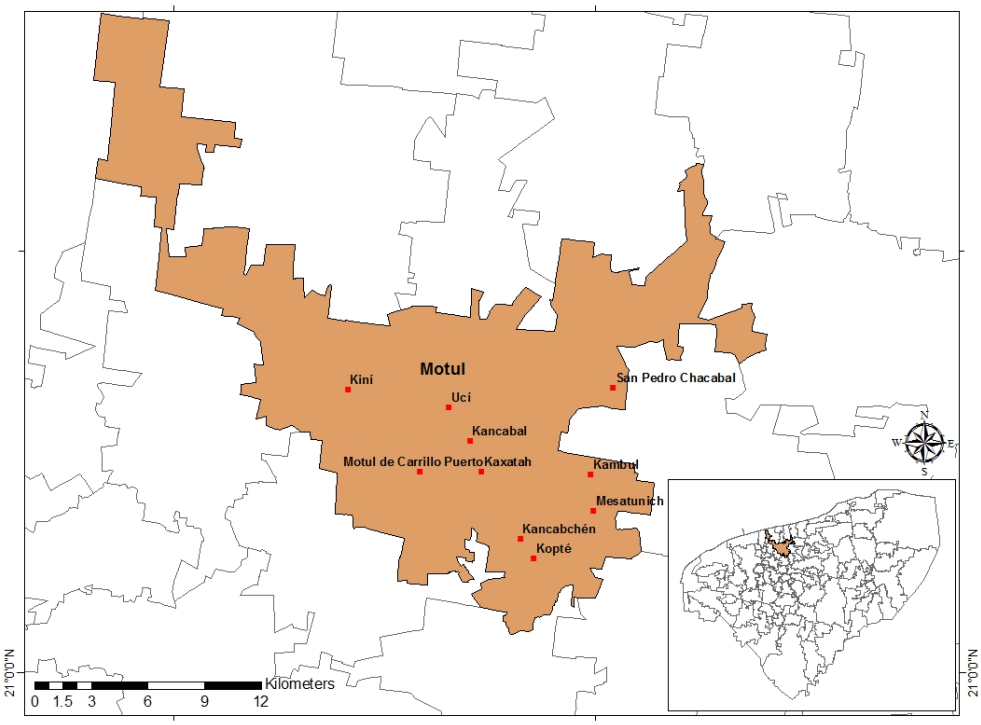
Motul municipality in the north-eastern part of the state has been strongly influenced by the vicinity of the state's capital and of the coast, which have contributed to the growth of its urban area (Figure 4.1). The population of the municipality is 33.978 people according to the latest census (2010), of which about 64% is located in the urban area of Motul, while the rest is spread in twenty communities and several isolated ranches. Motul's municipality is characterized by plain terrain and stony soils, mainly dark grey shallow *tsekel* (70% of the area) with low fertility, and low secondary vegetation, with small portions of tropical deciduous forest and fauna mainly composed o small mammals and birds. There are no surface water streams, but several underground deposits commonly known as *cenotes*, with sacred relevance for the Maya population, such as the Sambulá cenote located in the town of Motul, its main touristic attraction. According to Census data[21], a range of resource and capabilities deprivations related to health were experienced by people in the area: about 30%

[20] About sixteen interviews were carried out as part of a social network analysis of stakeholders influencing the agriculture sector in the Yucatán, which is analyzed as a separate work for publication.

[21] Overall statistics on the municipalities are based on Census data retrieved from: http://www.censo2010.org.mx/

of households do not have sanitation facilities, while 42% do not have access to health services nor to social security[22] (60%).

Figure 4.1: Map of localities sampled in Motul



Source: Own elaboration on data from CONABIO (2014)

The average schooling level of the population is 7.1 years against a state average of 8.2 and higher than in the other municipalities studied, but 11% of the population older than 15 years is illiterate, and 23% did not complete primary school. This might reduce their ability to achieve other relevant capabilities, such as employment opportunities if we consider that expanding the capacity to make valued choices through education will likely affect also other spheres of life.

About 28% of the population over 3 years old speaks Maya, however some large villages have higher indigenous language incidence such as San Pedro Chacabal (94%), Mesatunich (73%), and Ucí (60%). San Pedro Chacabal in particular is the only locality in the municipality classified with very high levels of marginalization in terms of education, basic

[22] The government measure for access to health insurance doesn't include the possibility that households access the Seguro Popular, a public programme that offers basic services (see par 4.).

assets and access to health services and insurance[23]. In fact, 35% of the population over 15 years old is illiterate, 60% without completed primary education and 80% without sanitation facilities, which is related to the being able to be free from disease and live in an adequate and clean shelter. Studies have found socioeconomic inequalities between indigenous and non-indigenous communities in Mexico to be closely linked to health achievements, especially in terms of higher child mortality (Torres et al., 2003; Méndez-González, 2010; UNDP, 2010).

The economically active population is mainly employed in the secondary sector due to employment opportunities in *maquiladoras* (46%), followed by commercial activities and services (35%), and agriculture (18%)[24]. Waves of international migration have characterized some of the localities in the municipality, Ucí in particular, one of the first in the country to beneficiate of the 3x1 programme for migrants of the SEDESOL (Secretary of Social Development)[25].

Motul is located in district 178, the *henequenera* zone, with several poultry and pig farms, and some programmes to replace *henequen* activity with citrus cultivation. As we have seen in Chapter 3 Motul has historically been one of the central areas for the development of the *henequen* industry. Genetic erosion has characterized the cultivation of this agave with the expansion of the industry and today only three varieties are cultivated (*sak ki, yaax ki* and *kitam ki*). However, this activity has been largely abandoned and *milpa* subsistence farming partly resumed, but yields are very low (an estimated 750 kg/ha) due to the previous extensive agave cultivation, which left low secondary vegetation that impedes an adequate slash and burn management (Jimenez-Osornio, 1995). Local fauna is mainly composed of

[23] The national population council calculates the marginalization index on four socioeconomic dimensions: education, household assets, population distribution, and income (CONAPO, 2010). Based on these data, the index is ordered from very low to very high and an ancillary index is drawn to define priority areas for development. The indicator used within the four dimensions are: percentage of the population above 15 years old who are illiterate, percentage of the population above 15 years old who have not completed primary education; percentage of households without drainage or sanitary facility, percentage of households without electricity, percentage of households without piped water, percentage of households with overcrowding; percentage of households with dirt floor; percentage of population in localities with less than 5000 inhabitants; percentage of population perceiving an income of at least two minimum salaries.
The concept behind the index recalls human development: CONAPO represents marginalization as the lack of development opportunities combined with the lack of the ability to take advantage of these opportunities, which recalls Sen's concept of capabilities.
[24] Only data from the year 2000 could be retrieved.
[25] At the end of 2013 the road pavimentation in Ucí started with an investment of 700000 pesos from the feral government, 350000 from the local government and y 350000 from the local Migrants' Club.

reptiles, such as snakes and lizards, and birds, given the prevalence of shrublands with decadent *henequen* residues. Nonetheless, there are no actions in place to address ecosystem degradation and deforestation related to former *henequen* cultivation and frequent uncontrolled fires during the burning season augmented by the extension of scrublands, while the CONAFOR (National Forestry Committee) is especially absent in the area.

The main problems highlighted by the participatory assessment carried out by the state's agricultural agency in Motul relate to low prices of *henequen* fibre for marketing, soil fatigue, pests and diseases, low income generation, lack of agricultural inputs, and inefficient public support (OEIDRUS, 2005a). Low *henequen* profitability due to competition of other fibres and materials is pushing farmers to look for other employment opportunities, but the *maquiladora* industry tends to employ young people, which reduces their employment options for ageing farmers. Soil fatigue and low organic matter content affect the ability to produce enough maize for self consumption, while pests and disease affect other cultivations, partly because of the increased inappropriate use of agricultural inputs. Livestock and vegetables production are dependent on pasture and water, but low rainfall and lack of irrigation are major constraints. On the other side, lack of farmers' organization, training in alternative agricultural practices, and low levels of education prevent them from taking advantage of formal marketing opportunities. Lack of access to credit is also mentioned as a barrier to agricultural improvements.

On the environmental side, the contamination of wells due to lack of sanitation facilities in many communities and the uncontrolled dumping of waste by *maquiladoras* and mechanical shops increases the demand of treated water and the incidence of water borne diseases. Finally, inappropriate use of agricultural inputs and the reduction of fallow periods seem to favour soil erosion while farmers are not aware of alternative practices that could contribute to sustainable management and there is a widespread lack of environmental awareness among different stakeholders whose actions affect the environment.

The *Cono Sur*: Tekax and Tzucacab

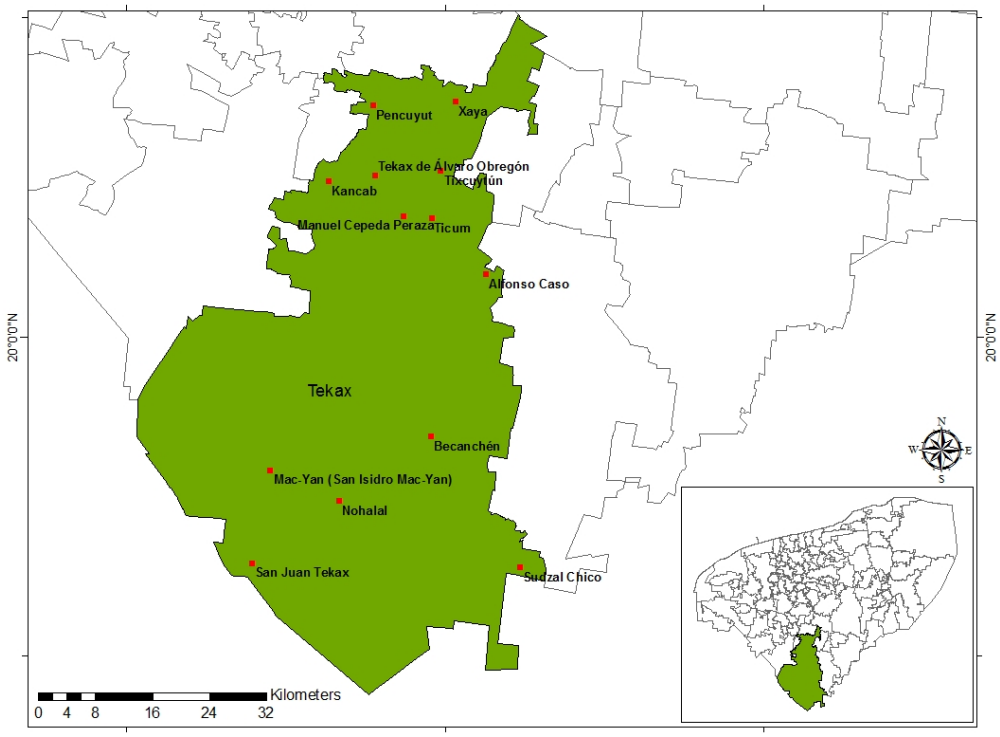
Tekax and Tzucacab are located in district 179, in the so called Southern Cone where mechanized maize producing areas can be found along with the cultivation of citrus,

especially orange and lemon, for the production of processed juice for export. Pig and poultry farming are mainly carried out as traditional activities in homegardens to complement household consumption rather than as commercial activity. While cattle ranching is not the main economic activity in the district, many farmers are taking advantage of appropriate soils to start it. Beekeeping is carried out in particular in southern areas in an extensive way but only for honey production, without exploitation of other products such as pollen, beewax and royal jelly.

Tekax

The area of Tekax is characterized by irrigated agriculture dedicated to fruit and vegetables and large mechanized extensions in the southern plains topping the only elevated area in the state (Figure 4.2).

Figure 4.2: Map of localities sampled in Tekax



Source: Own elaboration on data from CONABIO (2014)

The municipality has undergone strong economic change since the sixties through urbanization, the creation of the juice export plant, the establishment of *maquiladoras* and the push towards irrigated cash crops with intensive use of pesticides to create a thriving

agroindustry.

In 2010, 40547 people lived in the municipality, concentrated in Tekax town (63%), and in five other localities with more than 1000 people, while the rest is distributed in numerous small villages (63 with less than 50 people). The communication infrastructure, an important conversion factor based on the built environment, is strongly inadequate except in some areas where commercial agriculture is carried out and is connected through a highway. The highway that connects several villages to a large agriculture *maquiladora* (Valle del Sur) and mechanized maize production areas such as Becanchen is highly deteriorated from the side of Tekax, where driving 25 Km can take up to an hour due to potholes. The dispersion of localities and the bad quality of communication infrastructure have strongly affected rescue and aid operations when Hurrican Isidoro struck in 2002, linked to the lack of decision support tools such as maps and vulnerabilities of the affected areas (Frausto, 2006). Lack of economic facilities and protective security have therefore contributed to higher loss of well-being.

The dispersion of many villages also reduces people's ability to access health services, a deprivation affecting 12.5% of the population, while as much as 77% of them do not have access to social security, while 49 doctors serve the whole population. On average, the schooling level is about 6.7 years, with 17% illiterate people older than 15, while 24% did not complete primary school. Localities with stronger indigenous roots experience higher deprivation in terms of education and employment opportunities. In Kancab for instance, a large community with more than 2500 inhabitants, 35% of the population older than 15 is illiterate, 60% hasn't completed primary school, while 40% of households do not have sanitary facilities, 100% of the population speaks an indigenous language and 40% do not speak any Spanish, which makes integration and the ability to take advantage of employment opportunities outside the community quite difficult.

The economically active population of Tekax is employed in the tertiary (38%), primary (32%), and secondary sector (28%) (OEIDRUS, 2005b). Women in several communities specialize in crafting of traditional clothes (*hipiles*), however they often lack resources and capacity to expand production and carry out the activity as a small source of surplus for the family.

Soils in the region are generally plain with slightly higher elevation in the southwestern part of the municipality. There is a prevalence of evergreen forest along with secondary vegetation from slash and burn farming, and several precious tree species are present such as poppy, *bohom* (hard wood for furniture), mahogany and cedar. Numerous wild animals populate the southern forests including rabbit, raccoon, deer, armadillos, iguanas, and others. In the western part of the municipality, soils are K'ankab reddish deep soils with no drainage problems, while swampy ak´alchés and plains with poor drainage characterize the eastern area. Main agricultural activities include citrus and vegetables cultivation, cattle breeding, cedar production, and maize cultivation. The availability of different types of soils, an environmental conversion factor, appears as an important determinant of the different management choices of farmers, also subject to external drivers such as agricultural policies and support programmes that incentivised certain land uses over others.

Citrus production is almost exclusively for the juice plant in Akil but it is constrained by bad state of communication infrastructure, old irrigation systems, and competition from citrus producers in nearby municipalities flooding the juice plant with their product[26]. Lack of planning for marketing and lack of or inadequate storage systems cause the farmers to commercialize their products at the same time, saturating citrus, but also vegetables and maize markets, bringing prices down.

Farmers mostly lack economic resources to invest in their irrigation systems and are often mentioning lack of capacity to monitor and repair them. Moreover, bad infrastructure conditions raise transportation costs, especially since most farmers have to rent vehicles and only in Tekax some have organized common systems of transport. Cattle breeding is also limited by bad infrastructure and lack of pasturelands. Forestry programmes are in place especially through payments for ecosystem services schemes and conservation programmes for hydrological services, however as we discuss further in this Chapter their implementation is based on prohibition of use without other support and consensus building for the

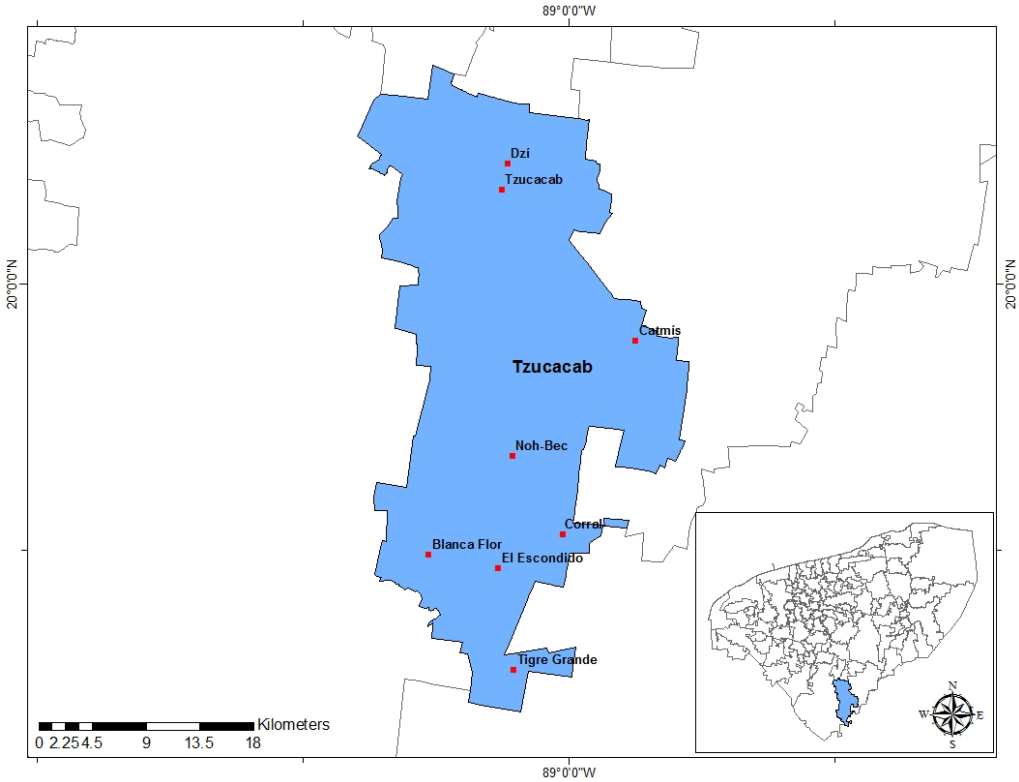
[26] A key informant from the juice plant explained that the plant buys fruit in October-November when the fruit is more mature and produces better juice. However, because of non-transparent budgeting the plant went bankrupt and finds financing through the *ejido* union. In order to survive an agreement was made with Coca-Cola Company, which provides credit and infrastructure but requires higher quality of products but provides diversification through citrus oil production. Therefore the plant works as a *maquiladora* from June to October, as a juice maker for export in autumn, and also sells citrus peel for breeders who buy it through support from the Secretary of Rural Development (Secretaría de Desarrollo Rural).

population, who sometimes resorts to illegal logging and hunting due to economic motives and partly lack of environmental conscience, but also lack of appropriate alternatives or incentives (OEIDRUS, 2005b; Bioasesores, 2011). Beekeeping is also affected by seasonal farming: in bad harvest years fewer economic resources are available to feed animals, while farmers often apply inadequate pest management strategies that contaminate their honey.

Tzucacab

Several of the problems faced by the municipality of Tekax also affect that of Tzucacab, however the latter does not benefit from the presence of the juice plant and is more oriented to maize production, cattle breeding and beekeeping.

Figure 4.3: Map of localities sampled in Tzucacab



Source: Own elaboration on data from CONABIO (2014)

Tzucacab municipality (Figure 4.3), located to the south-east of Tekax, has a population of 14011 inhabitants, mostly located in Tzucacab (71%) followed by one locality with 949 inhabitants (Catmis), while the rest is distributed in villages with few hundred of people and several individual ranches.

About 55% of the population over 3 years speaks Maya, a value that reaches more than

85% in some medium-sized localities such as Tigre Grande, Ek-Balam, Noh-Bec, and Corral. The average schooling is 6.1 years, significantly below state average (8.2), 16% of the population over 15 years old is illiterate, and 25% didn't complete primary school. Capability deprivation in terms of education is particularly relevant in strongly indigenous communities such as Tigre Grande where 29% of the population is illiterate, Ek-Balam (25%) and Corral (22%). These communities are also highly isolated due to bad communication infrastructure that reduces their ability to take advantage of employment opportunities in the nearby urban area but also increases costs of selling their products. About 90% of households in Tigre Grande and 69% in Noh-Bec also lack sanitation facilities, despite most households were rebuilt and reallocated by the government after Hurricane Isidoro. There are 12 doctors serving the whole population, while 15.3% of the population has no access to health services, and as much as 85% has no social security, deprived in their ability to face distressful times, which is highly correlated to a fundamental instrumental freedom, that of protective security.

Economically active population is employed mainly in the primary sector (50%), tertiary (30%) and secondary (18%). Women are often dedicated to hammock weaving but are constrained by lack of resources and organization to increase production and lack of a stable market demand. The lack of employment opportunities seems to be driving a growing part of the population towards the main touristic area, the Riviera Maya, as mentioned in the diagnostic study (OEIDRUS 2005d) and by key informants, and confirmed by our data.

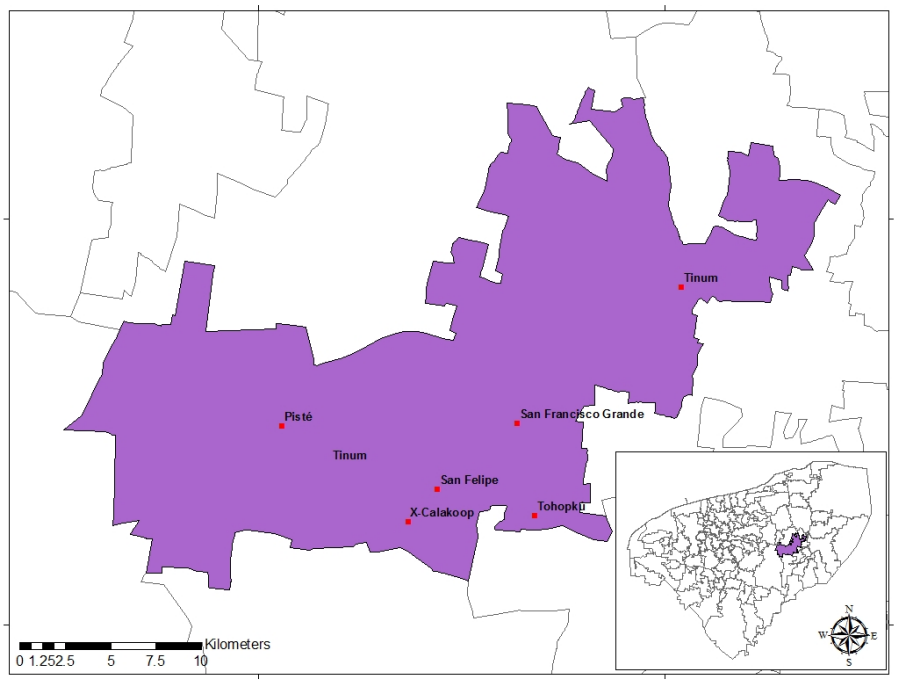
Due to the ancient prevalence of slash and burn *milpa* cultivation, there is a majority of secondary low vegetation, with parts of evergreen forest in southern areas. Some k'ankab reddish soils apt for mechanization can be found near Tzucacab town and especially in the south where Corral is located. Most of the soils are instead ts'ek'el shallow grey calcareous soils that retain humidity and are apt for *milpa* agriculture. Several fauna is found in the evergreen forest, including deer, wild turkey, armadillo, rattlesnake, rabbits, and even coyotes and tigers in very isolated communities. The presence of some *aguadas* or collapsed *cenote* roofs that create small water bodies has incentivized the cultivation of vegetables and fruits and pasture for cattle (OEIDRUS, 2005d). Livestock breeders are organized in a union, but their main constraint is cattle diseases, partly due to lack of training in preventive measures. Several farmers are dedicated to honey and beeswax production, but are affected by pests and

low flowering depending on rainfall and temperature variability. *Milpa* cultivation is mainly for self-consumption usually in small 2 ha landholdings, affected by seasonality and inadequate use of chemicals that contributes to soil degradation. A study by Wyman et al. (2008) finds that major drivers of deforestation and land use change in Tzucacab compared to neighbouring communities include government supported land intensification, incentives to citrus cultivation and better soil conditions for large-scale mechanized agriculture and pasture growth.

The *milpera* region: Tinum

Tinum municipality lies in the central corn-belt (Figure 4.4), the *milpera* region (District 181) where traditional maize cultivation represents 93% of the cultivated area, almost exclusively for home consumption, while other activities are based on beekeeping and artisanal production.

Figure 4.4: Map of localities sampled in Tinum



Source: Own elaboration on data from CONABIO (2014)

The municipality also hosts the main Maya attraction of the state, the vestiges of the ancient city of Chichén Itzá, which constantly attracts large waves of tourists. Pig and poultry farming are carried out at family level, while some people market honey and beeswax.

There are 11421 inhabitants according to the 2010 Census, almost half of them located in Pisté, the metropolitan area that grew around Chichén Itzá, while little more than 2000 people live in Tinum town, followed by San Francisco Grande (1603) X-calacoop (1313), and Tohopkú (541) and the rest are sparsely settled in the remaining 16 localities. About 65% of the total population speaks Maya, with higher incidence in San Francisco Grande (96%), Tohopkú (91%) and San Felipe (81%). In these localities there is also a large part of the population over 5 years old that doesn't speak Spanish (13% in Tohopkú, 8% in San Francisco Grande and 19 over 76 people in San Felipe). The population without access to social security reaches more than 40% in these communities. On average 15% of the population in the municipality is illiterate, with higher incidence in the aforementioned localities (25% of the population in Tohopkú). Some villages, such as San Felipe and San Francisco Grande are quite isolated, with inadequate communication infrastructure and complete absence of local transport, a service operated by taxis.

Due to a rising tourism sector in Pisté, a relevant part of the economically active population is employed in the tertiary (44%), followed by the primary sector (38%), which is based on *milpa* and beekeeping, and the secondary (18%), as many people work in Valladolid or the close Riviera Maya as daily or weekly commuters. Two relevant problems have emerged in Pisté and affected marginally the other villages, mentioned by key informants and in the participatory assessment of the SAGARPA: one is the low diversification of activities, in fact the population is mainly offering food catering and handicrafts, which has brought prices and revenues down; the second is the growing social conflicts due to petty crime and increase of drug trafficking.

Agricultural production is carried out on smallholdings, affected mainly by pests and diseases, lack of capacity to face changing environmental conditions and lack of irrigation. Beekeeping is also affected by inadequate use of pesticides that contaminates honey, with negative consequences for its commercialization (OEIDRUS, 2005c). Lack of organization, capacity building and follow up by government agencies is felt as one of the main problems for economic activities in the area. The isolation and lack of organization of farmers and artisans is also a problem that forces them to sell their products at low prices to outside

intermediaries.

Slash and burn farming in the area is considered the main driver of deforestation, as fallow periods have reduced to 4-6 year cycles of regeneration, leaving only low secondary forest and scattered remnants of deciduous forest in peripheries of the area, without any environmental protection scheme (SEMARNAT, 2003). Vegetation is in fact the typical low deciduous forest left by *milpa* cultivation, with local varieties such as Ramon (breadnut or Maya nut), Ceiba (the sacred Maya tree), mahogany and cedar. Local fauna consists of reptiles and small mammals, often threatened by illegal hunting. While *milpa* agriculture has been decreasing, the rise of the handicrafts sector is posing new threats to the remnants of precious woods in the area given the absence of conservation actions. Both in the diagnostic study (OEIDRUS, 2005c) and in conversations with people in the community it emerged that people have to look for wood in other areas, increasing their transactions costs, because of the results of slash and burn agriculture unsustainable tree cutting for handicrafts. A conservation policy that take into account economic needs of stakeholders whose dependence on provisioning goods is conflicting (*milpa* agriculture and beekeeping or precious wood for instance), for instance creating employment in reforestation of local varieties, monitoring of tree cutting, and development of agroforestry, would be badly needed in the area.

4.1.2 The household survey

The household survey was developed through interviews with people from the communities, academics, and development practitioners, previous surveys carried out by researchers at the Universidad Autonoma de Yucatán (UADY), survey modules from the Oxford Poverty and Human Development Initiative (OPHI) and other surveys focussing on agrobiodiversity. The household survey covers different areas of well-being and environment relevant in the area of study: demographic data; migration; livelihood assets; household expenditure; dietary diversity; availability, production, marketing, use and consumption of native cultivars; perceptions on native cultivars (enriching/cultural services) and on agriculture as a source of decent work (Annex III). Farming households in the Yucatán are characterized by a gendered division of labour (Schmook and Radel, 2008): the part of the survey dealing with household demographics, migration, assets, expenditure, dietary diversity and perception of well-being was carried out with the farmer's spouse or the person who was attending the house, usually

interviewed by female surveyors while the husband was interviewed by another interviewer in order to make the interview more comfortable. The household survey is reported in Annex III.

The survey was validated and adapted for language and concepts through a preliminary application to randomly selected households from three communities and revision by practitioners and academics knowledgeable of the area, its dynamics and who already conducted surveys in the region. Four students from the Faculty of Economics of the UADY were enrolled from the end of February 2012 to the beginning of June 2012 to pre-test and administrate the survey. They were trained and mentored during our travels to the communities on weekends, and worked in couples.

Survey administration was planned according to the availability of sampled households. The first time we entered a community, we would meet the farmers' leader (*comisario ejidal*), ask for permission to carry out surveys in the area and obtain farmer's addresses. Households were then approached and when permission was granted they were interviewed directly (face to face). The part relating to farming, animal husbandry, agrobiodiversity, agriculture and employment was submitted to the head of household, usually a man. If he was absent, a date to come back was agreed and the interview carried out with him at that time.

4.1.3 Sampling strategy

The population of the four communities from which the stratified sample was drawn is composed of 184 farms with irrigation and 5288 farms without irrigation, according to lists from PROCAMPO and *Adquisición de Activos Productivos* (*Alianza para el Campo*) which cover more than 90% of farmers in the Yucatán peninsula incorporating a range of geographic, agro-ecological, social and market diversity that characterizes the state [27]. The communities include five towns with more than 2500 inhabitants (Tekax, Motul, Tzucacab, Pisté, and Kancab), while the rest are rural villages, some with less than 100 inhabitants. The

[27] Information on beneficiaries and number of producers can be retrieved from:
http://www.inegi.gob.mx/prod_serv/contenidos/espanol/bvinegi/productos/integracion/pais/aepef/2010/Aepef2010.pdf
http://subsidiosalcampo.org.mx/
http://Yucatánahora.com/noticias/-analisis-padron-procampo-19815/

survey sample was stratified to represent the irrigation and non-irrigation farmers in the four municipalities[28].

The sample size was 185 irrigated farms and 94 non-irrigated farms in 39 villages, however the households interviewed were 260 because there were no more farmers to interview in some villages, particularly in Sudzal Chico in the Southern Cone, despite being enlisted in public support programmes, and in some villages of Motul municipality[29]. Households within each stratum were sampled using simple random sampling. The whole sampling design is available in Annex I. Sampling weights are applied for estimation of means, variances, standard errors, and confidence intervals, following analysis of household surveys described in Deaton (1997), but not for descriptive statistics. A complex sampling strategy was chosen to have an adequate number of households with the targeted characteristics (water and land availability that influence production practices, choice of crops and productivity) and be able to have variation in productive resources, conversion factors and opportunities at the household, village and landscape level, which according to our framework contribute to determine the level of agricultural diversity managed and influence the intensity of use of on-farm and off-farm ecosystem goods.

Table 4.1 shows the number of interviews conducted in each municipality. After data collection, data entry was carried out using MS Excel software. The dataset was then exported into STATA 12 for analysis. Data cleaning was an iterative process throughout the data entry and analysis phases.

[28] This disproportionate sampling introduces a bias in the sampling frame by over or under-representing some groups of the population. Because this is done on purpose in order to be able to take into account key variables of interest, sampling weights are applied in the estimation of means, variances, standard errors, and confidence intervals. The survey command in STATA 12 (svy) is used to declare survey design and sampling weights. Sampling weights are the inverse of the likelihood of being sampled and compensate for unequal probabilities of selection by inflating the impact of those groups that are under-represented, and deflating the impact of those that are over-represented so that the original population is approximated. This reduces bias induced by the sampling design as it takes into account the number of individuals in the population that a sampled individual represents. The weighted sample distribution is therefore adjusted for the key variables of interest to conform it to the known population distribution. The "subpop" command is applied to analyze subpopulations in the dataset. The advantage of this command is that the calculation of estimates is based only on the cases defined by the subpopulation, but all cases are used in the calculation of the standard errors. Cochran (1997) shows the importance of correcting mean values for design effects when simple random sampling is not applied. An example of correction for stratification and weighting in the analysis of crop diversity can be found in Benin et al. (2004).

[29] The reason for this is that they moved to urban areas and were not cultivating the plot, at least in 2011 and 2012, but they were still receiving support due to an inefficiency of the programmes, which are meant for households who are actually cultivating the plot.

Table 4.1: Households interviewed by municipality

Municipality	Irrigation		
	No	Yes	Total
Motul	34	0	34
Tekax	51	60	112
Tinum	44	0	44
Tzucacab	43	27	70
Total	173	87	260

Source: Survey data

4.2 Summary statistics for the four municipalities: conversion factors, capabilities and endowments

In this paragraph we look at households characteristics and subsequently at how they are linked to agrobiodiversity and how they shape the multiple use strategy. We focus on age, sex, cost of transport, and type of soils as conversion factors; education, type of employment, migration, and being able to be adequately nourished as capabilities; and household and farm resources as endowments.

4.2.1 Demographic characteristics, education and Maya roots

Our sample shows that the Yucatec peasant population is characterized by ageing farmers (Table 4.2): the average age of household heads is 57 years while the average age of household members is 41. The data is similar in the four municipalities and shows a distress of the agricultural sector, which is led by older farmers while youth tends to abandon agriculture for off farm employment opportunities, an issue that we will expand throughout the Chapter.

A village level measure of population ageing from the 2010 Census shows that although the percentage of individuals over 60 years in the four municipalities is 9% on average, in some villages it reaches 17%, such as in Mesatunich and Kinì (Motul); 14% in Tinum; 17% in Dzi and 12% in Tzucacab; and as much as 19% in Nohalal (Tekax).

Table 4.2: Age and schooling

Variables	Total		Motul		Tekax		Tinum		Tzucacab	
	Mean	Std dev	Mean	Std dev	Mean	Std dev	Mean	Std dev	Mean	Std dev
Nr of household members*	4.43	2.22	4.09	2.08	4.69	2.28	3.93	2.14	4.50	2.21
Age of household members	41.00	16.89	45.96	18.04	39.26	16.91	44.30	18.28	39.31	14.81
Age of HHH	57.58	12.54	60.00	12.73	57.22	13.60	57.61	12.49	56.94	10.71
Years in schooling (adults)	5.34	3.05	4.83	3.12	5.51	3.10	5.24	2.86	5.38	3.09
Years in schooling (HHH)	4.25	3.72	3.79	3.25	4.31	4.15	4.98	3.07	3.91	3.56
Years in schooling (spouse)	3.42	3.38	2.81	3.28	3.52	3.44	3.50	3.41	3.53	3.36

* One outlier omitted

Source: Survey data

Households sampled in these villages are also those where we found higher levels of migration, strong Maya roots and low levels of human development in terms of education, health and employment opportunities.

About 17% of individuals in the sample are illiterate, 20% when we consider women (Table 4.3). Deprivation in terms of education is higher for older people and in fact 23% of household heads are illiterate while most of them only attended primary school (61%), in many cases just for the first one or two years (Table 4.3).

Table 4.3: Education level of people 15 years and older by gender and HHH

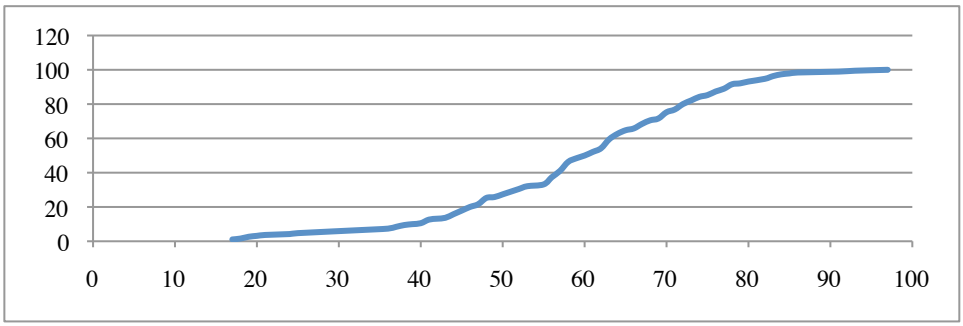
Education level	Total		Men		Women		HHH	
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
None	160	17.32	72	15.19	88	19.56	60	23.08
Primary (6 years)	379	41.02	196	41.35	183	40.67	158	60.77
Secondary (3 years)	219	23.7	105	22.15	114	25.33	24	9.23
Preparatory (3 years)	133	14.39	82	17.3	51	11.33	12	4.62
University (4-5 years)	33	3.57	19	4.01	14	3.11	6	2.31
Total	924	100	474	100	450	100	260	100

Source: Survey data

This is not surprising considering the advanced age of household heads and that many

dropped out of school early to work on the fields. This is also shown by the fact that illiteracy levels are concentrated in the age range between 55 and 80 years (Figure 4.5).

Figure 4.5: Cumulative frequency of age of illiterate people



Source: Survey data

Anecdotic evidence from key informants in the communities links many farmers' inability to read and write to difficulties in accessing public support programmes, and however local public agents are meant to help farmers fill out their forms it often becomes a cause of conflict especially in municipalities where political belonging is an issue.

Some differences in higher education seem to have a gender dimension: 17% of men attended preparatory school against 10% of women. Among women attending the house, 48% of them have reached primary level of education (often not completed), while 26% of them are illiterate. About 15% of women in the sample have reached upper secondary or university level: a third of them were still pursuing their studies at the time of the survey and a third were employed in petty commerce, services or *maquiladoras* mostly in urban areas (14/23). The rest was attending the household, even after studying for university or having a university degree. This might be an indicator of capability deprivation linked to social opportunities based on a conversion factor, sex, that can prevent women from taking advantage of their education level because of lack of employment opportunities or because of gender roles still well defined in social norms. On the other side it might as well be their own choice, unrelated to these factors. The complexity of household and individual characteristics, family strategies and arrangements in relation to employment can all be determinant factors of this choice and are beyond the scope of this thesis. Aguayo and Lamelas (2011) find that gender employment disparities are higher in areas devoted to agriculture in Mexico and with lower economic development.

In one of the villages sampled, San Pedro Chacabal, a community with strong Maya roots, some of the girls were not attending preparatory school despite they wanted to because their parents would not let them ride a bike to the closest town where the preparatory was located. Paying for transport would have been a burden and was also felt as an unsafe option. The reason was based in the fear that being young girls travelling alone something could happen to them on the way, which would not be unusual. The absence of a formal school transport service, low economic resources and the lack of an appropriate institutional protection framework, including juridical actions, prevent these girls from achieving their valued well-being outcomes.

Another important aspect of the Yucatec population is its indigenous culture, especially strong in rural areas. Only 13 families sampled were not of Mayan descent. Presence of Maya speaking members at the household level is higher in localities with strong traditional roots such as Tinum, San Felipe, Kancab, Xaya, Escondido, Corral and San Pedro Chacabal where the language is spoken by more than 90% of the population sampled, mirroring census data. However, the data for young people shows a trend of abandonment of the language: in our sample 82% of adults speak Maya while only 45% of people under 18 and over 5 years old have learned the language. The majority of them are still attending school, in fact only ten boys work as farmers and four girls stay at home. Table 4.4 shows that in terms of education opportunities at village level these families are located in areas where there is higher percentage of people over 15 years who didn't complete primary school and of people over 5 years who do not speak any Spanish. There seems therefore to be an association between being a household with stronger indigenous roots, where even young people speak Maya, and indicators of education deprivation at the community level and economic poverty at the household level. One should note that we are comparing between peasant Mayan households, and not Mayan against non-indigenous families, where these differences are likely to be higher. The UNDP report on inequality of opportunities for indigenous people in Mexico (UNDP, 2010) in fact finds that indigenous young people in particular have lower education, economic and health opportunities than non-indigenous people. There has been a recent wave of recognition of the value of Maya culture, with particular interest from the tourism industry given the advent of December 2012, which according to the most common interpretation of the Mayan calendar represented a turning point in the history of mankind. How much of the

government attention linked to tourism development will help increase substantial freedoms of indigenous people in Mexico is a question open for research.

Table 4.4: Selected characteristics of households with members under 18 and over 5 years old who speak and do not speak Maya

	Households with people under 18 who do not speak Maya (n=63)		Households with people under 18 who speak Maya (n=51)		
	Mean/Perc	Std. Err.	Mean/Perc	Std. Err.	*F*-statistic
HHH with primary education	0.57		0.54		0.11
Average years of schooling (adults)	4.98	0.54	4.23	0.46	1.10
Percentage of households falling under the economic poverty line	0.89		0.91		0.03
Urban household	0.25		0.21		0.13
Percentage of households in villages with above average population without completed primary education	0.47		0.70		4.32**
Percentage of households in villages with above average population who doesn't speak Spanish	0.36		0.58		3.52 *

* $p < 0.05$, ** $p < 0.05$, *** $p < 0.01$

The F-statistic is shown for differences across means. The Pearson's chi-squared test statistic is shown for characteristics that are percentages

Outliers are excluded from calculations.

Source: Survey data

4.2.2 Employment opportunities

From a capabilities' perspective, the ability to choose between alternative employment opportunities can entail two aspects: on one side the availability of employment opportunities can represent an opportunity freedom, the freedom to choose among different alternatives, on the other side, if opportunities are available, they represent capabilities which one can choose to activate or not.

The employment profile of people 18 years and older brings in evidence some emerging patterns: Table 4.5 shows that two thirds of men in the sample work in the agricultural sector, 18% in services, and 5% in construction or assembly plants. However, when we leave out the household heads, all of which are engaged in farming as their primary or secondary occupation, about 40% of adult men report themselves as farmers, and only 10 of those whose main occupation is outside agriculture report working on farm as a secondary

occupation.

Table 4.5: Main occupation of people 18 years and older by gender

	Men		Men excluding the HHH		Women	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
Agriculture	288	0.67	75	0.41	6	0.01
Construction or industry	22	0.05	14	0.08	11	0.03
Petty commerce and services	79	0.18	59	0.27	69	0.17
Retired	13	0.03	8	0.04		
Attends the household					310	0.75
Student	31	0.07	31	0.17	15	0.04
Total	433	1.00	187	1.0	411	1.00

Source: Survey data

Those employed in agriculture work on their own plot or ranches, while only few are day labourers. People in services work in the public sector as teachers or government agencies' employees, in petty commerce, taxi and pedicabs, which are special bicycles for two or more passengers, while in the secondary sector they work in construction or in the Lee and Southern Valley *maquiladoras* in Tekax. Off farm employment opportunities are higher in urban areas: 54% of people over 15 years are employed in agriculture in urban areas against 68% in rural ones, while 38% of them work in petty commerce or services in the cities against 26% in rural areas. There is no significant difference in the percentage of household heads employed in agriculture in rural and urban areas (86% against 83%), therefore the employment diversification trend seems to be led by younger people. Table 4.5 also indicates that 21% of women 18 years and older perform their main activities outside the household, mainly petty commerce in small family shops or food kiosks (30%), as housekeepers (20%), dressmakers (10%), or in the textile *maquiladoras* in Tekax (10%). Moreover, there are 32 women whose main occupation is taking care of the household but also carry out a secondary occupation: they weave hammocks or *hipiles*, the traditional dress for women, sell traditional food or attend the family shop, and a third say their second activity is farming.

Table 4.6: Sector of occupation by municipality

Main occupation	Motul		Tekax		Tinum		Tzucacab		Total
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent	
Primary	33	0.62	133	0.62	38	0.51	97	0.69	301
Secondary	9	0.17	20	0.09	1	0.01	3	0.02	33
Tertiary	11	0.21	62	0.29	35	0.47	41	0.29	149
Total	53	1.00	215	1.00	74	1.00	141	1.00	483

Secondary occupation	Motul		Tekax		Tinum		Tzucacab		Total
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent	
Primary	16	0.64	41	0.59	17	0.55	31	0.61	105
Secondary	4	0.16	9	0.13	5	0.16	4	0.08	22
Tertiary	5	0.2	20	0.29	9	0.29	16	0.31	50
Total	25	1	70	1	31	1	51	1	177

Source: Survey data

Among people older than 15 who are occupied in a productive activity we find trends following economic specialization of the municipalities (Table 4.6): the percentage of people employed in agriculture as main occupation is higher in Tzucacab where other employment opportunities are scarcer, while it is lower in Tinum, where a significantly higher percentage of people are employed in the services sector due to the presence of the archeological area of *Chichén Itzá*. Also, employment in the secondary sector is more common in Tekax (8%) and Motul (5%), due to the presence of *maquiladoras*. In terms of secondary employment, occupation in petty commerce, transport or tourism related activities is common in all municipalities, with fewer people in the secondary sector, mainly construction.

Forty-five household heads (17%) say farming is their secondary occupation. Their main activity is petty commerce (20%), teaching or employment in government agencies (17.5%), construction (15%), taxi and pedicabs, handicrafts or other. They are significantly younger and more educated as shown in Table 4.7a: the average age of the household heads is 63 years when they work only on farm against 50 years if they also work off farm. Moreover, the average years of schooling attended by the head and adults are higher in households where the household head works off farm.

Table 4.7 a: Household age, education versus off farm employment of household head

	HHH doesn't work off farm (n=131)		HHH works off farm (n=129)		
	Mean	Std. Err.	Mean	Std. Err.	*F*-statistic
Age of adults	51.361	1.580	41.865	1.046	25.11***
HHH with primary education	0.175		0.278		7.47***
Years of schooling adults	4.768	0.325	5.714	0.337	4.14**

* $p < 0.05$, ** $p < 0.05$, *** $p < 0.01$

The F-statistic is shown for differences across means.

Source: Survey data

It is interesting to break down the data between household heads whose main employment is off farm and those who undertake other jobs but are primarily dedicate to farming (Table 4.7b). This differentiates the type of opportunities and choices that they made: those who are working primarily off farm have decided to maintain their on farm activities as a source of food and additional income, but most of their revenues derive from a different activity. On the other side, others are principally working on their farm but need to complement it with off farm work on a seasonal or necessity-driven basis: the choice seems rather driven by the difficulty of living off just the products of the plot. Finally, for those who only work on farm, it might be that they are able to satisfy their needs just with that, but it might also be that there are no alternative income opportunities, or that they cannot take advantage of them due to lack of education or resources.

From a capability perspective, those who can make the choice over alternative sources of employment have a potentially larger capability set than those who can't, independently of the reason why this choice is made. The others might be constrained because of conversion factors (age, health, lack of adequate communication infrastructure etc.) or of a smaller capability set (lack of employment opportunities, low levels of education etc.) or lack of endowments (for instance a vehicle or a shop). For instance, household heads working off farm, both as primary or secondary employment, are significantly younger than those who do not (Table 4.7 b). However, only the education level of those whose primary employment is off farm is significantly higher compared to those with secondary or no off farm employment, and this is true also for the education level of adults and spouse. There seems therefore to be

an element of opportunity freedom that differentiates the choice of primarily working off farm from the others: these people apeear to have taken advantage of their higher education level and the availability of other employment opportunities.

Table 4.7 b: Household age, education versus off farm employment of household head as main or secondary activity

	A. HHH doesn't work off farm (n=131)		B. HHH works off farm as secondary job (n=92)		C. HHH works off farm as primary employment (n=37)					
	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.	*p-value* B vs A	*p-value* C vs B	*p-value* C vs A	*F*-statistic Joint
Age of adults	51.36	1.58	42.75	1.30	39.53	1.62	p<0.01	ns	p<0.01	15.19***
HHH with primary education	0.34		0.49		0.76		p<0.10	p<0.05	p<0.01	6.62***
Years of schooling adults	3.14	0.38	4.24	0.41	6	0.64	ns	p<0.01	p<0.01	7.53***

* p < 0.05, ** p < 0.05, *** p < 0.01

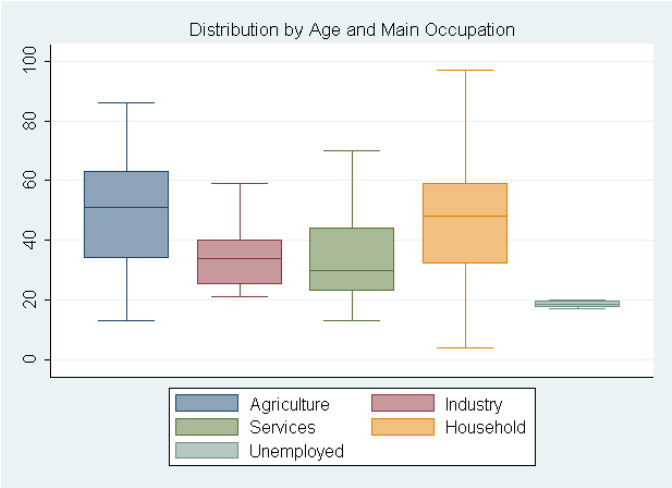
The F-statistic is shown for differences across means.

Source: Survey data

According to data from the National Institute of Statistics (INEGI) in 2002 there were 145,367 people dedicate to agricultural activities in the Yucatán while in 2010, the number fell to 99,725, a 31% drop. Following global trends, younger and more educated individuals look for jobs that seem more in accordance with their aspirations or economic needs. The box plot in Figure 4.6 shows that the average and median age of people working in agriculture is significantly higher than within the other sectors. The average age of those working in agriculture is in fact 49 years old against an average of 35 in the secondary and tertiary sector. Younger households also have fewer people dedicated to farming, often only the household head.

Based on our analysis it appears that young people who have on average a higher level of education than their fathers and changing views of quality of life are less likely to work on farm partly because of different opportunities open to them, but also because of a reduced cultural bond with the land, which instead characterised their fathers, many of which have chosen to stay on farm out of necessity but also tradition (see next paragraph).

Figure 4.6: Age and main occupation



Source: Survey data

There seem to be two trends: where the household head is younger and more educated he might work outside agriculture, but still attend the family plot or delegate someone to do it. These are people who have grown up in a farming household and have learned how to work on the plot in their youth. On the other side, there is the young generation, most of which did not work on the plot because they or their fathers didn't think it was useful or necessary as they were supposed to be in school, which would open other employment opportunities in the future. Therefore, people from the older generation coming from a farming family are able to attend the plot or to return to it during their retirement years because they have the knowledge necessary to work on the plot. Most of the younger generation instead, will not be able or willing to come back to agriculture, even as a secondary occupation or in their retirement, because they lack the associated knowledge and are looking for different life opportunities. While many researchers in the Yucatán say this trend has been seen for the past thirty years and yet traditional agriculture has not been abandoned, the current young generation doesn't see agriculture as a source of decent work and living conditions. The expansion of the capability set for young people through education and alternative employment opportunities, even through migration, shows that agriculture in the Yucatán, especially at small-scale level and with low or inadequate inputs, is not a source of decent work[30].

[30] "Decent work sums up the aspirations of people in their working lives. It involves opportunities for work that is productive and delivers a fair income, security in the workplace and social protection for families, better prospects for personal development and social integration, freedom for people to express their concerns,

It is true that there are many families where at least one member under 30 is a farmer as a main or secondary occupation: 68 households in our sample, 22 if we consider members under 20. Forty of these households are mechanized plots planting maize hybrids that provide higher yields, while only 22 grow native maize and other local crop varieties. The pool of people who are maintaining genetic crop resources on farm is getting narrower by the day. The challenge in addressing decent work in rural areas lies in a series of interrelated issues: poor economic rewards, low productivity, self employment and informality, casual or temporal wage employment, lack of insurance against sickness, accidents and unemployment, lack of social security, employment of child labour, hazardous practices, climatic risks and uncertainties of agricultural production, seasonal migration, information asymmetries, gender and age-based inequalities, and limited representation and participation in the political and development agenda (ILO 2012, ILO 2010, Carte et al. 2010, ODI 2007).

If ways to make agriculture a decent work and an attractive, sustainable alternative are not implemented, associated knowledge and diversity of genetic resources, especially of maize, beans, squash and local fruits that have provided subsistence, income and cultural values for thousands of years and might still have unknown value in the face of future changes and opportunities, will be lost. The option value of this crop diversity might be important for instance for climate change adaptation: several farmers grow different varieties of landraces to face the uncertainties of rainfall and for their resistance to pests and diseases even with poor storage conditions. Moreover, local varieties of beans, squash and especially maize have an undeniable role in the culinary tradition, the preferences, and the cultural and spiritual life of the heirs of Mayan civilization. The fact that there are different tortillas during the year according to the harvesting time of maize varieties, and they all have specific culinary and cultural functions is a cultural heritage that cannot and should not be lost. Despite these values seem to become less relevant with the integration of young people in the global economy and the change of consumption preferences, they are festures of crop genetic resources that make them semi-public goods that should not be managed and conserved only by private agents, who should be rewarded for the value they provide to society.

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organize and participate in the decisions that affect their lives and equality of opportunity and treatment for all women and men" (ILO, website statement: http://www.ilo.org/global/topics/decent-work/lang--en/index.htm).

4.2.3 Farmers' perception of work in agriculture

In order to better understand what are the problems that farmers face in this centre of crop domestication we asked farmers their perceptions on working in agriculture: 250 farmers responded to this open-ended question in the survey. Half of them state they work in agriculture out of tradition rather than choice and 15% because they like it. Several farmers talked about agriculture with emotional attachment, as a source of their cultural identity and the life that was meant for them since they were young because they were following family traditions. However, 25% of them stress it was not a choice but a necessity due to lack of education or of other employment opportunities. Representative responses were "*it's the only thing I know how to do because I didn't study"* or *"It is where I come from, where I live, I like it*" and "*there are no other employment options in the village"*. Moreover, they often mentioned that when agriculture is viable and people work hard and know how to work the land adequately, there is no need for leaving your place of origin and migrate in search of employment, which can be felt as a dramatic choice. Some also shared the opinion that working on farm lets you stay away from gangs and petty crime and that it prevents you to become *vago* (lazy).

Secondary jobs are vulnerable employment that does not provide a solid source of livelihood, but are rather part of a coping strategy where subsistence is satisfied by *milpa* production, while other household basic necessities can only be satisfied when these small jobs are available. This vulnerability of households practicing traditional *milpa* agriculture is one of the reasons why the young generation is leaving the fields looking for better fortunes and decent living conditions, and is one of the reason farmers stated for not wanting their sons to keep working on the plot, or that agriculture is not a good employment opportunity because without support, training and productive assets '*no deja, uno no se puede levantar'* - it doesn't provide enough, one is not able to lift one off (poverty).

If we focus on those whose main occupation is not on farm (45 farmers) we find that none thinks agricultural revenues are good, but bad or regular, meaning they are just enough for survival. Even if they are mainly occupied somewhere else they say that the main reason for maintaining the plot lies in tradition and custom, while the rest say that it is out of necessity, to save something on food expenditure. About half of them (20) feel that work on the fields is

part of their cultural heritage, "*por tradición, por costumbre*", it is where they grew up and it is a 'tranquil' occupation that enables one to have a stable source of food, but that it is just enough for that. In fact, the rest of them feel agriculture is not a good employment opportunity precisely because it doesn't give anything more than food for survival. They mention that the problem of agricultural work partly lies in inadequate support by the government to make necessary investments. Other respondents whose main activity is farming also shared the opinion that most of public support doesn't reach the farmers because it stays caught up in bureaucratic traps and political controversies, sometimes to the point that subsidies reach them with difficulty if they belong to one political party or the other.

Finally, related to our previous discussion on agriculture as decent work for young people, 61% of farmers said they taught their sons how to work on farm, but in only 26% of these households their sons are actually dedicated to farming as main or secondary activity. A quarter of farmers taught their sons in order to give them an employment opportunity, in many cases they say "*so they know how to do something if they do not find any other jobs*". More than half of farmers however do not wish their sons to work in agriculture because they think pursuing education or finding another employment would be better for them. There is therefore a wide perception that agriculture is not an employment opportunity that can satisfy the young generations' aspirations and needs.

4.2.4 Migration opportunities

The necessity to leave one's place of origin in search of employment opportunities entails two aspects under a Capability Approach perspective. On one side it can be a symptom of lack of employment opportunities that match one's desires or needs, therefore a deprivation within a certain socio-economic context. On the other side the ability to take advantage of employment opportunities through migration has a positive aspect as opportunity freedom: for those with the ability and the opportunity to migrate to benefit from desired employment, the capability set of the individual is expanded from a previous situation if it was constrained by lack of real alternatives or lack of the work desired. The individual therefore makes a choice to activate this capability given conversion factors, for instance age and physical ability, resources available, for instance for relocation, other household characteristics, and personal motives. We do not take into consideration the effects on social or family ties as this

is beyond the scope of this study, but we will take into account the relationship between migration opportunities and choices concerning agrobiodiversity made by households where members have emigrated.

There is few although growing international migration: this is a recent phenomenon in the Yucatán (Cornelius et al., 2007) and specific to certain localities as already mentioned. Within all households sampled where at least one member migrated (56 households), only one person migrated to Canada from Tinum and one to the US from Tzucacab. Instead, there is strong intra- and inter-state migration: 57% of migrant households have relatives in Cancun in the coastal Riviera Maya in the bordering state of Quintana Roo, 26% in Merida, the state's capital, and 30% in other places of the peninsula. Three households report that all their children moved to Cancun, while in 39% of households only one member migrated, in 22% two members, and in 14% three members. Only in one household sampled the migrating member was the household head as he was migrating seasonally.

According to some authors, the migration from rural areas to the Riviera Maya in search of employment opportunities has been driven by policies that urbanized areas with touristic potential and marginalized rural areas with traditional agriculture (Torres and Momsen, 2004; Wilson, 2008; Carte et al., 2010; Anderson and Anderson, 2011). Carte et al. for instance analyze through in-depth interviews the decision making process that migrants in the adjacent state of Quintana Roo faced when deciding to move from the country side and abandon agriculture to be employed in the tourism industry of the Riviera Maya. One of his findings is that the process was not joyous but a pragmatic response to the agricultural crisis as work on the fields within the conditions of smallholder farmers in Mexico does not offer more than basic survival. Also, they find that agriculture as a livelihood is strongly perceived as a failure also due to lack of support and incentives from government policies while the tourism industry is perceived as offering better livelihood opportunities. In our sample, from an adjacent state to that of Quintana Roo studied by Carte et al., we find further supporting evidence to their interpretation. It appears in fact that localities with a strong agricultural past are particularly affected by migration in the sample: half of households where at least one member has migrated come from villages in Tzucacab and one fifth from Tinum town, which have been both areas dedicated mainly to agriculture in the past. Both migratory movements

are directed mainly towards the Cancun and the Riviera Maya, the coast in Quintana Roo, a bordering Mexican State where a least 8 million (OCDE, 2008) of tourists arrive every year from around the world. This is easy especially for households in Tinum, which in two hours' drive can be in Cancun. Despite its administrative role, the town of Tinum is characterized by lack of basic services, political conflict and few employment opportunities outside traditional agriculture or the tourism market in Pisté, which is focussed on one attraction and is becoming saturated as already mentioned. Migration in Tzucacab municipality seems to be led in part by the high level of marginalization of localities where many households lack basic services and are located in areas of difficult access, such as Corral or Blanca Flor, but also by lack of employment opportunities outside agriculture in the main urban centre, the town of Tzucacab, where 15 over 29 households sampled have family members in the Riviera Maya.

Instead, there are few migrants from the main urbanized areas that are characterised by higher diversification of the job market, Tekax and Motul. In Tekax municipality the large urban area offers employment alternatives in *maquiladoras*, services, and some tourism, but also better marketing opportunities for agricultural products thanks to vicinity of the large regional fruit and vegetable market of Oxkutzcab and the presence of the juice plant of Akil. In Motul, the presence of a *maquiladora* and the closeness to the state's capital provide different employment opportunities, however some localities such as Ucí are affected by strong migratory movements directed to the United States, as mentioned in the opening paragraph of this Chapter.

In 7% of households sampled one or more members commute to other localities where they are employed during the week, but come back on the weekend, basically working in Merida, the capital, or in Cancun, on the coast. Eleven percent of households sampled both in Motul and Tinum have one member who commutes, in fact they are closer and better connected to Merida or Cancun than the other municipalities. Moreover, the prevalence of seasonal agriculture determines the need for many rural families to combine farm and off farm activities or temporal wage agricultural labour out of the community after the harvest. From key informants' interviews and farmers' response it emerges that there are in fact temporal waves of migration to the coast or the capital after the end of the productive season.

About 40% of migrants' households receive remittances, which are quite low: these are spent almost exclusively on food (22/23 households), few households spend them also on other daily household expenditures or offspring education (6 and 4 households respectively), while none reported spending them on plot improvements. A third of migrants send in kind gifts to the family, mainly non-perishable food for the pantry and goods for the house.

Finally, we asked interviewed households why their relatives moved to another part of the peninsula: 42 out of 56 people said it was for lack of employment opportunities alternative to agriculture. The perception that agriculture is a 'failed livelihood' and that better employment opportunities can be found somewhere else is a strong motive for its abandonment, both for migrants and for those that chose another type of employment in their own community.

4.3 Multiple use of agrobiodiversity in the four municipalities

We have seen in Chapter 3 how the multiple use of agroecosystems implemented by Mayan farmers has recently been the object of study by ecologists, economists, geographers, anthropologists and others, to understand their appropriation of nature (Toledo et al., 2003; Arias et al., 2004; Barrera-Bassols and Toledo, 2005; Roy Chowdury and Turner, 2006; García-Frapolli et al., 2008; Schmook and Radel, 2008; Wyman et al., 2008; Radel et al., 2010; Busch and Vance, 2011). In this analysis, we enter this literature by understanding the relationship with agrobiodiversity and the ecosystem services it provides within the regional context and differences of the Yucatán state, using the lens of an Extended-Capability-Ecosystem-Approach.

4.3.1 A diversity of management systems

We argue that Yucatec peasant households manage a diverse range of farming systems and landscape units based on their environmental conversion factors, in particular soil type and quality, availability of forest areas and level of biodiversity, different agricultural endowments they have access to, such as land area, farming inputs, animals, labour available, their personal characteristics and preferences but also the socio-economic environment in which they make their choices. Table 4.8 shows a summary of farming systems, livestock and

off farm ecosystem goods used by sampled households in the four municipalities. Just over half of households sampled cultivate *milpas* in traditional slash and burn systems, whereas mechanized *milpa* is only practiced where environmental conversion factors allow it, specifically in the form of deep, rich alluvial soils without stones. In our sample, these types of soils are limited to the southern hill areas of Tekax and Tzucacab, where about half of sampled households practice mechanized agriculture. A third of farmers cultivate permanent croplands in the form of fruit plantations, mainly in Tekax and Tzucacab, where the government developed the citrus cultivation plan in the sixties, as mentioned in Chapter 3. Most households sampled have a homegarden surrounding their house, but we can see that this is becoming less common in highly urbanized areas, such as Tekax and Motul town, with less space for the homegarden.

Table 4.8: Frequency of different land uses and activities

Type of land use	Overall		Motul		Tekax		Tinum		Tzucacab	
	Freq.	Perc.	Freq.	Perc.	Freq.	Perc.	Freq.	Perc.	Freq.	Perc.
Cultivated Plots										
Traditional *Milpa*	146	0.56	34	1.00	32	0.29	44	1.00	36	0.51
Mechanized *Milpa*	86	0.33	0	0.00	50	0.45	0	0.00	36	0.51
Fruit Plantation	61	0.23	1	0.03	41	0.37	2	0.04	17	0.24
Henequen	12	0.05	12	0.35	0	0	0	0	0	0
Homegarden	205	0.79	32	0.94	77	0.69	32	0.73	62	0.89
Livestock										
Cattle and sheep	52	0.20	5	0.15	14	0.13	3	0.07	30	0.43
Honeybees	67	0.26	4	0.12	28	0.25	11	0.25	24	0.34
Poultry	160	0.62	15	0.44	71	0.63	29	0.66	45	0.64
Pigs	20	0.08	1	0.03	8	0.07	6	0.14	5	0.07
Forest goods										
Firewood	239	0.92	31	0.91	102	0.89	38	0.86	68	0.97
Huano palm leaves	71	0.27	0	0.00	25	0.22	10	0.23	36	0.51
Game	40	0.15	5	0.15	13	0.12	7	0.16	15	0.21
Wood	20	0.08	0	0.00	9	0.08	1	0.02	10	0.14
Medicinal plants	20	0.08	3	0.09	6	0.05	4	0.09	7	0.10
Wild fruits	11	0.04	1	0.03	2	0.02	2	0.05	6	0.09
Manure	10	0.04	4	0.12	2	0.02	0	0.00	4	0.06
Coal (wood)	6	0.02	3	0.09	1	0.01	1	0.02	1	0.01
Fodder	1	0.00	1	0.03	0	0.00	0	0.00	0	0.00
Total Households	260	1	34	0.13	112	0.43	44	0.17	70	0.27

Source: Survey data

As much as 92% of farmers collect firewood, mainly for cooking, many collect palm leaves for their house roofs, while few collect fodder and produce carbon for commercialization. Hunting is more common in areas where off farm biodiversity is higher, especially due to the presence of forest, while collection of medicinal plants, wood for commercialization and fruits is less common. Households in Tzucacab area seem to derive the largest diversity of ecosystem goods from their environment. In fact, the municipality is endowed with secondary and mature forests (*monte alto*) with high biodiversity that provides diverse tree species, wild fruits, medicinal plants, flowers, animals, and space to place beehives during the flowering season. In the municipality, half of farmers sampled have traditional *milpas* and the other half mechanized ones, while a third of them complement it with orchards or permanent croplands. Livestock breeding and beekeeping are quite common in the area, as well as the use of different forest resources, especially firewood, *huano* leaves to repair traditional roofs, wood for construction, but also game hunting and collection of wild fruits and medicinal plants. Among the main problems faced by farmers in the area according to interviews and the participatory diagnostic carried out in 2005 (OEIDRUS, 2005d), draught strongly reduces yields from seasonal *milpas* but also affects wild flowering, reducing nourishment for bees and honey production, that along with pests, lack of training and low organization affect farm profitability.

In Tekax, fewer farmers cultivate traditional *milpas* as they have taken advantage of specialization opportunities opened by the government in the sixties with the push for commercial farming systems under mechanization in adequate soils, or citrus cultivation, which benefitted from the development of irrigation systems. We have already seen that the efforts to create a thriving commercialization system by the government through the large fruit and vegetables market of Oxcutzcab and the plant of Akil have not achieved the level of economic growth expected. Access to many villages is difficult due to bad road conditions which reduces marketing opportunities and increases prices due to transport or middlemen, the cost of input is high and there is no support system in place for farmers after one-time capacity building activities. Irrigation systems are obsolete and malfunctioning, further decreasing agricultural profitability, and even when government programmes are in place for modernization of these systems, such as the *Programa de Adquisición de Activos Productivos* (programme for the acquisition of productive assets), farmers lament their inability or lack of

resources to repair the system when it breaks. As aforementioned there is also a problem of market saturation as farmers flood it with their fruits and vegetables to at the same time of year as they lack planning and information systems on prices and marketing opportunities, and do not have adequate storage capacity. Similarly to Tzucacab, Tekax area is characterized by large mature forests where farmers collect wood, medicinal plants, manure and wild fruits, and have been the object of conservation schemes. However, indiscriminate hunting and wood exploitation are again an ongoing problem linked to lack of employment opportunities, inefficient monitoring and sanctioning, but also lack of information to obtain exploitation permits. Both the areas of Tekax and Tzucacab are characterized by high deforestation pressure, wildlife conservation problems due to indiscriminate use of resources, traditional slash and burn agriculture, and clearing for pasture, and they have been recently selected as priority areas under the REDD+ early action strategy[31].

Peasant households in the municipality of Tinum are all dedicated to traditional seasonal *milpa* and it is interesting to note that *milpa*s sampled in the area have the highest species richness on average (see paragraph 4.6). Many families complement subsistence agriculture with poultry breeding mainly for home consumption and sometimes pigs for marketing. We mentioned already that most of the economic revenues of the area are generated in Pisté, which has developed into a touristic hub thanks to the presence of the main Mayan archaeological site of the region, Chichén Itzá. In fact the tertiary sector employs many people in sampled communities around the site, especially in accommodation and catering services, while some people have specialized in artisanal production. People interviewed confirmed that overcrowding of these services is leading to market saturation keeping revenues low especially for smaller hotel and restaurant owners that cannot compete with resorts, woodcutting for *milpa* production and artisanal purposes puts high pressure on the biodiversity of the area, while prices inflate through the presence of many intermediaries between artisans and tourists. The area seems to have taken a vicious path of high pressure on natural resources surrounding the main touristic spot, with lack of investment and creation of employment opportunities in the surrounding villages, which depend on subsistence agriculture and are subject to increasing outmigration. While this abandonment of agriculture might reduce the pressure on forest resources, which are nonetheless under pressure due to cutting of precious trees for handicrafts, it also reduces the pool of farmers that are

[31] http://cambioclimatico.Yucatán.gob.mx/agendas-cambio-climatico/agenda-regional-proyectos-redd.php

maintaining local crop diversity in an area that was at the centre of Mayan *milpa* cultivation and were *milpa* plots are the ones with highest species and varieties' diversity.

Finally, among households sampled in Motul the use of different ecosystem goods seems significantly lower than in the other areas: the local drivers seem to be the reduced importance of the agriculture sector with the *henequen* crisis, lack of forest resources as there is only low vegetation left by decades of monocrop *henequen* cultivation, but also alternative opportunities brought about by urbanization and expansion of the secondary sector through *maquiladoras* and mining activities. In fact, agave cultivation, remnant of the fibre exporting past, is only carried out in this former *henequenera* area, where 35% of farmers sampled still cultivate *henequen*, mainly because they receive government support in terms of planting material and production subsidies. Except one large plot of 24 ha, the rest are small plots of 1.6 ha on average, producing mean revenue of 681 Mexican pesos (88 USD) per ha, accounting for herbicide expenditure. Four farmers actually incur in net losses, but this is reversed when taking into account Procampo subsidy, which for three farmers represents the whole yearly income from agricultural activities, as shown in Table 4.9. It is also interesting to note that homegardens in Motul area have the highest species richness in the sample (see paragraph 4.3.3). In fact, in some areas of the peninsula, homegardens represent the only productive alternative in areas where past traditional crops are not an providing a sufficient option for livelihood support.

Table 4.9: Net revenues and government support for *Henequen* producers

Net revenue	Net revenue with government support	% of government support on overall farm income
1560	3640	0.57
1940	1940	0
1820	2220	0.18
-1130	170	7.64
-1491.6	3508.4	1.42
-2160	440	5.9
-382.5	-382.5	0
1384	2684	0.48
630	1930	0.67
20600	28400	0.27
1480	5380	0.72
1780	3080	0.42

Source: Survey data

From a brief description of the multiple uses found in our sample we can already see that environmental conversion factors, of the natural and built environment, and the real opportunities open to people contribute to shape the use of agroecosystems by Mayan households. We will now look more in depth at the different ecosystem goods derived by agrobiodiversity.

4.3.2 *Milpa* production: the importance of maize

As detailed in Chapter 3, there is a large literature about crop diversity within the *milpa* focussing on maize varieties, or on the overall diversity including its two 'sister' crops, beans and squash. This study takes upon the challenge of looking at the combination of different species and activities linked to this agricultural system and the multiple use of Mayan farmers, to understand dependencies and vulnerabilities. The point of view is that of the farmer, who recalls the crop and animal species and other ecosystem goods used during the year.

Table 4.10: Main characteristics of different land uses

Type of plot		Size (*ha*)				Irrigation	Stoniness (*Perc*)			
	*Freq**	*Mean*	*Std. Dev.*	*Min*	*Max*	*Perc*	High	Regular	Low	Zero
Only traditional *Milpa*	102	2.35	1.58	0.12	7.2	0.11	0.45	0.3	0.16	0.09
Only mechanized *Milpa*	68	6.09	6.31	0.48	30	0.34	0.03	0.05	0.3	0.62
Only permanent cropland	27	2.25	1.39	0.4	6	0.59	0.27	0.5	0.19	0.04
Traditional *milpa* and tree plot	20	3.49	2.76	0.12	12	0.6	0.35	0.45	0.13	0.05
Traditional *milpa* and henequen	12	5.18	9.15	1.28	34	0.16	0.5	0.33	0.17	0
Mechanized *milpa* and tree plot	5	6.936	5.836735	1.98	13.5	0.6	0.2	0.2	0.6	0

Source: Survey data

As shown in Table 4.10, about 40% of farmers only cultivate traditional slash and burn

milpas, which are the predominant production systems in the Northeast part of the state, while mechanized and fruit tree plots are mainly present in the South. Twenty farmers complement traditional maize plots with fields cultivated with fruit trees, most often in Tekax (9) and Tzucacab (7). Irrigation is only common on citrus plots in these areas and on some mechanized maize plots, half of which are located in the *ejido* of Corral. Apart from two large privately owned plots of 90 and 150 ha, usually only the process of plowing is mechanized: farmers rent a tractor collectively, as very few have resources to buy their own. Land endowments are higher for farmers with access to mechanized plots or who have more than one plot.

Yucatec farmers use Mayan names to define maize varieties, but the main identifier is the colour of its seed: white and yellow are the most common types of maize cultivated in the area, with few other colours, usually found in specific localities. However, the categorization that is particularly interesting for our study in order to understand farmer's choices is the one based on improved and traditional varieties, the latter including landraces and 'criolized' varieties. As Bellon et al. extensively explain, farmers have adapted maize to local conditions through centuries by adding traits from different varieties usually obtained from known and observed sources such as neighbours, but they also adapted improved varieties to local conditions through the management of several generations, creating so called 'criolized' varieties (Bellon et al., 2006).

Table 4.11: Maize varieties on traditional and mechanized *milpa* plots

Type of *milpa*		Number of maize varieties (*Perc*)			Improved varieties	Buys seed	Intercrops w/ beans or squash
	*Freq**	One variety	Two varieties	Three varieties	*Perc*	*Perc*	*Perc*
Traditional *Milpa*	138	0.79	0.19	0.02	0.18	0.19	0.7
Mechanized *Milpa*	84	0.87	0.11	0.02	0.88	0.88	0.46

*Households that cultivated in 2011

Source: Survey data

Table 4.11 shows that 80% of farmers who cultivate traditional *milpas* use native seed, landraces or criolized varieties, which is saved from the previous harvest. In contrast, 90% of farmers with mechanized plots buy improved varieties each year (nine of them received by

the government), as they perform better in deep soils and especially with irrigated systems. However, 18% of farmers with traditional plots buy improved seed: the reason they provided was that they have better soils with low stoniness and that they have an irrigation system (half of them), conditions under which improved varieties seemingly perform better.

About 65% of households grow white maize, 25% yellow maize, while only six and four households cultivate blue and red maize varieties respectively. It is more common to find more than one maize variety on traditional *milpas* than on mechanized ones. Traditional *milpa*s are plots of 2 ha on average, seldom under irrigation, while half of mechanized plots have more than 5 ha. Moreover, while two thirds of farmers intercrop maize in traditional *milpas* with different types of squash and beans, more than half of farmers with mechanized fields monocrop maize because of mechanization and the intensive use of herbicides required on arable land to fight weeds, strongly affecting squash and beans growth. However, it is interesting that despite mechanized plots planted with hybrids are usually cultivated mainly with maize for commercialization, most farmers tend to leave an area of the plot for other crops that sustain family consumption. As Barrera-Bassols and Toledo (2005) and García-Frapolli et al. (2008) point out the strategy of Yucatec Maya farmers is not one based on maximizing yields per hectare through monocropping, but to manage risk through a multiple use strategy that guarantees subsistence and food security even when socio economic or ecological disturbance occur.

Table 4.12: Reasons for growing traditional or modern maize varieties

Reasons for growing modern varieties			Reasons for growing traditional varieties		
	Freq	Perc		Freq	Perc
Better under mechanized plot	51	0.54	Withstands pests & weevil	41	0.34
Higher Yield	18	0.19	Better under seasonal farming	28	0.23
Withstands drought	8	0.09	It is the only seed available	14	0.12
Government incentive	6	0.06	Withstands drought	9	0.08
Faster growth	5	0.05	Adapted to local stony soil	8	0.06
Irrigated system	2	0.02	Cheaper	7	0.06
Larger cob	2	0.02	Custom	7	0.06
Custom	2	0.02	Allows to save seed	2	0.02
			Better for consumption	2	0.02
			Higher price for sale	1	0.01
			Faster growth	1	0.01
			Easier to handle	1	0.01
Respondents	94			121	

Source: Survey data

We can already see that agricultural biodiversity and ecosystem goods seem to represent an instrument and a coping mechanism, recalling Duraiappah's concept of ecological security: ensuring that vital ecosystem services are kept intact to provide safety nets to individuals who depend on them is vital for current and future human well-being.

Farmers were asked why they grow traditional or improved varieties (Table 4.12)[32]: half of people with mechanized plots say they use improved varied because they perform better under mechanized systems; they provide higher yields (under the right conditions): or because they find they are more resistant to drought or they were incentivized by the government. This pairs up with perceived soil quality: only 45% of farmers that use traditional varieties say they have good soil quality, against 63% of farmers with improved varieties. On the other side, traditional varieties are preferred because they are more resistant to pests and weevils, requiring lower use of pesticides, and because they perform better under seasonal farming which depends on increasingly unpredictable rainfall and are adapted to local soils. It is interesting that 12% of traditional farmers say they use local maize varieties because it's the only seed available, which seems an indicator of their lack of access to technological innovation and extension, and that these farmers might be willing to experiment with new seed if given the opportunity, but they are constrained in doing so. According to Faust (1998) Mayan farmer's diversification approach '*is not to experiment with only a few isolated variables, but to incorporate the new within an awareness of system, context, interrelationship, and long-term processes*'.

Therefore one reason to grow traditional varieties is that improved varieties require specific environmental conversion factors and endowments: access to specific soil types, inputs such as mechanization, water, fertilizers, herbicides, and other investments that are not affordable for many smallholders. While this is a challenge for the conservation of crop genetic resources on farm as it would appear that with modernization and higher income farmers would abandon traditional varieties, it is also important for the creation of conservation programmes that take into account the needs and characteristics of farmers providing them with concrete options.

[32] Only four households that cultivate two different plots have a mixture of modern and traditional varieties: they say they prefer traditional maize for consumption but use the modern one on the mechanized plot because that is the variety that this type of soil requires.

For instance, according to farmer's responses the fundamental value of traditional varieties lies in their adaptation to unfavourable conditions of seasonal farming, in their stronger resistance to pests and diseases and to the fact that they can be stored for the whole year under local, usually difficult, storage conditions without being attacked by weevils. These aspects of risk management linked to traditional varieties are of utmost importance for food security of subsistence farmers and reveal a fundamental value that is not accounted for when valuing only the income generation potential of modern varieties.

The fact that improved varieties are high yielding is confirmed by sample data, yielding more than traditional ones both with and without an irrigation system (Table 4.13). Under irrigated systems maize yields are even higher (2338 kg/ha on average for mechanized systems and 996 kg/ha on traditional ones). These aveage yields are quite low but consistent with maize yields in other studies with similar environmental conditions throughout the peninsula and the rest of Mexico (Perales, 1998; Tuxill et al. 2010; Anderson and Anderson, 2011).

Table 4.13: Maize yield, area and expenditure

Type of *milpa*	Maize yield/ha*				Maize area (ha)**				Expenditure on chemicals/ha			
	Mean	*Std. Dev.*	*Min*	*Max*	*Mean*	*Std. Dev.*	*Min*	*Max*	*Mean*	*Std.*	*Min*	*Max*
Traditional *milpa*	854.37	724.81	104.16	3750	2.34	2.16	0.06	13	711.11	1080.07	0	8870.96
Mechanized *milpa*	1844.54	1107.66	180	4500	5.63	6.22	0.4	30	1366.98	1145.01	0	7400

*To calculate mean yields for modern and traditional varieties yields lower than 100 kg/ha (12) were omitted as outliers. The latter were considered outliers because these are households that mentioned a strong yield loss due to drought or because wild animals entered the field and ate the crop.
**Outliers omitted from calculations

Source: Survey data

Expenditures on chemicals per ha, mainly for fertilizer and herbicides, are twice as higher in mechanized *milpas*, and in fact 60% of farmers with mechanization have received training on the use of chemicals, against 30% of traditional ones. On one side, the reduced need for chemicals for traditional varieties that are pest and disease resistant is the most important value that farmers specified, which allows the production of food without incurring in high input costs. On the other side, these data reflect a problematic of traditional farmers in the Yucatán who are left out of capacity building programmes, do not have access to information

on training activities and even when they are involved they are often left without monitoring and ongoing support.

Mechanization, irrigation, improved varieties and chemicals are inputs that not all farmers can afford and to a certain degree they can represent a proxy for household's participation in the market. In fact, 67% of farmers with mechanized *milpas* sell their maize harvest, against 24% of traditional farmers.

About 26% of households who cultivate maize are self-sufficient and do not buy it throughout the year, but there is no significant difference between household with mechanized and traditional *milpas*. Also, even if households with mechanized plots have higher yields and larger cultivated areas they do not appear to have significantly higher per capita consumption of maize, nor there are significant differences in per capita monthly expenditure on food and maize or on the incidence of food expenditure[33] over all household expenditure (Table 4.14).

Table 4.14: Maize consumption and expenditure

	Traditional *milpa* (n=131)		Mechanized *milpa* (n=84)		
	Mean/Perc	Std. Err.	Mean/Perc	Std. Err.	F-statistic
Maize for self consumption (kg/year/per cap)	574.69	48.52	581.75	52.89	0.91
Percentage of households who do not buy maize	0.24		0.24		0.00
Per capita monthly expenditure on food	556.09	29.46	566.36	49.72	0.03
Percentage of food expenditure	0.49	0.02	0.45	0.02	1.86
Percentage of maize expenditure on food	0.16	0.01	0.16	0.02	0.05

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$
The F-statistic is shown for differences across the means. The Pearson's chi-squared test statistic is shown for characteristics that are percentages.

Source: Survey data

About 66% of households who produce maize were able to consume maize for the whole year: excluding seven households that chose not to consume their maize production because

[33] Household economic vulnerability can be measured by the percentage of total household expenditures devoted to food over a reference period. Households that spend a larger proportion of their income on food are more food insecure because reductions in household income or market price increases of goods typically bought by the household tend to link to a reduction in food consumption or food quality.

they sold the whole harvest, the mean months of maize self-consumption is 10 months, while the median is 12, excluding 15% of households who had failed harvest. Those seven households who sell their whole production cultivate hybrid maize on mechanized plots except one on a traditional *milpa*: three of them are large producers dedicated to commercial agriculture, while four are small producers. Those who didn't harvest any maize in the year of reference explained that either wild raccoons (*tejones*), birds or cattle entered the plot and savaged the harvest, or it failed because of drought. Several households also use own maize production to feed their animals: 43% of them feed maize from the harvest to their hens, chickens and turkeys sometimes combined with poultry feed, while six households also use maize to feed their pigs.

More households in mechanized systems produce enough to satisfy maize consumption for the whole year (62% when *milpa* is traditional against 70% when *milpa* is mechanized). There are however 51 households (25% of maize producers) whose maize harvest is not sufficient year-round: only six of them have 5 or more ha while the rest are smallholders with 2 ha on average (Table 4.15). In 47% of them the household head has a secondary employment off farm. In fact, half of these households whose harvest is not sufficient for the whole year look for off farm employment mainly as day labourers on other fields or as construction workers. Moreover, the percentage of food expenditure over total household expenditure for households whose maize production is not sufficient for the whole year is higher.

Table 4.15: Households whose maize production is not sufficient for the whole year

	Less than 12 months own maize availability (55)		Year-round own maize availability (151)		*F*-statistic
	Mean/ Perc	Std. Err.	Mean/ Perc	Std. Err.	
Rural household	0.74		0.71		0.11
Migrants	0.15		0.20		0.52
Off farm work (primary)	0.13		0.10		0.22
Off farm work (secondary)	0.47		0.29		3.66**
Percentage food expenditure	0.51	0.03	0.46	0.01	3.33*

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

The F-statistic is shown for differences across the means. The Pearson's chi-squared test statistic is shown for characteristics that are percentages.

Eleven households with failed maize harvest due to climatic events are omitted from calculations.

Source: Survey data

These households experiencing maize shortages mainly cultivate traditional *milpas* (80%), and except two they only cultivate one maize variety. It does appear that farmers cultivating at least two maize varieties are less likely to suffer from maize shortages.

On the side of income generation, considering that only 32 farmers with traditional *milpas* (24%) sell part of their maize production against 73% of farmers with mechanized plots, it is not surprising that the income generated by selling maize is significantly higher on the latter (Table 4.16). Therefore, if the difference in terms of self-consumption of own maize is not significant between the two types of *milpas*, the real economic difference is the ability to generate surplus on mechanized plots given apt soil conditions and economic resources to buy production inputs, but also given the possibility to access markets where to sell their product.

Table 4.16: Maize marketing

	Traditional *milpa* marketing maize (n=62)		Mechanized *milpa* marketing maize (n=68)		
	Mean/Perc	Std. Err.	Mean/Perc	Std. Err.	F-statistic
Maize for marketing (kg/year)	591.91	133.68	4748.85	1253.64	10.76***
Average percentage of maize harvest that is marketed	0.35	0.03	0.54	0.06	6.68***
Average per capita income from marketing maize	1164.76	207.39	5822.99	1415.80	13.3***

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$
Outliers are omitted from calculations

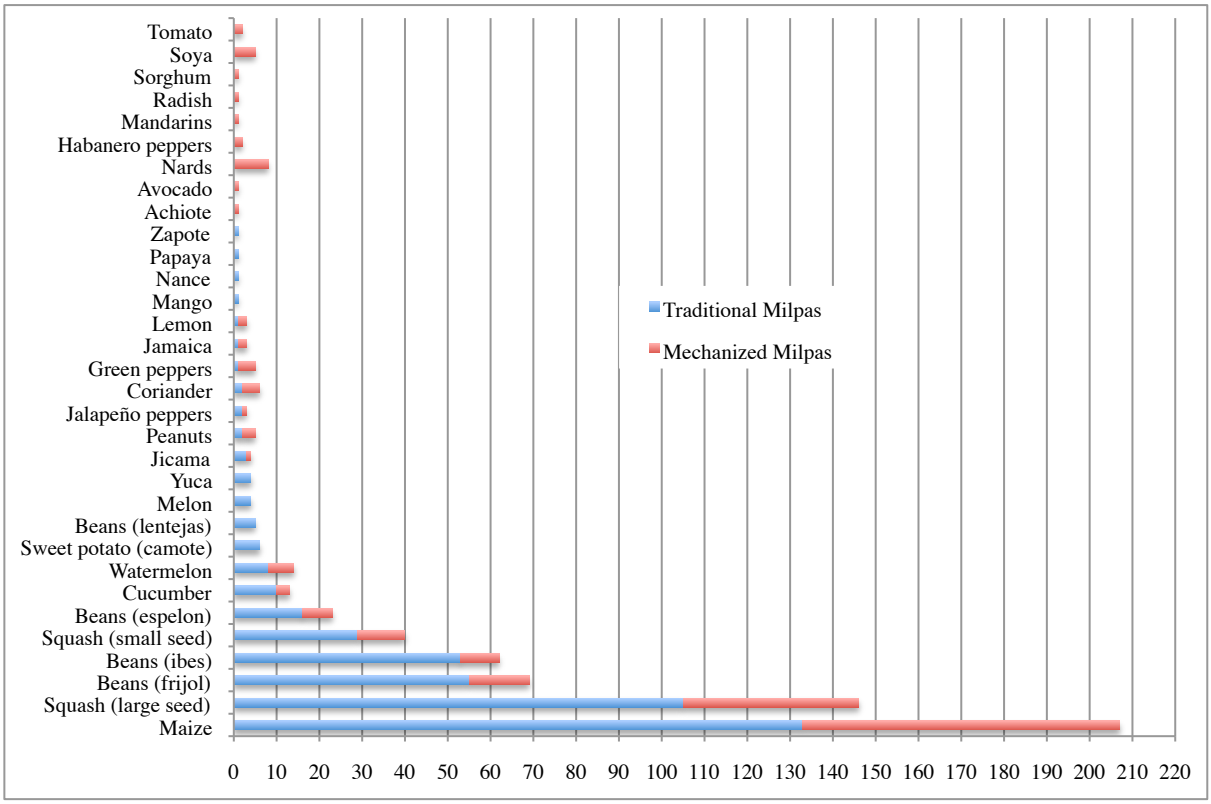
The previous analysis points to the fact that households with traditional maize varieties find it more difficult to market their product because their production is lower given soil conditions and their productive endowments, but part of the explanation might also be that market demand is more oriented to improved varieties and marketing channels have been incentivized for farmers with a commercial orientation on mechanized plots.

While the main value of traditional maize varieties does not lie in income generation we can see that they have particular value for risk management through their pest and drought resistance, contribution to adequate nourishment, income saving value, and stability of harvest in marginal economic and agronomic conditions, but also strong culinary and cultural value.

Other staple and cash crops

Milpas are not only based on maize production and in fact there is quite a degree of variability in species richness between and within traditional and mechanized *milpas* (Figure 4.7). From Figure 4.7 it becomes clear that it is more common to find higher species diversity on traditional *milpas* than on mechanized ones and in particular that native varieties and species of squash and beans are more common in traditional plots, while cash crops such as chilli peppers, tomatoes and even nards can be found on deeper arable soils, often irrigated. Given the absence of mechanized *milpas*, more than 85% of households in Motul and Tinum intercrop maize with squash, against 37% and 54% of farmers in Tekax and Tzucacab. Predominant complementary crops are squash and bean species: the large majority (77%) of farmers with traditional *milpas* intercrop maize with early large seed squash (calabaza xtop - *Cucurbita mixta* Pang. or *Cucurbita argyrosperma* Huber) cultivated mainly to consume its seed, which is the basis of several local dishes.

Figure 4.7: Crops cultivated on traditional and mechanized *milpas*

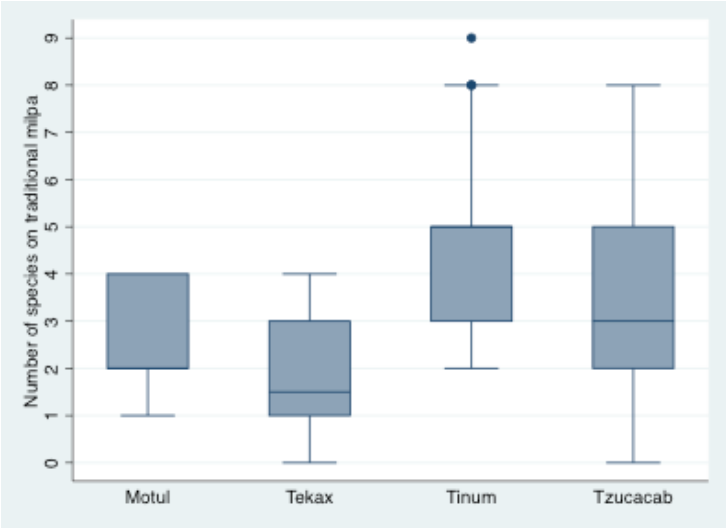


Source: Survey data

About 20% of farmers with traditional *milpas* also grow the late small-seed squash

(*Cucurbita moschata)*, roasted and grounded to prepare typical dishes but also used for its fruit in desserts when mature[34]. This squash is mostly grown in the municipality of Tinum (50% of farmers) in the *milpera* zone, as it is most adapted to its stony soils. Half of farmers with traditional plots intercrop maize and squash with bean species, and a third of them cultivate not just one but two (frijol - *phaseoulus vulgaris* - and ibes - *phaseolus lunatus* or Xpelon - *Vigna unguiculata* (L.) Walp), and five even grow three native bean species, with different growing cycles. In total 83 farmers grow maize, squash and beans: 43% of them are located in the strongly traditional municipality of Tinum, where farmers cultivate the highest diversity of species in the sample, as shown in Figure 4.8, followed by Tzucacab (23%), Tekax (19%) and Motul (15%). About ten households with traditional *milpa*s use smaller parts of the plot for cucumber (*Cucumis sativus* L.), mostly in Tzucacab municipality in the south, while eight households cultivate watermelon (*Citrullus lanatus* (Thunb.) Matsumura & Nakai) mostly in Motul and Tinum. Some households in Tinum and Tzucacab municipality grow tubers like camote (*Ipomoea batatas* (L.) Poir.), yuca (*Manihot esculenta* Crantz.) and the native jícama (*Pachyrhizus erosus* L.). Few households also shade *milpas* with fruit and flower bushes like lemon, mango, papaya, zapote **(***Manilkara zapota* L.**),** nance (*Byrsonima crassifolia* (L.) Kunth) and jamaica (*Hibiscus sabdariffa*).

Figure 4.8: Number of species cultivated on traditional *milpas* in the four municipalities



Source: Survey data

[34] http://www.mda.cinvestav.mx/milpa/cd%20articulos/ARTICULOS/jaime-co.pdf

There are also 20 traditional *milpas* which are only cultivated with maize, 9 located in Tekax municipality, 7 in Tzucacab and 4 in Motul, but none in Tinum. In half of these households, the farmer works off farm and therefore dedicates less time to the plot, while the rest are older farmers that can dedicate less labour to the farm. From figure 4.8 it becomes apparent that Tinum, the locality which has stronger Maya roots and where several native varieties of beans and squash are intercropped with maize providing the basis of subsistence for local smallholders, is an obvious candidate for programmes aimed at on farm conservation. Considering the strong reduction of the primary sector in the area in favour of services for the tourism industry and to outmigration, it is important to understand that this area where native crops and associated knowledge have particular historical and social meaning is in danger of losing both while the pool of farmers diminishes for lack of adequate incentives to agriculture and conservation and the difficulty to provide a kind of life that younger people aspire to or need. The fact that this important repository of genetic resources with its strong cultural and nutritional values is in danger, while the capital of the ancient Maya civilization formerly inhabiting this area is attracting an increasing number of tourists leading people out of agriculture the challenge is how can conservation agriculture become a decent work that satisfies the needs of actual and potential future farmers while conserving fundamental crop genetic resources.

Following the productive dichotomy between traditional and mechanized fields, we look at the diversity that is still conserved on these more commercially oriented plots. Mechanized land can only be found in the southern hills where deep soils with low or absent stoniness are available, which were mechanized to incentivize economic diversification by the government since the sixties. However, these soils are found closer to mature forests and most of them are in villages that are not easy or cheap to reach without own transport. The 84 mechanized plots cultivated in 2011 are far less diverse in terms of crop diversity: 27% of them are monoculture fields located in Tekax (only five in Tzucacab), but the majority of farmers still choose to grow other crops alongside maize. Six farmers who own large mechanized plots in the *Cono Sur* area of Tekax municipality also cultivate transgenic soy: they produced 237 tonnes in 2011, which were sold at a price of 700 USD per ton, twice the value of maize production.

A third of farmers with mechanized land intercrop maize only with large seed squash, and 26% cultivate beans. Interestingly, twelve households still grow both squash and bean species along with maize: they are mostly located in isolated and difficult to reach villages (three in El Corral, two in Kancab, Becanchen, and Sudzal Chico and individual ones in Escondido, San Juan Tekax and Tzucacab). Eight farmers in one of the most remote and marginalized villages of Tekax municipality, Sudzal Chico, also grow nard (*Polianthes tuberosa* L.), an endemic plant used in the pharmacological and fragrances industries, which generates good profits. Some farmers that own an irrigation system grow cash crops such as tomatoes, coriander and chilli peppers, and a couple of farmers also have fruit trees at the edges of the *milpa*. Environmental conversion factors and endowments seem to drive diversification strategies among commercially oriented farmers: among those that have only one plot available, mechanized, it appears to be the availability of an irrigation system that makes the difference and facilitates the cultivation of cash crops; while when farmers have access to different plots and different types of soils they use them to grow diverse crops, independently of irrigation. Among mechanized systems, only fifteen have more than one plot, therefore this is not generalizable and purely based on observation. However, we will test for this type of trend in Chapter 5 for overall and native crop diversity in our sample.

4.3.3 Ceremonies

We have seen in Chapter 3 that there are different types of ceremonies that Mayan farmers perform to propitiate their harvest, while others are not linked to agriculture and are meant to wish children a purpose in life or cure from bad 'winds' that bring negative influence to someone's life. Here we briefly look at those farmers who still practice some of these ceremonies to understand emerging trends. The importance of these traditions does not only lie in their cultural value but also in their value as a form of social organization for the achievement of a common good: these are ceremonies that are practiced collectively by farmers each year at different times of the year, where each person brings something to offer and share, and where each person commits to a respectful use of the environment.

Table 4.17 shows that while basically all farmers except few who are not of Maya descent know at least one agriculture-related ceremony, about 115 (44%) practice at least one. The *Cha-chaac* ceremony that propitiates the end of drought between March and May, so that

seeds receive adequate rainfall after sawing, is the most common ceremony practiced by farmers sampled (42%).

Table 4.17: Agricultural ceremonies

	Wajil kool	Chá-chaac	Jets' Lu'um	Total
Knows	151	144	147	255
Perc.	0.58	0.55	0.57	0.98
Practices	98	106	70	115
Perc.	0.38	0.41	0.27	0.44

Source: Survey data

It is more common in most traditional localities of Tzucacab and Tinum where 55% and 47% of farmers interviewed practice it. The *Wajil kool*, when farmers give thanks to the spirits for the maize (*kool*) harvest is more common in Tzucacab where 58% of farmers practice it, followed by Motul (41%), Tinum and Tekax (both 27%). Finally, the Jets' Lu'um is performed to ask the spirits well-being for the people and animals that inhabit the field and its surroundings. This ceremony is less common and performed by 36% of farmers in Tzucacab and about 20 to 25% in the other municipalities.

Table 4.18 indicates that while age and education of the household head do not appear associated with the participation to agricultural ceremonies, it is more associated with being subsistence oriented farmers and cultivating traditional *milpas*. On the other side, in terms of environmental conversion factors, it appears that households located in more isolated villages, far from urban centres, are more common to these practices, as well as those located in villages where a higher percentage of the population doesn't speak Spanish. Strong indigenous roots and geographical isolation appear therefore to contribute to the conservation of these practices: we didn't ask younger people their view or participation in these activities, but several farmers commented on the fact that few are still interested in them. Without making value judgements on the role of these ceremonies, their loss puts further strain on associated knowledge and cultural value, but also on the conservation of native varieties, especially maize, to which they are strongly associated. For instance, there are food and beverages that are prepared and consumed in these special occasions, such as the *sakab*, a maize beverage prepared only as a ceremonial offering, and maize for a red stew that is used in rain and harvest ceremonies (Tuxill et al, 2010). This type of cultural services linked to

traditional maize varieties are also in part instrumental to a good participation in life of the community, as we have seen that these ceremonies are practiced collectively, have specific rules, rites, and even culinary preparations that make them unique. Morever, the milpas, homegardens or community plots where these ceremonies are celebrated could even be devised as environmental conversion factors as they provide spaces for socialization or environment related activities. The contribution to capability formation of ecosystem goods and services can be both direct, through provisioning, and indirect, through cultural value or other services. Their conservation could maybe achieve further approval not only as an end in itself but also as a means to human well-being, as a mean to expansion of social, cultural, economic, nutritional, and employment opportunities. The issue of letting this value emerge and be recognized by society is probably the most pressing one in the preservation of these services.

Table 4.18: Characteristics of households attending agricultural ceremonies

	Doesn't practice ceremony		Practices ceremony		
	Mean	*Std. Err.*	*Mean*	*Std. Err.*	*F-statistic*
Traditional *milpa*	0.45		0.77		10.69***
Markets products	0.60		0.43		4.11**
Off farm work	0.48		0.50		0.09
Migrants	0.14		0.21		0.15
Age of HHH	56.46	1.65	57.18	1.51	0.10
Education HHH	4.03	0.38	4.21	0.46	0.09
Cost of transport	17.12	1.85	26.55	4.44	3.82**
Average percentage of people who do not speak Spanish (village)	0.04	0.01	0.08	0.02	4.25**

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$
The F-statistic is shown for differences across the means. The Pearson's chi-squared test statistic is shown for characteristics that are percentages. Outliers are omitted from calculations

Source: Survey data

4.3.4 Provisioning goods beyond the milpa

Permanent croplands

While *milpas* have a fundamental consumptive, income generating and cultural value, Yucatec farmers also manage other cultivated systems, permanent croplands and homegardens, which are the most diverse units in terms the main provisioning good, crops, and are managed mainly for income generation (orchards) or for household consumption

(homegardens).

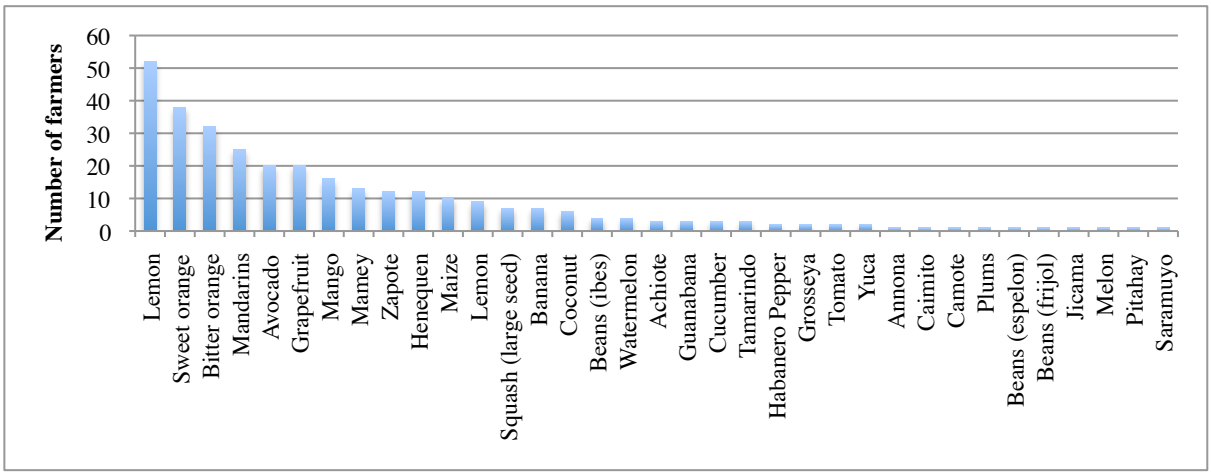
About 37% of farmers cultivate only a traditional *milpa*, 28% only a mechanized one, 10% only a permanent cropland, 78% have a homegarden, while 21% combine different types of plots. There are two types of permanent croplands in the area studied and their production is almost completely destined to the market: these are orchards cultivated with fruit tree species and plots under *henequen* monoculture, which we have analyzed at the beginning of this chapter. Orchards are cultivated in the southern areas of the region, where the government incentivized the cultivation of cash crops. About 37% and 27% of households in Tekax and Tzucacab municipality have an orchard mainly cultivated with citrus species, and most of them are located in the surroundings of the two urban areas. In fact, 40% of households growing orchards live in Tekax town, 10% in the nearby Ticum and 18% in Tzucacab town. Marketing of citrus is relatively easy and profitable in Tekax given the closeness of the fruit market in Oxcutzcab and the juice plant in Akil: in fact more than 80% of farmers in Tekax and Ticum only own one tree plot, irrigated and cultivated with fruit trees. Moreover, about 64% of them also work off farm: the cultivation of permanent crops is less time intensive than *milpas* and the presence of employment opportunities in the town allows farmers to diversify their income strategy. On the others side, farmers in Tzucacab have taken advantage of the possibility to cultivate more plots: except three, they all cultivate two or three fields complementing *milpas*, from which they get their subsistence, with irrigated orchards for income generation.

As shown in Figure 4.9, the large majority of orchards are cultivated with lemon trees (*Citrus aurantifolia* Christh. Swingle), followed by sweet orange (*Citrus sinensis* (L.) Osbeck), and bitter orange (*Citrus aurantium* L.). A third of households cultivate mandarins (*Citrus reticulata* Blanco), avocadoes (*Persea americana* Miller), and grapefruit (*Citrus paradisi* Max.). Given that most of the production in Tekax goes to the juice plant, farmers in the municipality mainly plant lemon (93%), sweet orange (71%), mandarins (46%) and grapefruit (50%).

A few farmers use parts of the plot to cultivate annual crops: especially those who have an irrigation system plant tomatoes, cucumbers and chilli peppers, but also maize varieties,

squash, beans or tubers. In fact six farmers cultivate an average half-hectare with maize only for subsistence within the same plot where they have their orchards.

Figure 4.9: Species cultivated on permanent croplands



Source: Survey data

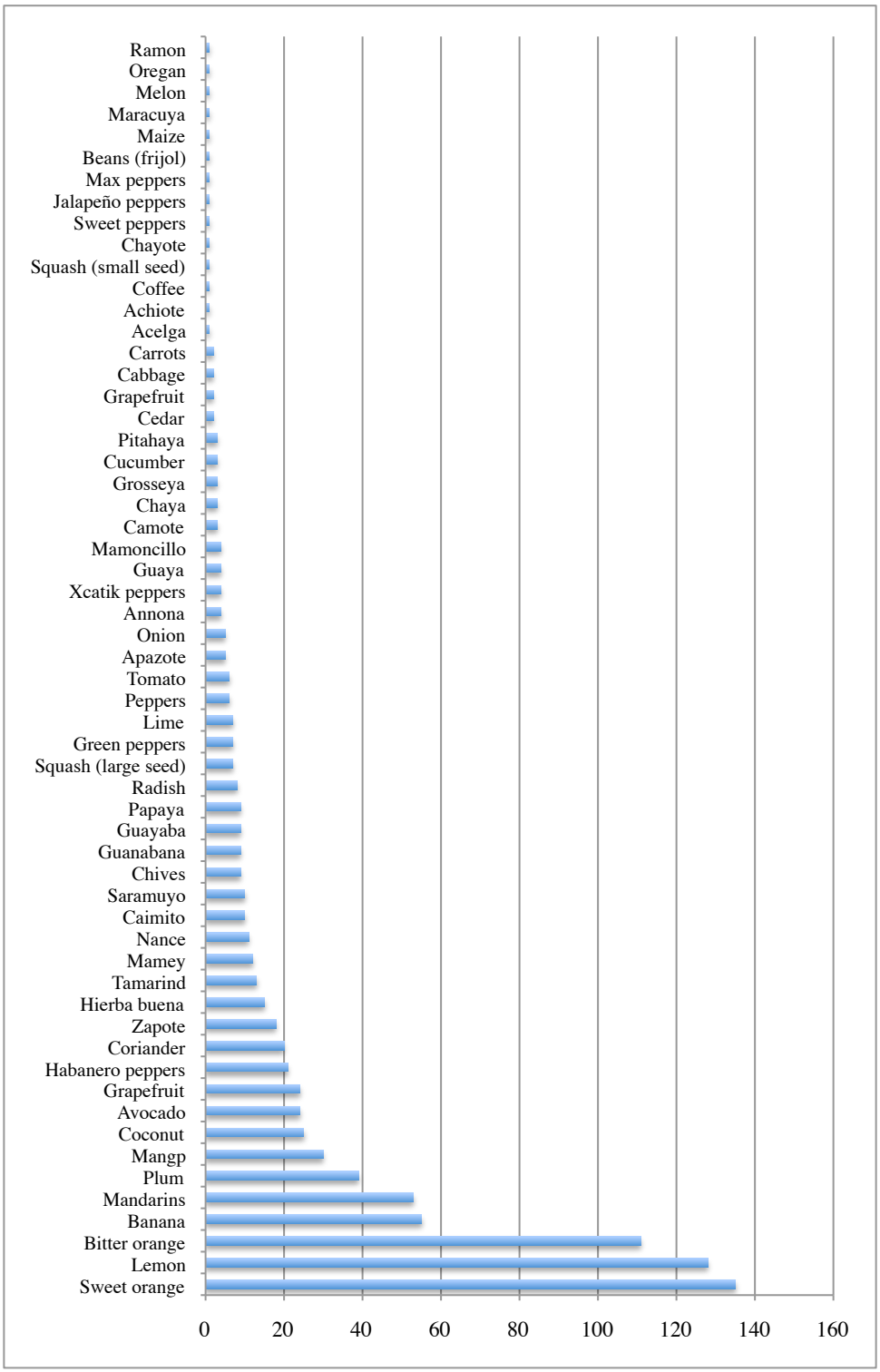
Homegardens

As mentioned in Chapter 3, several researchers have studied the importance of *solares*, the homegardens, and the economic, nutritional, cultural and ecological benefits they provide (Barrera et al., 1977; Acosta et al. 1993; Jimenez-Osornio et al., 1999; Barrera-Bassols and Toledo, 2005). About 78% of households sampled have a homegarden and we have already seen that there are fewer in urbanized areas (68%) against rural ones (84%). The majority of households with a *solar* grow sweet (67%) and bitter oranges (62%) and lemon trees (64%), in fact the production is so high, especially in the southern municipalities, that most of the harvest rots on the garden soil as the family is not able to consume it, while they are impossible to market given that most households already produce them.

Figure 4.10 shows that Bananas (27% - *Musa paradisiaca* L.), mandarins (26%) and native plums (19% - *Spondias purpurea* L.) are also common, followed by mangos (13%), grapefruits (13%) and coconuts (12%). About 10% of households grow chilli peppers, cilantro and mint: they are fundamental condiments in local cuisine, but because they need constant watering not every household is able to grow them. Many native tree species are often encountered in homegardens, such as mamey (*Pouteria sapota (*Jacq.) H.E. Moore & Stearn) and zapote (*Manilkara zapota* L.) which produce large and sweet fruits common in

the local diet; nance (*Byrsonima crassifolia* (L.) Kunth), and saramuyo, a native plum (*Annona squamosa* L.).

Figure 4.10: Crops cultivated in homegardens



Source: Survey data

Households in a same village tend to have the same type of crops in their homegarden as many of them grew spontaneously or are better adapted to local conditions: it is therefore unusual to sell significant quantities of homegarden products. In fact, only 20% of households report some marketing from the *solar*, basically lemons, sweet oranges and mandarins, while the average revenue of those who sell is about 390 pesos yearly (30 dollars). This small income is owned by women, as they take care of the homegarden, and is used for small household expenditure along with the income from selling eggs or poultry, when they are available. In 60% of households with a homegarden, there is also poultry, mainly managed by women: the median value is 6 hens per households, but there are about 43 households that own more than twenty hens, while only twenty household report selling them, which might be underestimated especially for households with several units. Yearly income gained is low, and only six households reported more than 1000 Mexican pesos (about 130 USD). In terms of consumption, two thirds of households with hens in the homegarden report consumption of their eggs and meat, a fundamental source of protein and income saving. Also, 56 households manage turkeys in their homegarden: the median value is 6 but twelve households have more than 15 turkeys as they breed them for marketing. Poultry represents therefore a fundamental nutritional and income complement, especially when households are able to manage larger units, given medical and feed expenses. Most of these households, except those who only grow an orchard, feed their own maize to their poultry: 70% only use their own maize to feed chickens and hens without buying feed in the shop, while half of them are also able to feed their turkeys only through their own production.
The complementarity of *milpa* and homegardens in the multiple use strategy is therefore quite strong.

What is interesting about the high level of crop and animal diversity in the homegarden is the fact that however the monetary value of crop production is low, homegardens are the most diversified units managed by households. Homegardens provide goods for pure consumption and a sort of buffering mechanism in which production can be intensified in times of distress, providing fruits, vegetables and protein when other productive activities fails. The value of pigs and partly turkeys in the homegarden has a strong insurance element, as they represent an asset easily liquidated in times of economic need. On the other side, spices, medicinal and

aromatic plants and vegetables for everyday consumption are cultivated in the homegarden and provide a fundamental source of vitamin and minerals rich food.

The multiple roles of the Mayan homegarden as a fundamental element of households' food security, a buffering mechanism, a laboratory for experimentation, a small income source for women, a repository of genetic resources, and a place of diversion and cultural cohesion are however being slowly abandoned and swallowed by urbanization, as shown by the lower presence of homegardens in urban areas. The magnitude of this trade-off can only be measured to the point that urbanization and reduction of spaces for homegardens bring about better economic, living conditions and opportunities for people, while the possibility to make these places a source of decent employment are wide especially focussing on the role of women. Some research has been done on the theme, but there is wide room for further development (Jimenez-Osornio et al, 1999; Hernández Juárez, 2004; Mariaca Mendez, 2012). Moreover, at least in houses with the typical Maya homegarden, the *solar*, they take care of the household and work on the family plot, but also attend the different aromatic plants, vegetables and fruits cultivated in this space, often managing hens, chickens, turkeys, ducks or rabbits. The role of women and their relationship with local agrobiodiversity appears interesting even in light of the fact that several work on the plot, even if not regularly. There is still few research on their role on farm, but mirroring farmer's responses in our sample they attend the plot often for specific tasks, such as bean harvesting, weeding and sowing (Lope-Alzina, 2007; Radel, 2011). Lope-Alzina (2007) for instance finds that women's labour, knowledge and preferences predominate in post-harvest processes. In our sample, at least 52 women work on the plot quite regularly, as mentioned by them and their spouse. They spend 5 hours on average on farm: half of them work three days per week on average, while the rest goes monthly, especially for weeding, or seasonally for bean harvesting, which demands a lighter physical effort. Not only they actively work on the farm, but they also bring food, help maintain the plot clean and often recollect wood for cooking and heating. Ten farmers also said that the management of crops on the plot is carried out in common with their wife and that they take decisions together. Four of them have mechanized plots with parts of the field left for other crops than maize, especially local varieties of beans and squash, and two have nards; while the rest have more than one plot cultivated with *milpa* or fruits. Moreover, in fifteen households also daughters work on the plot, but mainly during harvesting season.

However, women have very limited access to agricultural endowments: in our sample only 12 women over 260 farming households interviewed were the owners of *ejidatario* rights on the plot, but only two are working the plot themselves every day, while the rest have spouses or relatives working on farm. As Radel (2011) argues, the extensive participation of women particularly in smallholder agriculture in Latin America tends to be largely invisible.

4.3.5 Value of self-consumption and marketing

We complete our analysis of provisioning goods provided by on farm crop diversity by looking at the value of consumption and income generation from the different farming systems. Households with different plots are on average the most crop diverse as they appear to adapt diverse cultivars to different soil conditions, an hypothesis that is tested in our econometric model in Chapter 5, while mechanized plots are on average more specialized one as they are commercially oriented and intercropping is not convenient with mechanization and hybrid maize. We imputed the value of products consumed by the households using the average annual price per kilogram for each product in the market of Oxkutzcab[35]. Table 4.19 shows mean and median values for each production system: excluding few outliers and those who didn't cultivate in 2011 the average value of self-consumption from different land uses is not significantly different except for permanent croplands and homegardens.

Table 4.19: Imputed per capita value of crop self-consumption

Type of plot	Number of crops			Imputed annual value of overall production for self-consumption					
	Mean	Median	Std. Dev	Freq.	Mean	Median	Std. Dev	Min	Max
Traditional *milpa*	3.69	4.00	1.99	102	1644.58	1179.55	1664.90	0	7060
Mechanized *milpa*	2.58	2.00	1.46	70	1657.13	1029.19	1864.35	0	9175
Permanent cropland	5.09	5.00	2.27	34	349.17	167.33	491.36	0	1605
Different plots	5.54	4.00	3.34	41	1664.26	1263.98	1470.22	23.53	7270.35
Homegarden	4.41	4.00	2.67	201	398.04	86.30	727.923	0	4217.32

Values are in Mexican Pesos from 2011 (1 USD=13 MXN approximately)

Source: Survey data

[35] http://www.campomexicano.gob.mx/mercados_nl/M_Principal.phtml

The annual value of crops cultivated on permanent croplands is significantly lower than that of *milpa* products because a high percentage of fruit harvest is marketed, their market price for buyers is quite low, and households do not consume as much fruit as diet staples such as maize, beans and squash. The same is true for homegardens, but without the marketing component. The standard deviation is significantly larger than the median for both traditional and mechanized plots, reflecting different production levels between several smallholder farmers and fewer large producers. It is also interesting to note that among households who cultivate more than one plot, which appear to be the most diversified, all of them managed to consume products from their harvest, however in low quantities (none has zero value).

Interestingly, the saving income component of diversifying production is confirmed when looking at significant differences in household expenditure for households with below and above average number of crops. Table 4.20 shows that the percentage of food expenditure on total household expenditure is significantly lower for households that have a higher variety of crops for consumption, therefore diversification for consumption purposes strongly reduces their economic vulnerability. When looking at households that market their crops, instead, it does not appear that higher diversity for marketing significantly affects the incidence of food expenditure for households. However, despite households that diversify the production of crops for consumption spend a lower amount of their income on food, their overall household expenditure is on average lower than that of households that have more specialized production.

Table 4.20: Household expenditure and crop diversity

	Number of crops for consumption below median		Number of crops for consumption above median		*F*-statistic	Number of crops for marketing below median		Number of crops for marketing above median		*F*-statistic
	Mean	Std. Err.	Mean	Std. Err.		Mean	Std. Err.	Mean	Std. Err.	
Percentage food expenditure	0.52	0.02	0.44	0.02	7.24***	0.47	0.02	0.46	0.04	0.06
Overall per capita expenditure	1232.73	54.40	1077.34	48.27	4.61**	1267.33	79.04	1137.28	91.26	1.17

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Source: Survey data

Diversifying production for consumption seems therefore associated with lower household income on average but linked to lower economic vulnerability: the role of crop diversity appears predominant as a coping mechanism that contributes to the ability of households to be adequately nourished, at least in terms of access to diverse foods and reduction of the incidence of food expenditure. This line of research is not developed in this dissertation for reasons that are put forward in the conclusion, but open for future development following other authors studying the link between nutrition and diversity in *milpa* systems (Arias et al., 2004; Becerril, 2013).

On the side of per capita income generation (Table 4.21), among households who participate in the market this is significantly higher when farmers have access to mechanized plots, even excluding eleven notable outliers (large farmers gaining more than 40000 Mexican pesos per capita per year from cash crops on large mechanized farms). Differences are significant but highly skewed by the presence of large producers as shown by median values. However, median yearly per capita income is still low even on mechanized plots, about 5500 Mexican pesos (about 700 USD).

Table 4.21: Agricultural income

Income per capita generated by type of plot	Obs	Mean	Median	Std. Dev.	Min	Max
Gross income						
Traditional *milpa*	39	2009.54	1125	2552.53	56.66	11350
Mechanized *milpa*	51	8152.03	5500	7812.16	477.27	32466.67
Permanent cropland	29	3188.48	2210	2995.04	177.14	12016.67
Different plots	34	4147.94	1555.773	6686.65	67.5	36180
Net income (with farm expenditures)						
Traditional *milpa*	39	1413.23	833	2187.81	-823.33	8594
Mechanized *milpa*	51	5514.15	3664	7547.75	-14791.67	27032.08
Permanent cropland	29	2393.75	1627	2633.19	-790.83	11440
Different plots	33	3348.60	1240	6581.29	-2107.5	35556
*Net income (with PROCAMPO)***						
Traditional *milpa*	39	2344.80	1500	2507.92	-502.33	8594
Mechanized *milpa*	51	6672.91	4966	7792.54	-14791.67	28340.12
Permanent cropland	29	2885.61	1892	2982.57	-464.5	14040
Different plots	33	4219.30	1994.5	6660.18	-2107.5	35556

Values are in Mexican Pesos from 2011 (1 USD=13 MXN approximately)

Source: Survey data

Diversifying production on different plots again appears instead as a strategy that not only produces comparable value of self-consumption as other farming systems but also a surplus income compared to only cultivating traditional *milpa*.

When including expenditure on chemicals, rents for tractors or water rights, and total subsidies for agricultural production received by the government these averages are little changed, but what becomes apparent is that a portion of farmers would incur in high losses without government support. The average expenditure on chemicals per hectare on mechanized plots is 1349 (972) Mexican pesos against 535 (652) Mexican pesos on traditional ones, 791 (878) and 846 (966) for those with different plots. Also, more than 90% use chemicals on all types of plots except traditional ones, where 80% do. Farmers that are cultivating more commercially oriented plots, both mechanized ones and fruit cultivations, are also more likely to have received training by extension agents sent by government agencies, as we saw that only 30% of households with traditional *milpas* have received training, against 60% of those with mechanized plots and 54% of fruit growers. About 17% of marketing farmers incur in losses when accounting for expenditure on chemicals, rents for tractors or water rights (seven on traditional *milpa*s, eight on mechanized *milpa*s, 3 on permanent croplands and 8 with different plots) but only two in each group are still loosing when Procampo payments are included. Interestingly when Procampo payments are included the difference on median per capita income generated on traditional and mechanized *milpas* is reduced (of about 2000 Mexican pesos). It is confirmed therefore that Procampo is a relevant source of disposable income especially for smallholders, however it has been shown that the largest part of its emoluments reaches large commercial farms (Scott, 2010).

In conclusion, traditional *milpas* and permanent croplands are significantly more crop diverse than mechanized systems in terms of species and varieties and make lower use of chemicals, and generate a similar level of income saving by providing a more diversified range of goods for consumption. However, income generated by mechanized *milpas* is a complementary benefit to the ability to save money through self-consumption of own production and makes this type of systems more attractive for those farmers that have endowments, the access and the ability to pay for them, and the environmental conversion factor, soil, to implement them.

Moreover, there are also differences in the percentage of households with members who have migrated between the different types of plots: 45% of households with more than one plot have members who have migrated, followed by households who only have traditional *milpas* (23% of them have migrants), permanent croplands (11%), and mechanized *milpas* (12%). This might pose further issue of conservation if migration, given other variables affecting crop diversification, results highly associated with the likelihood to grow native varieties, a hypothesis that we test in our econometric model in Chapter 5.

4.3.6 What were they growing before?

Farmers sampled were asked if they were growing different crops than the present ones in the fifteen years prior to the survey. Almost 40% of them were growing different species or varieties, especially in Motul and Tzucacab (56% and 46% respectively), while in Tinum only 8 farmers have changed or reduced their crops. The cultivation of watermelon in particular has been abandoned by 31 farmers, mostly in the south (16 in Tzucacab and 11 in Tekax municipality) and especially in the village of Corral, where an organization was created to incentivize its production but the person in charge left with the money that were meant to repay the debt opened to cultivate the plantations. In other villages, farmers abandoned watermelon cultivation because of lack of inputs (irrigation or pesticides especially in Tzucacab), climate unpredictability (especially in Motul) or because of the heavy workload (particularly in Tekax). The large majority of these farmers said they would like to cultivate it again because it is a favourite for consumption, especially to make beverages, however they do not because it requires time and money that they do not have to spare.

Another 10% of farmers sampled have abandoned the cultivation of chilli peppers - habanero (*Capsicum chinense* Jacq.) and some green peppers (*Capsicum frutescens* L.) - mainly because of their input intensity, especially to fight pests. They are located in the irrigated south and almost all of them would like to plant it again because it has good value on the market, but once again they do not because of the time and money investment it requires.
Another important crop that has been abandoned by 12 households located in different villages is the native bean species, ibes (*Phaseolus lunatus* L.), because the seed is not easy to find, or because they are now working on mechanized plots and the use of herbicides would

damage its cultivation. A couple of respondents from Corral said the problem is that they cannot burn new forest plots for traditional *milpas* due to the PES scheme and therefore they can only plant on mechanized plots. All these households would like to cultivate it again because it is very much appreciated for consumption, an important value for the conservation of native crop genetic resources.

Similar problems to the *ibes* are encountered for other local beans, the large seed squash, and tomatoes, as 5% of farmers stopped their cultivation either due to having switched to mechanization or because of pests, despite these crops are local favourites for consumption. Nine of them did grow maize in the past, about 10 to 15 years ago, but abandoned its cultivation because the time they could dedicate to the plot was limited as they were engaged in off farm work, while two of them abandoned maize as they switched to cash crop cultivation. Nine farmers in the urban and peri urban area of Tekax grew maize in the past, about 10 to 15 years ago, but abandoned its cultivation to plant citrus because the time they could dedicate to the plot was limited as they were engaged in off farm work, while two of them abandoned maize as they switched to pasture. Few farmers have abandoned other crops: in Motul five farmers used to grow *henequen* but then the profits were too low, while others grew *camote* tubers which went lost after hurricane Isidoro came in 2002. Others abandoned papaya cultivation because the market got saturated or stopped taking care of their citruses because they couldn't repair the irrigation system or pay water rights.

All and all, the problems faced by farmers when deciding to abandon a cultivation were of different nature: one is lack of marketing opportunities because markets got saturated or prices of locally grown varieties are not competitive, another is linked to the type of inputs they require, or to having switched to cash crop cultivation for better earnings, but also because the seed is not easy to find anymore. The latter in particular is worrying considering the importance of these genetic resources for consumption, especially in the case of local beans, and for their potential value as pest and climate variability resistance crops.

4.3.7 Livestock management and beekeeping

The multiple use of agroecosystems implemented by Mayan farmers may also include breeding different animals, such as cattle, sheep, pigs and poultry, and beekeeping as shown

in Table 4.22.

Table 4.22: Cattle, sheep, beekeeping and pasture

	Units/area						Per capita income from selling					
	Freq	*Mean*	*Median*	*Std. Dev.*	*Min*	*Max*	*Freq*	*Mean*	*Median*	*Std. Dev.*	*Min*	*Max*
Cattle	43	19.49	10	23.97	1	100	31	7454.93	3125	9551.92	400	33333.33
Sheep	15	38.73	17	58.11	3	200	6	5006.79	7578.483	109.09	20000	2395.83
Pasture	34	17.79	15	17.76	0.3	80						
Beekeeping	67	32.34	20	36.13	2	200	58	5081.39	2550	6688.39	83.6	27000

Source: Survey data

For what concerns livestock a distinction should be made between maintaining bovine and ovine species for marketing as a main income generating activity, or just own a few as saving instrument that provides income in times of distress, a common practice among farmers in the region. We have already analyzed poultry management when talking about homegardens, cattle and sheep breeding instead is an activity carried out in the large mechanized farms of the south, especially in Tzucacab municipality, where 36% of farmers have cattle and 11% sheep. Cattle breeding can be found especially in more remote villages at the forest frontier where pasture and natural grasslands are available such as in Catmis, Corral, Blanca Flor, Becanchen, Sudzal Chico and Escondido. In these areas, alongside mechanized plots and protected forest areas there are many pasturelands and ranches, few of which also started the production of milk and cheese. In Catmis for instance, where nine out of ten interviewed farmers have ranches, the presence of an organization of cattle breeders and the creation of an annual milk fair about fifteen years ago have promoted a thriving activity, which is threatened by aging of cattle units. However, in our sample only nine households consume their cattle or sheep meat, which are raised mainly for marketing. Income gained from cattle and sheep marketing is not as high as in the eastern region of the Yucatán, which is dedicated to livestock breeding and only few farmers manage to produce high per capita income. Twelve farmers only breed cattle without other animals, and only 6 have both cattle and sheep. Three farmers own large ranches with between 60 and 100 cattle units in Becanchen and Catmis, and two with more than 150 sheep, all located in Tzucacab town. The majority of cattle owners sell some units during the year, providing a median income of 3000 Mexican pesos per capita. Twenty farmers also own pigs mainly for household consumption.

Radel et al. (2010) in their analysis of rural households in the Southern Yucatán peninsula find farmers who establish pasture on former maize plots in hopes of eventually obtaining cattle, but also to keep receiving payments from Procampo. Wyman et al. (2008) also indicate that Procampo has in several cases encouraged deforestation by smallholders who increase the size of their *milpa* to receive larger subsidies, which often resulted in planting pasture. We find some indicators of potentially similar trends: Table 4.8 shows that 34 households in our sample have pasture, but eight of them do not own any cattle. More than 60% are located near the southern forest bordering Tzucacab municipality, especially in Catmis, where the cattle producing area is located, and Corral, and then in Tekax, especially in Becanchen and Nohalal. In these communities, farmers have taken advantage of better soils for mechanization, but have also diversified their marketing strategy through pasture and cattle breeding. It was surprising to find out that three farmers in Tinum municipality have between 10 and 20 hectares of pasture, but grow traditional crops on less than 4 hectares and two of them have bought ownership of the land. They are the exception among a panorama of smallholders with traditional *milpas*.

There appears to be a link between privatization and switching to pasturelands: seven farmers with pasture are not *ejidatarios* (farmers cultivating community plots) and have bought out the land under the privatization system, which contributes to explain their access to large areas for cattle ranching. They represent 20% of farmers with pasture, while only 6% of the farmers without pasture are private owners. Wyman et al. (2008) make a potential link between privatization of *ejido* lands and intensification in *milpa* cultivations that cannot expand further to privatized lands, which might create an incentive to sell their land to those with financial resources to convert to large-scale agriculture or cattle ranching[36].

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[36] A note on social networks: only 7 farmers said they belonged to an association or organization, all of them for agricultural producers, while 220 are only associated with the *ejido*. We asked them what were the services that belonging to the communally-owned land organization was still providing them, given the reduction of its role since the land reform of the nineties: 20% of them say that it is a place for capacity building and learning from each other, but 60% of them say it is the main place where to obtain information on subsidies and options for farmers, to settle conflicts on land use and negative effects during the burning season, or on the use of water rights. In fact it appears the *ejido* members are particularly active in irrigated areas, where conflicts on water use might arise. One farmer in the *ejido* of Pisté also mentioned that conflicts in the area arise from the fact that is has become a small *Cancun* (the main touristy city on the coast) and everybody wants to buy land, but the decision to sell must be approved by the members. An interesting line of research could focus on privatization, tourism and agrarian conflicts linked to conservation of local crop diversity in the *milpera* area surrounding Chichen Itza.

Among households who have pasture and cattle, 14 have less than 5 hectares cultivated with crops, but they all have between 8 and 40 hectares of pasture except two. Similarly, among farmers who cultivate more than 5 hectares with crops three have 1, 5 and 6 hectares of pasture, while the remaining 9 have between 20 and 80 pasture hectares. Five of the eight households with pasture without cattle have less than two hectares cultivated, while the remaining have 10, 15 and 40 pasture hectares respectively, on which they receive large Procampo payments. The trend could be one of conversion to pasture, waiting to buy cattle or simply receiving government support, while reducing cultivated area. Finally, four households in our sample completely converted their plot to pasture in order to breed cattle, but they keep receiving both payments from Procampo (on the land) and Progan (for livestock).

Finally, with about 305,000 hives in 2011, Yucatán is the largest producer of honey in Mexico: in fact, 25% of farmers sampled are dedicated to beekeeping. The range of knowledge associated with this ancient activity includes selecting appropriate sites for the establishment of apiaries, knowledge of flowering times for different species, and the influence of different forest species on nectar. Beekeepers are located in large part in the south where the forest provides a natural choice for farmers to place their beehives, particularly in the area of Tzucacab, where honey production is also favoured by diversity of fruit trees and flowering plants in the plots[37]. While many beekeepers live in the cities of Tekax and Tzucacab, half of farmers dedicated to beeekeeping are located in the most remotes areas of El Corral, Becanchen and Sudzal Chico, who cultivate mechanized plots surrounded by high vegetation where farmers place their hives. But also a quarter of farmers in Tinum municipality are beekeepers, growing traditional *milpas* in an area surrounded by secondary vegetation. Eighteen households not only have bees but also own cattle or sheep, highly diversifying their strategy. The largest productions are located in Tzucacab and Tekax but prices per kg are the same in the four municipalities (about USD 1.8 per kg). The Yucatán produced about 10000 tonnes of honey per year until 2010, providing a livelihood for 3000 beekeepers and generating about USD 34 million per year (Duran et al., 2010). As mentioned in chapter three, honey consumption is not common and in fact only half of farmers consume

[37] None of the farmers interviewed was producing honey from the native *Melipona beecheii*, Xunan-kab by it Mayan name, a stingless bee, which is at the verge of extinction in the area, due to the last century of conversion to agave monocoulture and cattle ranching, and partly also due to Hurricane Isodoro (Villanueva, 2005). In our travels through the Peninsula, we met one farmer in Tzucacab, who still had these beehives.

their product, while most production is meant for tourist areas and export especially to the European Union. Transgenic soy has been incentivized since 2009 by the agricultural secretariat, SAGARPA, and has been at the centre of many debates because of damages to honey producers of the area. For instance, in 2012 the presence of large areas to transgenic soybean production in southern Yucatán has widely affected beekeepers in the area as bees were carrying transgenic pollen to their beehives, contaminating honey. Twenty tons of honey from Yucatec producers where rejected by the European Union, their main market, because they contained traces of transgenic pollen[38]. After a brief one year prohibition to cultivate soybean, in 2013, SAGARPA reinstated the permit for Monsanto to produce transgenic soy on about 253000 ha in the south of the Yucatán peninsula, generating new concerns for local beekeepers[39]. Mayan beekeepers, honey gatherers and exporters, the UCCS, peasant, environmental and human-rights organizations against these plantations have formed an activist organization called 'Sin Transgénicos' (Without GMOs). Through collective action and an active involvement by scientists against GMO plantations they are still fighting for the elimination of transgenic soybean and maize production, with a victory in 2014 in the close state of Campeche. Yucatán and other states' stakeholders are still fighting in court against Monsanto and government agencies, but this sets an important precedent.

Table 4.23: Household characteristics and other agricultural activities

	Beekeeping		No Beekeeping		F-stat.	Cattle		No Cattle		F-stat.	Pasture		No Pasture		F-stat.
	Mean	Std. Err.	Mean	Std. Err.		Mean	Std. Err.	Mean	Std. Err.		Mean	Std. Err.	Mean	Std. Err.	
Age of HHH	57.30	1.35	54.92	2.02	0.96	56.99	1.36	55.76	1.78	0.30	56.62	1.25	57.90	2.46	0.22
Education of adults	5.18	0.26	5.40	0.53	0.14	5.10	0.28	5.79	0.37	2.21	5.04	0.25	6.83	0.70	5.75**
Off farm work	0.42		0.51		0.93	0.37		0.52		2.44	0.45		0.50		0.15
Migrants	0.20		0.16		0.57	0.34		0.13		9.30***	0.35		0.15		5.70**
More than 5 ha	0.30		0.18		2.85*	0.42		0.16		10.37***	0.46		0.18		8.86***
Markets crops	0.68		0.49		4.20**	0.7438		0.4913		6.78***	0.71		0.51		2.8986*

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

The F-statistic is shown for differences across the means. Pearson's chi-squared test statistic is shown for characteristics that are percentages.

Source: survey data

[38] http://sipse.com/archivo/laboratorio-aleman-detecta-polen-transgenico-en-miel-yucateca-154310.html

[39] http://www.inforural.com.mx/spip.php?article119514

Table 4.23 shows significant association between being large-holders and engagement in beekeeping and livestock breeding activities. In fact, as much as 30% of households dedicated to honey production and more than 40% dedicated to cattle breeding and owning pastures cultivate plots larger than 5 ha. Farmers with access to larger cultivated areas seem therefore to have a commercial oriented strategy, taking advantage of different opportunities: they might be taking advantage of higher economic resources that allow them to manage more activities but also of the marketing channels in which they already operate to allocate their diversified production.

Another interesting association is that with having household members who migrated and allocating land to pasture and cattle breeding: this result is in line with Radel et al. (2010) who found relatively high rates of migration among households that established or maintained pasture. This decision by the household to undertake more commercially oriented production centred on cattle might reflect availability of higher disposable income that allows acquisition of animal units and land. The long term effects of such trends however are difficult to predict, considering that households expanding pasture and cattle production, an activity highly correlated with deforestation, are particularly located within the southern forest area characterized by high biodiversity providing different ecosystem goods. Half of these households receive government support for livestock breeding through the PROGAN programme, but only four are also engaged in conservation activities through the Payment for Ecosystem Services programme in their area. A coordination between different agencies might provide a sustainable solution to the problem of creating employment and increasing income generation through cattle ranching while conserving relevant ecosystem services, especially taking into account the potential effects of migration. A policy action might involve a similar strategy to that of the 3x1 programme mentioned in Chapter 3: linking remittances to reforestation or other activities that improve the sustainable use of natural resources while supporting cattle breeders.

4.3.8 Off farm ecosystem goods

Mayan farmers derive many benefits from ecosystem goods provided by the forest, such as wood for construction and fuel, timber, medicinal plants, fruits, wild animals, seed, pasture, and palm leaves. Yucatán has very distinctive native biodiversity: there are 182 plant

families, 992 genera, 2477 species and 98 varieties or subspecies, and 168 endemic species, 125 species of mammals and 445 species of birds, which represent 50% of all bird species reported for the whole country. Different ecosystems directly benefit its inhabitants, through water catchment and filtration services, wildlife refuge, scenic beauty, soil retention, and carbon sequestration, among others. Deforestation is one of the main problems affecting the Yucatán: forest area amounted to 3,208,600 hectares in 1970 and to 2,234,800 hectares in 2000, with a 1% average annual loss (REDD+). Partly the reduction of the fallow period for slash and burn farming due to lower availability of areas for this activities, monoculture of agave cultivation in the past, and cattle ranching with expansion of pasturelands are cited among drivers of this deforestation (Wyman et al. 2008; Busch and Vance, 2011). However, the state still lacks a forest law, despite a council for its drafting and approval was set up in 2008.

Table 4.8 at the beginning of this Chapter shows the percentage of people using different ecosystem goods in the four municipalities. Traditional Mayan houses are made with *huano* palm leaves rooftops and walls of mud (*pak'lu'um*) with wooden poles (*kolóojche*), with no windows and one or two large doors that provide light and ventilation, protecting against the heat. About 35% of households sampled live in houses with palm leaf rooftops, of which some have been rebuilt with walls of concrete, while about 13% live in completely traditional houses, mainly in rural areas (82%). Households collect huano leaves mainly to repair rooftops and in the sample they collect about 500 leaves per year. Hurricane Isidoro, which was an extremely strong climatic event, destroyed many traditional houses in Motul area and most were rebuilt with concrete: in fact no household interviewed in the area used huano leaves. Instead, about 50% of households have collected huano to repair their rooftops and for few other uses mainly from the forest or their *milpas*: some of them have concrete houses and a traditional Maya one room house as an addendum where they cook or use as living room. The use of this ecosystem good appears therefore stronger in the southern area where there is higher availability. An interesting analysis of the evolution of its use is suggested in Caballero et al. (2001) link its reduction to demographic pressure but also to its use by the tourism industry, which extracts it to embellish 'traditional' hotels and restaurants. Martínez-Ballesté et al. (2006) also found that the growth of the tourist industry and the abandonment of agriculture by young people are leading to a widespread loss of the traditional knowledge

of the management of the Yucatec *sabal* palm. The use of ecosystem goods is obviously linked to the associated knowledge that enables their utilization: for instance in our sample only twenty farmers collect medicinal plants from the forest and only four of them have less than 50 years, for an average age of 60 years, older than the sample mean. They have mentioned 34 different medicinal plants, most of them to ease stomach pains or headaches, including orange leaves, common rue, basil, mint and a number of plants identified by their Mayan names.

Forty respondents hunt wild animals: 15 of them in Tzucacab municipality, 13 in Tekax, 7 in Tinum and 5 in Motul. Interestingly, in Tzucacab most hunters are located in the urban area, hunting in the close forest, while three are in Blanca Flor and Corral respectively. About 11% of farmers hunt deer, which is a protected species found especially in the southern forest: 45% of hunters are in Tzucacab, Blanca Flor of Corral; 30% in different localities of Tekax; but even 4 and 3 farmers from localities of Tinum and Motul engage in this activity, mainly for self-consumption, as this is the only. Five farmers even reported hunting between four and seven units in 2011: the price of its meat is highly valued, however none of them said it was for marketing because of the prohibition of this activity. There does not seem to be a specific trend of characteristics of farmers who hunt deer, except that they are more often found in areas surrounded by high forest, where it is more likely to encounter the animal. Few research is available on deer hunting, which in Mayan conservation ideology has specific rules, such as prohibition to hunt pregnant females (Léon, 2008).

Firewood is used for cooking in the majority of traditional households; in fact 92% of them collect it for this purpose, while it is sometimes used for construction or house repairing. Even among households who have a gas stove (28%), firewood is used to cook as a money saving alternative to gas: in fact only 21 households didn't collect firewood in 2011, and a third are in the urban area of Tekax. Except three, these households who do not collect wood have more modern houses made of concrete, with more than one room, and only in six of them the household head doesn't work off farm. Most households instead collect firewood from the forest or secondary vegetation surrounding the plots: 2 tons are collected per year on average by households in the sample, for an average of 1.7 kg per day per person, not dissimilar from other studies (for instance Quiroz-Carranza, 2010). The estimate is an

approximate based on the measurement made by farmers on *tercios* of about 15 kg, and it might actually underestimate the real use of this resource. As shown in Table 4.24 firewood extraction is more intensive in Tekax and Tzucacab municipalities, where medium evergreen and semi-deciduous forests are available and especially on mechanized plots, which are located in areas surrounded by higher vegetation.

Table 4.24: Use of forest resources

	Firewood (kg/year)				Wild animals (nr)			
	Freq	*Perc.*	*Mean*	*Std. Dev.*	*Freq*	*Perc.*	*Mean*	*Std. Dev.*
Motul	31	0.91	1783.68	1360.26	*5*	0.15	2.80	1.79
Tekax	102	0.91	2360.69	1690.79	13	0.12	3.00	2.68
Tinum	38	0.86	1809.82	1292.62	7	0.16	2.00	0.58
Tzucacab	68	0.97	2570.61	1862.60	15	0.21	3.53	2.85
Traditional *milpa*	97	0.90	2067.69	1529.25	*13*	0.12	2.92	2.47
Mechanized *milpa*	72	0.97	2656.58	1722.67	11	0.15	2.36	1.69
Permanent cropland	28	0.82	1821.77	2044.38	3	0.09	1.67	0.58
Different plots	41	0.98	2391.43	1408.53	13	0.31	3.92	2.93

Source: survey data

The intensive use of ecosystem goods carried out by farmers in the area is partly regulated by the government through the ProArbol payments for ecosystem conservation scheme and water management in irrigated areas, especially at the borders of the mature forest surrounding mechanized *milpas* in the South, as shown in Figures 4.11 and 4.12. The figures indicate that the use of forest resources is particularly intense in the South, Centre and Eastern part of the state, the agricultural and cattle breeding areas, while it is less so in the areas closer to the state's capital and Motul's urban area. Figure 4.12 shows that conservation schemes are in place in Tekax and Tzucacab's municipality in the bottom South three quadrants. Despite conservation schemes in place, farmers in these areas, especially in Corral and Sudzal Chico, located on the border with Quintana Roo and the deep mature Southern forest of the peninsula, lament the growth of illegal logging and hunting: the value of precious wood such as mahogany and deer and wild turkey meat is a high incentive for this practice, while monitoring and sanctions seem inadequate and inefficient. From key informants' interviews with the Secretary of Environment and Development (SEMARNAT)

and researchers of the Regional Research Centre (CIRS) it became clear that there is conflict between government agencies dedicated to environmental protection and the main agency for agricultural development (SAGARPA), which are providing conflicting incentives to farmers.

Figure 4.11: Intensity of use of forest resources in the Yucatán. Colour legend: red = high, yellow = medium; green = low. Source: SEDUMA.

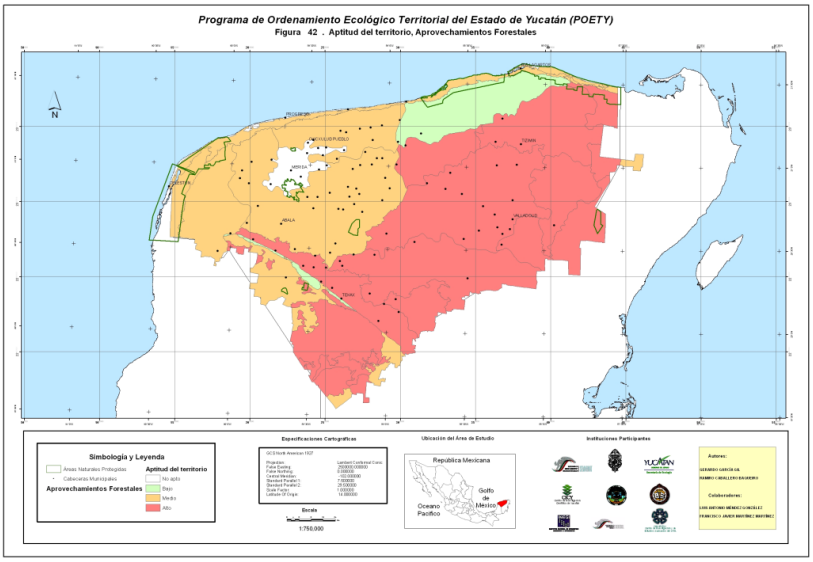
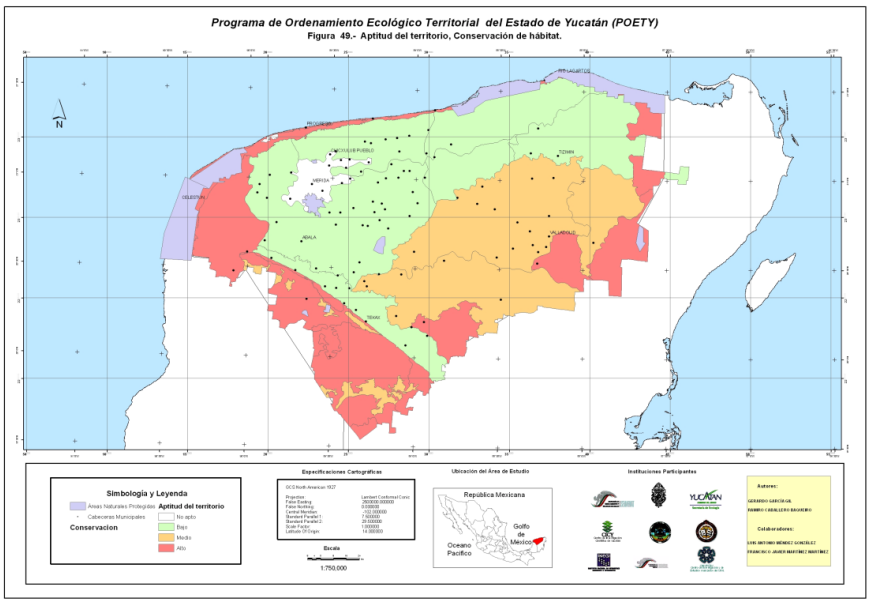


Figure 4.12: Intensity of conservation schemes in the Yucatán. Colour legend: red = high, yellow = medium; green = low. Source: SEDUMA.



On one side, it appears that the monitoring system implemented by the Federal Attorney for Environmental Protection (PROFEPA) is inefficient in discouraging illegal use of forest resources, and it creates an aura of criminalization for people who use forest resources for productive uses. On the other side, the SAGARPA through Procampo payments incentivizes cutting down of forest resources in order to demonstrate that farmers are still cultivating and can access the subsidy. On the other the request of permits for their use is an expensive process for people in remote rural areas, who prefer to keep using the resources for lack of other consumption or income alternatives.

If we take as an example the community of Corral, where all farmers cultivate mechanized plots of 3 ha on average and most receive ProArbol payments, 7/20 engage in precious wood extraction, while all of them keep collecting high amounts of firewood in the forest (an average of 3 tons per year per household). In this village households are strongly dependent on ecosystem goods: we have seen already from farmers response that some would like to be able to still plant traditional *milpas* to grow seeds that have been abandoned, they hunt, use a high amount of firewood and they still practice traditional ceremonies to propitiate rain and good harvest despite having switched to hybrids varieties of maize cultivated mostly on irrigated plots. This is also a highly isolate community, at almost two hours drive from the main urban centre because of the bad conditions of the road. Almost half of the population older than fifteen years did not finish primary school and 5 over 20 households have their kids in the Riviera Maya. Despite they have irrigated mechanized systems all households sampled in this community fall under the economic poverty line, even when self-consumption is imputed. The situation is not dissimilar for instance in Sudzal Chico, where twenty farmers grow mechanized plots, hunt deer, and use 3 tons of wood per year per family, but here only two farmers sampled received payments for forest conservation. Because of the vicinity to the agricultural *maquiladora* Valle del Sur some farmers work there as day labourers, but many have left their fields and moved to the urban area of Tekax. Several farmers with small mechanized plots, with lower crop diversity but oriented to marketing, are located in traditional and isolated communities, in areas difficult to reach, lacking basic services, and not generating income high enough to allow them to reduce the use of firewood and switch for instance to gas. We have seen in fact that the per capita income generated on mechanized plots while higher than in other productive systems is still

quite low.

In such a context, the necessity to identify the type of groups that benefit from ecosystem goods and services is quite evident. Governance-related drivers appear to have an influence on the use of resources especially through lack of participation and involvement by groups dependent on ecosystems in decision-making. The payment for ecosystem services programme does not seem to address the problem of these communities at the root, as using firewood is for them a basic need to which they have no alternative. The logic of the programme, as it has been developed in the areas surveyed, has been based on prohibition to use and reforestation (about 0.2% of the area of Tekax municipality and 1.1% of Tzucacab were reforested between 2005 and 2010). Its success seems limited by the factors on which participation in the programme depends, such as living in a marginalized community with high indigenous prevalence, because this specific factor seems correlated with higher economic deprivation and higher dependence from ecosystem goods that a small direct payment is not able to reduce. An independent evaluation carried out in 2011 found that the main problem of the payments for ecosystem services programme was in fact the prohibition to manage the forest for productive uses, allowing only extraction for self-consumption, which seems to contribute to illegal activities. Disaggregating the direct and indirect beneficiaries of ecosystem goods and services could provide a step forward by linking the programme with sustainable and coherent development policies that provide something more than a payment to prohibit their use. The use of wild fauna and flora can be seen as an indicator of traditional associated knowledge and a key component of the well-being and subsistence strategies of people who depend on ecosystem goods and services. Duraiappah (2004) defines the crucial role of institutions and organizations in helping individuals earn a sustainable income from the provisioning services offered by ecosystems: in particular clear ownership of and easy access to a variety of resources is needed to make the conversion of natural resources into economic activities successful.

4.4 Conclusion

The picture emerging from our analysis is one of high use of agricultural biodiversity by Mayan farmers who are characterized by different endowments, conversion factors and

especially opportunities. Agricultural biodiversity and ecosystem goods emerge as fundamental safety nets that provide alternatives for people to achieve stability in consumption, income, basic functionings, cultural identity and social participation. Their availability embeds the notion of ecological security: changes in their levels and stability might determine changes in the ability of the ecosystem to provide these services, putting at risk the ability to achieve food security and other valued well-being outcomes for the people who depend on them. However, the picture that emerges from our analysis is one of distress of people in rural areas of the Yucatán, especially in traditional farming systems, which threatens the future conservation of crop genetic resources and associated knowledge.

In 1988, Hernández-Xolocotzi was describing traditional farming systems in Mexico as characterized by small-holdings, limited markets, production for self-consumption, low access to credit and technical assistance, increasing monetary needs, outmigration of qualified labour and rupture with basic cultural element (Hernández-Xolocotzi, 1988). Almost thirty years later, the situation of small and medium-holders in the Yucatán does not seem much different, even when looking at more commercially oriented cultivations throughout different agro-ecological environments. The difference is the strong reduction of the population involved in this activity, linked with higher out-migration to urban and touristic areas, increasing pressures from pasture and cattle ranching, and worrying trends for the conservation of crop genetic resources.

Following global trends, the younger generation is less and less exposed to the flow of knowledge and cultural value linked to agriculture as their fathers prefer them take advantage of education and employment opportunities off farm. While researchers in the Yucatán say this trend has been seen for the past thirty years and yet traditional agriculture has not been abandoned, the current young generation doesn't see agriculture as a real alternative. The expansion of the capability set for young people through education and alternative employment opportunities, even through migration, shows that agriculture in the Yucatán, especially at small-scale level is not considered as an alternative.

Farmers also lack organization to take advantage of marketing opportunities, acting alone or through intermediaries, often unable due to their low level of education to pursue formal

accounting practices and planning. Public support has often come to be seen by farmers as a form of owed salary by the authorities rather than an investment in farm improvements, which creates a vicious cycle of dependence and distrust. On the other side, it is in many cases linked to political questions of membership and local, state and federal authorities condition the distribution of subsidies and other types of support to votes during election times. The lack of communication and coherent action by government agencies is mentioned repeatedly by key informants as a problem in the state (and most likely of the whole Mexican nation as mentioned by Dyer, 2010 and Yunez-Naude, 2010) as it creates contrasting and perverse incentives that lead to loose-loose solutions.

Increasing participative freedom for sustainable management of ecosystems, establishment of formal institutions to protect ecological safety nets and for the fair distribution and use of these nets by local communities are badly needed. For instance, pure use prohibition strategies to conserve the southern forests without involvement of the local population do not appear effective, as our findings suggest along with other (Bioasesores, 2011). The main instrument for conserving biodiversity in Mexico is the federal policy of Natural Protected Areas, which have been managed with a centralized top down logic. Garcia-Frapolli et al. (2008), show that the most common difficulties arising from these instruments include conflict between environmental agencies and local people, the exclusion of their values and beliefs in policy development and implementation, and contrasting and incoherent action between different government agencies. In our research we found a typical example of these processes especially in an area where forest resources are not mainly threatened by slash and burn farming but conversion to pasture and cattle ranching. In the southern areas of Tekax and Tzucacab where commercial farming systems are in place, higher use of chemical inputs, irrigation and loss of traditional maize varieties and higher use ecosystem goods from the tropical forest. Here, the lack of consultation with local populations when implementing conservation schemes based on pure prohibition through direct payments, and the lack of inclusion of local knowledge on the use of forest resources strongly reduces the effectiveness of the policy. The tonnes of firewood collected every year are significantly higher than in other areas, while precious wood and forest animals are being hunted for their high market value and for home consumption, as they are part of their livelihood strategy. These forests do not only provide extractie values, but sequester carbon dioxide, shelter biodiversity,

prevent erosion and can play a important roles in regulating complex hydrological systems. Moreover, several of these farmers are located in strongly traditional communities where secondary crops are still being preserved for nutritional quality, culinary preferences, storage characteristics etc. Authors studying these processes in other areas of Mexico note that there is no evidence that these payments for ecosystem services have the desired impact on the conservation of forest ecosystems, mainly due to how the payments are provided to eligible population, on which information is generally inexistent (Muñoz et al., 2007; Alix-Garcia et al., 2009; Dyer 2010). Moreover, services with potential international markets, like carbon sequestration and biodiversity, may be particularly important for the tropical forests of Southern Mexico, given their lack of overlap with critical watersheds (Alix-Garcia et al., 2009).

However, opposite trends shape the threats to native crop diversity and use of off farm ecosystem goods: while pressure on the latter may be reduced by increasing migration and reduction of slash and burn farming, the same processes are linked with an increasing threat on the genetic diversity of native crops, their evolution and the rich associated knowledge that can only be maintained through their continued use on farm. Synergetic programmes that recognize associated local knowledge on ecosystem goods and services coupled with research for the sustainable conservation and enhancement of these benefits are badly needed. It is important to understand the reasons for the use of these resources by local communities which might be driven by lack of affordable alternatives, such as with intensive use of firewood, by distorted market prices that can incentivize illegal logging and hunting, such as with precious wood and deer meat, but also by tradition and preferences that are part of the subsistence and cultural identity of these communities. The simple prohibition without understanding the reasons of the use of ecosystem goods and services and how alternatives can be provided taking into account local identity appears a loose-loose strategy.

We have seen that many Yucatec farmers not only see farming as a mean to subsistence or economic value, but also as a fundamental link to their cultural heritage, and this is true not only for traditional milpa farmers but also for those who have switched to hybrid varieties, who keep conserving secondary crops native to these areas. They give fundamental meaning to their work on farm as the place where they grew up, their tradition and cultural heritage,

and a tranquil way of life that allow one to be independent from others. Thess values cannot be captured in monetary terms and their recognition should be rewarded, acknowledging its role in the conservation of crop genetic resources, cornerstones of present and future food security. Several farmers value local varieties for their resistance to pests and diseases, their adaptation to seasonal farming and their storage potential. These are values that cannot be overlooked while society is facing economic and environmental change. Moreover, the link between gender roles and crop diversity indicates that further value might be intrinsic to culinary and nutritional traits.

Smallholder production for self-consumption has been key for the food security of Maya peasant households and for the conservation of cultural and biological diversity. The protection of native local genetic resources entails protecting local food security, culinary culture, and maintaining genetic resources that might prove fundamental against future changes. Without an understanding of the multiple use of ecosystem goods and services that rural Mayan families pursue, the creation of an environmental conscience within the population, and without solution to the conflicts between environmental protection and agricultural development agencies, it will be difficult to achieve development that provides real opportunities based on sustainable use of natural resources. However, if the present and future value of conserving crop genetic resources and the cultural identity and heritage associated is not rewarded recognizing also its public good value there will be fewer and fewer conservationist farmers. Conservation and development programmes should be devised as coherent frameworks to complement income generation with sustainable agricultural practices that take into account the local knowledge and recognizing the instrumental role of agorbiodiversity could achieve important sustainable development objectives: that of conserving crop biodiversity while making agriculture a substantial opportunity for young people. The preservation of the values associated with agrobiodiversity cannot be left only in the hands of private actors, but should be rethought of as an instrument for enlarging the real opportunities available to them.

CHAPTER 5. Crop Diversity On Farm

We have seen in Chapter 1 that agrobiodiversity provides different ecosystem goods and services, while it can contribute to ecosystem functioning increasing long-term stability of the ecosystem (Altieri, 1999; Jackson et al., 2007; Hajjar, et al., 2008). Its role in providing subsistence, nutritional quality, stability, food security, cultural and spiritual value has been documented by several authors, and underlies the necessity for studying the determinants of its loss (Bellon and Brush, 1994; Bellon, 1996; Brush, 1995, 2000, 2004; Perales, Brush and Qualset, 2003; Isakson, 2007; Jackson et al., 2007; Arslan and Taylor, 2009; Bellon and Hellin, 2011). However, many goods provided by crop diversity can be substituted by alternatives purchased in the market, which can induce specialization in few activities for marketing (Bellon, 1996). In fact, different processes have been analyzed as drivers of on farm conservation: adaptation to agroecological conditions, seed-saving practices, selection of preferred traits, cultural values and identity, market isolation, opportunity costs. We underlie the importance of studying crop diversity in the context of larger cropping systems and economic environments. Drawing on the literature reviewed in Chapter 1 and 3, we analyze some factors influencing the conservation crop diversity in the Yucatán through the lens of the Extended Capability-Ecosystem Approach, developed in Chapter 2. The integration of the Capability Approach within an Ecosystem Approach takes into account the fact that households differ in endowments, access, availability, preferences and aspirations and that conversion factors and capabilities can influence the benefits they derive from ecosystems. We argue that the opportunities available to people, their capability set, should be explicitly taken into account when analyzing the drivers of on farm conservation of crop diversity, along with individual, social and environmental heterogeneities and resources that affect people's choices.

5.1 Econometric Model and Estimation Issues

5.1.1 Diversity measure

Crop diversity can be measured in different forms: the simplest measure is 'richness', or the number of species or varieties found in a specific area; but it can also take into account the

‘evenness’, or the relative distribution of species in a specific area (Magurran, 1988). We focus on diversification of crops for consumption and marketing, and on the conservation of native varieties through simple richness measures, which have straightforward interpretation in econometric analysis: the dependent variables in the regression models are counts of the number of crops planted by the household. Variety names were provided by farmers according to their recognition, which provides a useful estimate of the diversity they manage (Meng et al., 1998; Jarvis et al., 2000). We asked farmers how many maize, legume and squash varieties they were growing identifying them by their colour and recorded the Mayan name when they specified it (see Arias et al., 2000 and 2004 for in depth characterization of these varieties and species). Most commonly Xmejen-nal and Xnuk-nal white and yellow maize varieties were mentioned, with few farmers growing black and red varieties as well. Among squash varieties, both large and small seed species C. moschata L. y C. argyrospema L. are grown by farmers, but while the former is cultivated by 60% of farmers in our sample, only few grow the small seed one (16%). Finally, farmers mentioned up to four legume species, the most common being Xcoli-buul (Phaseolus vulgaris L.), grown by 27% of farmers, ibes (P. lunatus L.) cultivated by 25% of farmers, X-pelón (Vigna unguiculata L.) which is grown by only 10% of farmers, while five farmers in the milpera area of Tinum were growing Cajanus cajan (L.) by them identified as lentejas. The colour differentiation is a limited identifier especially of the rich diversity of maize and might underestimate the real diversity cultivated by farmers, but the bias should not be significant as their recalling provides a good estimate of the level of useful crops they manage.

5.1.2 Selection bias

The issue of selection bias has fundamental importance when studying conservation of crop genetic resources (Brush et al., 1988; Van Dusen, 2000). The decision to completely abandon an activity, for instance the cultivation of local landraces, has evident consequences on the availability of their genetic resources in space and time. In our sample, half of the farmers have completely abandoned the cultivation of native maize varieties, and even a larger proportion has stopped planting local legumes and squash species. However, different processes might govern their decision to cultivate these crops from that of planting different varieties or species of these crops, and we take this into account. The sampling strategy chosen aimed at including in the analysis a significant number of farmers with different

characteristics in order to better understand what influences their crop diversification strategy and the decision to keep growing local varieties.

5.1.3 Estimation issues

The economic model applied to analyze the determinants of on farm conservation takes the following form:

$$D_i = \beta_0 + \beta_1(Indiv\_conv_i) + \beta_2(Proxy\_cap_i) + \beta_3(Econ\_pov_i) + \beta_4(Environ\_conv_i) + \\ + \beta_5(Endowm_i) + \beta_6(Extens) + \varepsilon_i$$

where: D_i = measure of crop diversity of household i;

$Indiv\_conv_i$ = individual conversion factors of household i;

$Proxy\_cap_i$ = proxies for capabilities of household I;

$Econ\_pov_i$ = economic poverty indicator of household i;

$Environm\_conv_i$ = environmental conversion factors of household i;

$Endowm_i$ = productive endowments of household i;

$Extens_i$ = access to extension programme for household i;

ε_i = error term.

Explanatory variables are divided into six groups: individual conversion factors, proxies for capabilities, economic poverty, environmental conversion factors, productive endowments, and access to extension programme.

Two sets of regressions based on this model are applied. The first set of regressions estimates what influences overall crop diversity planted on the plot, and if different factors explain the number of crops used for consumption and for marketing. Because 36% of households do not market any crop, the decision to sell is modelled separately from the decision to diversify crops for marketing through a two-stage hurdle model, following other studies on crop diversity (Heckman, 1979; Van Dusen, 2000; Benin et al., 2004). The decision to sell can be seen as a two-stage process: in the first place, being able to market and deciding to enter the market depends on a set of factors, then a different process might affect the decision to diversify production for marketing. Following this logic, a Probit model is applied to

understand what factors influence the decision of the household to sell. Secondly, a truncated Poisson model is applied to the subpopulation of farmers that participate in the market as sellers, to understand what affects their decision to market a diversity of crops.

The second set of regressions is carried out on the level of native crop diversity managed by households. This analysis aims to understand what influences de facto conservation of crop genetic resources, which are adapted to local agroecosystems and climatic conditions, and entail culinary, nutritional, cultural, option and existence values as discussed in the previous chapters. The traditional milpa is the main productive system in the area, the main source of cereals, vegetables and pulses for household consumption, and the main repository of genetic resources native to the Yucatán. It is therefore relevant to understand what determines both the decision to plant native varieties and the number of varieties managed by farmers. Because of the issue of selection bias, a two-stage hurdle model is applied for each crop following the logic of the first set of regressions. The first equation conceptualizes the farmer's decision whether to plant or not a native variety through a Probit regression on a dichotomous dummy variable indicating if the household cultivates a native variety and therefore crosses the hurdle. Households that cross the hurdle because they cultivate native varieties are selected for the second stage where truncated count models are applied to analyze what determines the number of varieties or species planted. A general Poisson regression without the hurdle is also specified for each crop to provide a comparison. These regressions are carried out on native maize, squash and legume varieties.

5.1.4 Count data models

Count data models are appropriate when the dependent or response variable of interest is a nonnegative integer, such as the number of crops grown by a household. The Poisson model is well fitted for this kind of data. The probability of choosing k activities given n independent trials is represented by the binomial distribution:

$$P(Y = k) = \binom{n}{k} p^k (1-p)^{n-k} \quad (1.1)$$

where $\binom{n}{k} = \frac{n!}{k!(n-k)!}$ and p is the probability of choosing k. Statistical theory state that a series of binomial choices asymptotically converges to a Poisson distribution as n becomes

large and p becomes small.

$$\lim_{n\to\infty}\binom{n}{k}p^k(1-p)^{n-k} = \frac{e^{-\mu}\mu^k}{k!} \qquad (1.2)$$

where $p = \mu/n$ and μ is the mean of the distribution, or in this case the number of crops grown. This formulation allows us to model the probability that a household chooses a number of crops, k, given a parameter μ, the sample mean.

The Poisson regression model is the development of the Poisson distribution in equation (1.2) to a nonlinear regression model of the effect of independent variables x_i on an scalar dependent variable y_i. The Poisson distribution for the number of occurrences of the event has density:

$$\Pr[Y = y] = \frac{e^{-\mu}\mu^y}{y!}, \quad y = 0, 1, 2\ldots,$$

where the mean parameter is a function of the regression x , and a parameter vector, β

$E(y_i \mid x_i) = \mu_i \exp(x_i'\beta)$ and y= 0, 1, 2…

The Poisson distribution has the property of equality of mean and variance, such that

$V(y_i \mid x_i) = \mu_i(x_i,\beta) = \exp(x_i'\beta)$

The restriction of equality of mean and variance can often be too restrictive for sample data, as the conditional variance tends to exceed the mean resulting in an over-dispersion problem (Cameron and Trivedi, 1986). If there is in fact a problem of over-dispersion, the conditional mean estimated with a Poisson model is still consistent but the standard errors of β might be biased downwards. Extensions to the simple Poisson model the variance as a function of the mean in addition to a further term, α, to characterize the degree to which the variance differs from the mean. A more generalized model that accounts for the over-dispersion problem is based on the negative binomial distribution expressed as

$$f(y_i \mid \mu,\alpha) = \frac{\Gamma(y+\alpha^{-1})}{\Gamma(y+1)\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu}\right)^{\alpha^{-1}}\left(\frac{\mu}{\alpha^{-1}+\mu}\right)^{y}$$

where $\mu_i = \exp(x_i'\beta)$, $\alpha \geq 0$, y= 0, 1, 2…

Cameron and Trivedi (1990) have proposed a test for over-dispersion, which tests for the significance of the α parameter as compared to the Poisson model, and the survey data was

checked to determine if over-dispersion is a problem. We use the Negative Binomial Model, in which the variance is modelled as a quadratic term (NB-2) for the first set of regression, while we use the Poisson Model for the second set of regressions. Because we are dealing with complex survey data, the survey (svy) option was used to declare survey design as defined in Chapter 4 and sampling weights were calculated as the inverse of the probability of being included in the sample. With this kind of data, design-adjusted goodness-of-fit tests are not available, but graphic comparison of the modelled distribution of counts with the observed distribution from the survey are extremely useful in gauging the model fit over the range of responses (Heeringa, 2010), while the 'linktest' in Stata performs a test for model specification. Graphical analyses are provided in Annex II.

5.1.5 Hurdle model for selectivity

Two-part models allow different mechanisms for the decision to participate in an activity, in our case the decision to sell or to plant a native variety, and the amount of diversification chosen within that variety or species. Following Van Dusen (2000) we use the Hurdle model, generalized by Mullahy (1986). Hurdle models can be represented as the sum of two independent models: a binomial probability model and a truncated-at-zero count model. The log likelihood describes the sum of a log-likelihood for the binary outcome model and a log likelihood for a truncated-at-zero Poisson model. The Probit models are estimated by maximum likelihood estimation: coefficient estimates measure the change in the probability that the dependent variable will experience as a result of a unit change in the value of the explanatory variable. The likelihood function is specified as a combination of two independent processes over two different domains, therefore the two equations can be estimated separately. Maximum likelihood estimation separates maximization of the two terms in the likelihood, one corresponding to the zeros and the other to the positives.

$$L = \prod_{i=1}^{N1} P(y_i = 0 \mid x_i^{'}\beta_1)^{d_i} \left(1 - P\left(y_i = 0 \mid x_i^{'}\beta_1\right)\right)^{1-d_i} \times \prod_{i=1}^{N2} \frac{P\left(y_i \mid x_i^{'}\beta_2\right)}{P\left(y \geq 1 \mid x_i^{'}\beta_2\right)}$$

where N1 represents the full sample and N2 the restricted sample of only those who engage in an activity (in our case marketing or planting native species), while d represents the binary variable of the first stage zero-one choice.

In Stata, the survey command allows us to estimate Probit models taking into account survey

design and a goodness-of-fit test, which is reported.

5.1.6 Dependent variables

Dependent variables in our models are the counts of crop species and varieties planted by the households. Summary statistics for these variables are presented in Table 5.1. The first variable, total varieties, is constructed by summing up the total number of varieties the farmer cultivates. This variable reflects the overall crop diversification decision of households and is used to understand the prevalent factors generating this process. The following two variables are constructed on the sum of varieties of different crops cultivated for household consumption and the sum of varieties marketed. The hurdle model is then specified on the decision to sell and the diversification of crops for marketing. The same logic is used for the number of varieties planted for maize, squash and legumes. First the total number of varieties for each crop is reported, followed by dummy variables for the decision to plant a specific crop and then count variables for the decision to plant different varieties or species of each crop.

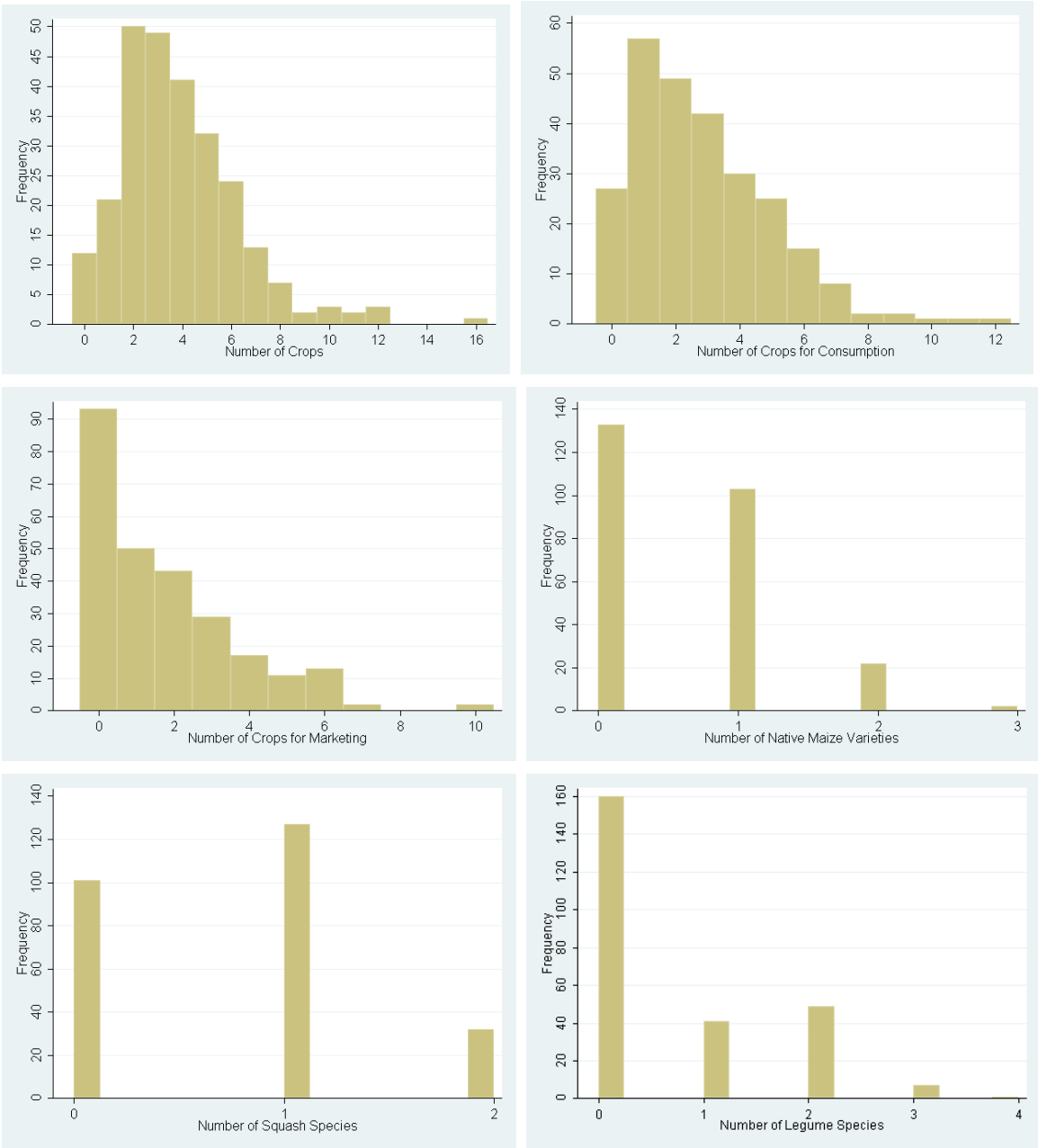
Table 5.1: Summary statistics of the dependent variables

Dependent Variable	Regression Type	Mean	Std. Err.	Min	Max
Total varieties	Negative Binomial	3.47	0.16	0	16
Total varieties for consumption	Negative Binomial	2.79	0.14	0	12
Total varieties for marketing	Negative Binomial	1.29	0.12	0	10
HH markets crops	Probit	0.53	0.04	0	1
Total varieties for marketing (HH that market crops)	Truncated Poisson	2.39	0.17	1	10
Total maize varieties	Normal Poisson	0.57	0.04	0	3
HH plants native maize	Probit	0.48	0.03	0	1
Total native maize varieties (HH that plant native maize)	Truncated Poisson	1.18	0.04	1	3
Total squash varieties	Normal Poisson	0.79	0.05	0	2
HH plants squash	Probit	0.65	0.04	0	1
Total squash varieties (HH that plant squash)	Truncated Poisson	1.21	0.03	1	2
Total legume varieties	Normal Poisson	0.70	0.06	0	4
HH plants legumes	Probit	0.43	0.04	0	1
Total legume varieties (HH that plant legumes)	Truncated Poisson	1.63	0.07	1	4

Source: Survey data

The histograms in Figure 5.1 show that variables for the overall number of crops planted follow a Poisson distribution with some over-dispersion, therefore a Negative Binomial Model is specified. Variables based on marketing diversity and native crops diversity have a high incidence of zeros, but follow a Poisson distribution once the zero truncation is taken into account, therefore the Hurdle model is more appropriate.

Figure 5.1: Histograms of dependent variables



5.1.7 Explanatory variables

Explanatory variables are divided into six groups: individual conversion factors, proxies for capabilities, economic poverty, environmental conversion factors, endowments and access to extension. Summary statistics and expected signs of the coefficients are shown in Table 5.2. Recalling our theoretical framework, we choose proxies for capabilities related to education, employment and migration opportunities, including a gender dimension that is linked to choice within a set of alternatives. These are proxies of capabilities, as one can only measure the result of the choice, the activated functionings within the capability set.

Table 5.2: Explanatory Variables

Set of Variables	Explanatory Variable	Hypothesized Effect			Std. Mean	Std. Err.	Min	Max
		Crop diversity	Market.	Native diversity				
Individual conversion factors	Age of HHH (years)	+ -	-	+ -	56.74	1.15	29	91
	HH labour (nr)	+	+	+	3.41	0.14	0	11
Proxies for capabilities	Education HHH (years)	-	+ -	-	4.1	0.29	0	16
	Migration (dummy)	+ -	+ -	+ -	0.18	0.02	0	1
	Off farm work HHH (dummy)	-	-	-	0.49	0.04	0	1
Gender	Wife works on farm (dummy)	+	+ -	+	0.23	0.03	0	1
Economic Poverty	Household falls under the national economic poverty line (dummy)	+	-	+ -	0.84	0.02	0	1
Environmental conversion factors	Average price of travelling to closest nodal town (Mexican pesos)	+	-	+	19.85	1.9	0	135*
	Land heterogeneity (nr of plots)	+	+	+	1.16	0.02	1	3
Endowments	Area cultivated between 2 and 5 ha (dummy)	+ -	+	+ -	0.21	0.03	0	1
	Area cultivated more than 5 ha (dummy)	-	+	-	0.20	0.02	0	1
	Irrigation (dummy)	-	+	-	0.07	0.01	0	1
	Pasture (dummy)	-	+ -	-	0.08	0.16	0	1
Access to extension	Technical assistance (dummy)	-	+	-	0.41	0.04	0	1

*1 USD=13 MXN approximately in 2011

Source: Survey data

Individual conversion factors represent the personal characteristics of households that might influence the number of crops that the farmer decides to grow and its diversified uses. Age of

the household head could be a constraint for cultivating multiple crops as they require higher labour intensity, or an advantage due to experience and knowledge of management practices and varieties that perform better under different conditions and purposes (Bellon, 2004). Older households might diversify production for consumption because of economic vulnerability or because their tastes and preferences are less prone to substitution with commercial products. They might also prefer native varieties for consumption purposes, but also because of their knowledge associated to farming practices. On the other side, the labour effort necessary to manage diverse crops could reduce the number of varieties planted by older farmers, and even reduce the likelihood that their effort is directed to marketing. The expected sign of the coefficient is therefore uncertain for diversity measures and expected to be negative with the likelihood to market.

Household labour measured by the number of household members with more than 14 years of age, is a conversion factor that represents the pool of family labour available to the household for cultivating diverse varieties but also engage in other activities. Family members are a potential source of high quality labour needing lower supervision that might favour the conservation of crop genetic resources, which are often labour intensive given the effort inherent in selection, storage, and management of many varieties (Bellon and Risopolous, 2001). On the other side, as many adults and young people look for employment outside agriculture, their influence on managing more diverse plots might be minimal and the farmer might resort to hired labour or planting fewer varieties to tackle labour shortages. The expected sign on diversity is positive but with a degree of uncertainty.

Years of schooling are a proxy being able to be educated, which depends on external factors such as access to education opportunities, but also choice and individual abilities. Low or absent schooling not only impacts the personal development of the individual, but also influences the ability to take advantage of study and employment opportunities, constraining social mobility and limiting abilities of the person. We have seen in Chapter 4 that many farmers interviewed didn't reach primary or higher education level because of lack of education opportunities. In terms of the link with crop diversity, education could have a negative effect on the diversity managed by farmers as the opportunity cost to dedicate more time to the plot can be higher for more educated individuals that might look for employment

off farm. Moreover, if they take advantage of employment opportunities elsewhere the income generated would be higher, which lowers the relative cost of purchasing products form the market and therefore reduces incentives for crop diversification. The expected sign is negative.

Off farm work is also a capability strongly characterized by a freedom aspect, the availability of these opportunities that might enlarge the capability set of a person, and a choice aspect, the activation of the related functioning. These opportunities represent a source of additional income, which can reduce the time available for farming and provide less use to a diversification strategy meant for risk management, increasing the opportunity cost of maintaining diversity (Zimmerer, 1991). The expected sign of the relationship with crop diversity is negative but uncertain as farmers may choose crops and varieties that are planted or mature at different times in order to address time constraints.

We have widely argued the role of migration opportunities in Chapter 4, as it represents a possible enlargement of the capability set available to people, but also entails other aspects such as lack of opportunities in one's own community that satisfy one's needs and desires. There is a growing body of literature on the association between new waves of migration and changes in farming systems in areas similar to the one we are studying as we have seen in Chapter 3. In about 20% of households members have migrated to other areas in search of employment opportunities outside agriculture, but there is no international migration, therefore remittances are low or absent. Migration might affect diversity negatively through reduced labour availability and substitution with market products through remittances. On the other side, remittances are so low that they might not incentivize this process, while households affected by migration might already be the ones that are more subsistence-oriented and vulnerable, and might diversify anyway to satisfy consumption needs. The expected sign of the coefficient is uncertain.

We choose to include a gender dimension as in some households (20%) women spend a significant amount of time working on the plot and this allows us to capture a possible relationship with diversity on Yucatec farms (Brush, 2000; Lope-Alzina, 2007; Radel, 2011). We have seen in Chapter 4 that they are most often in charge of weeding, cleaning, or bean

harvesting, but their presence on farm might be linked with varietal choice or with leaving a space for specific crops. By including this variable we want to understand if their presence on farm might be associated with different levels of crop diversity. The expected sign of the coefficient is positive but uncertain, and their contribution might come through additional labour or actual influence on varietal selection. Other studies show that their voice is often taken into account (Lope-Alzina, 2007).

We include a measure of economic poverty as it can be an important variable for crop diversity, since higher income makes purchasing market substitutes more affordable, but it can also allow the farmer to switch to input intensive practices and buy modern varieties instead of planting traditional ones, pay for irrigation water rights and hire tractors and labour. Lower income makes adoption of monocropping practices and high input varieties less likely as the immediate investment required is too high, while crop diversification provides a risk management strategy against adverse events that might affect the harvest (Bellon, 1996). As in Chapter 4, income poverty is measured by whether the household falls under the national economic poverty line according to predicted household per capita expenditure. The economic poverty line identifies the population that does not have enough resources to buy the goods and services required to meet food and non-food needs. The direction of the relationship between economic poverty and crop diversity is expected to be positive.

Two variables provide a good proxy for environmental conversion factors, one based on the built environment through infrastructure and services and the other on environmental heterogeneity. An environmental factor linked to the built environment are transaction costs measured by the price for transport to the main nodal town, which is highly correlated with a number of other aspects including distance from markets, availability of health and education services beyond primary school, and road infrastructure condition as the price increases where the road is in bad shape, geographical distance being equal[40]. Transaction costs are a proxy for the cost faced by households in marketing their output, or in purchasing substitutes for the diversity they grow. There is no daily provision of some food types and other goods in

[40] As in Chapter 4 we calculate the cost of transport based on census data from 2010 as an average between the minimum and maximum price of transport in the locality. Transport was not available in three of the sampled localities (Noh Bec, San Felipe Viejo and San Francisco Grande), in which case we applied the maximum price for transport in the nearest village.

most isolated villages, which might increase the need for crop diversification, while the prices of market substitutes may not be affordable. The hypothesised direction of the relationship with crop diversity is positive, while negative or not significant with the decision to market their products.

Land heterogeneity is measured by the number of different plots cultivated by the household and aims at understanding whether agro-ecological conditions determine the level of diversity managed by favouring or constraining intensification (Bellon and Taylor, 1993). The expected sign of the coefficient for land heterogeneity is positive as households might adapt different varieties to heterogeneous soil conditions when they have access to plots with different depth, fertility, stoniness and slope but also because they may choose varieties with different growth times or management, storage and consumption characteristics.

Productive endowments taken into account are the area cultivated, availability of an irrigation system and whether the household has pasture. The area cultivated by households in the region presents a certain degree of variation with a higher incidence of smallholders but with several medium and large-holders. This threefold subdivision works well to describe the socioeconomic landscape of rural Mexico (Taylor and Dyer, 2009). We use a dummy variable for medium-holders with more than 2 ha but less than 5 ha and a dummy for large-holders with more than 5 ha in order to compare both to small-holders. Large cultivated areas require higher labour and farming inputs but allow fixed costs to be spread over a larger production area, and might be managed with fewer varieties for market specialization. Medium-holders might instead be oriented to subsistence but be able to derive a surplus for the market, therefore they might take advantage of area and income to cultivate more varieties. The expected sign of the relationship for large-holders is negative with crop diversity and positive on the decision to enter the market, while it is uncertain for medium-holders.

The availability of an irrigation system may influence farmer's decision to switch to higher yielding modern varieties, therefore abandoning intercropping practices and reducing overall and native diversity. It is also linked to higher likelihood of marketing crops as payment for water rights and maintenance of irrigation systems are costly. The expected sign of the

relationship with native diversity and crops for consumption is expected to be negative, while it is expected to be positive for marketing.

We include pasture as an endowment to check if there is an association with reduced crop diversity as households focus on cattle ranching start converting their plots to pasture even without cattle, as we have seen in Chapter 4 (Wyman et al. 2008, Radel et al, 2010). The sign of the coefficient is expected to be negative with crop and native diversity, but only if a substitution is actually in place.

Availability and access to extension services is measured by whether the household has received any agricultural training, which in the area studied are provided by government programmes. These extension services are focused on yield increasing practices, use of fertilizers and other chemical inputs in a government strategy to incentivize more intensive and higher yielding production, tackling low prices for maize but also cash crops as citrus, as we have seen in Chapter 4. Contact with extension agents is expected to have positive influence on the decision to market while negative on crop and native diversity as more informed farmers might be more likely to adopt modern technologies, such as high-yielding varieties (Doss, 2003).

5.2 Findings from the Econometric Analysis

We discuss the results of our analysis in conjunct for the two sets of regression showing how conversion factors, capabilities and endowments influence the overall level of crop diversity and the on farm conservation of crop genetic resources. Econometric findings are presented in Tables 5.3, 5.4, and 5.5 at the end of this Chapter.

5.2.1 Conversion factors

Among individual conversion factors we find that age seems associated with lower likelihood to enter the market as sellers, but no significant association is found with measures of crop diversity for different uses. Participation in the market might be linked with farmer's physical ability to produce a surplus that can be sold on the market, as older farmers are more likely to

cultivate only for subsistence, given the physical effort they can input in production. However, there might be indirect effects through education that reduces their ability to take advantage of marketing opportunities or technological innovations. Older households are more likely to be detached from markets, which might increase their vulnerability of their already different needs due to age. When we consider that fewer households cultivating traditional milpas participate in the market, this also makes us consider the ageing of the farming population not only as an overall evident trend in the region, but also as signal which might have consequences for crop genetic resources conservation, especially those that are cultivated by fewer and fewer households as we find in the regressions on traditional varieties. Moreover, the lack of significance for the coefficients of another individual conversion factor, availability of household labour, might be a further indicator of the low contribution of younger household members to agricultural activities. Household labour does not appear associated with the cultivation of native species, although there is a feeble negative association with the likelihood to grow more than one squash species, which might derive from availability of more income sources and substitution in consumption of minor squash varieties. When we look at the set of estimations based on native crop diversity we find that age is not associated with the abandonment of native crops, but is associated with opposite sign with maize and legume diversity among households that plant these crops. This finding is not surprising considering that maize is significantly more labour intensive than legume cultivation and age might represent a constraint in deciding to grow different varieties. Moreover, it might also be associated with experience and knowledge of the cultivation of different legume varieties that might be regarded as traditional culinary favourites, and an age effect might be associated to this feature. In an area where the farming population is quickly aging this might mean that fewer maize varieties will be grown in the future by fewer farmers, which poses further strains on the conservation of their genetic resources on farm.

Environmental conversion factors linked to transaction costs and land heterogeneity are significantly associated with the level of crop diversity managed, as found in other studies (Van Dusen, 2000, Bellon and Hellin, 2011). Transaction costs appear to positively influence the likelihood to grow a diversity of crops for consumption, while they don't appear to have a significant influence on the decision to market. In fact, while several commercially oriented

farmers are located in urban areas of the Cono Sur, where they sell to the citrus market and the juice plant, many as well are located in more remote areas from which they sell their harvest, often through intermediaries when they do not own a vehicle for transport nor rent it collectively. This double pathway of commercialization characterizes the whole region where commercially oriented farmers can be found both in thriving urban centres where they are sometimes able to reach higher prices, and in isolate, marginalized communities where they are more dependent on intermediaries or their ability to reach the markets. It is also evident that households more removed from markets are growing higher levels of crop diversity on the plot. These farmers might diversify crops for consumption, as their ability to market is low due to remoteness and the likeliness that several other households in their community grow similar crops, reducing demand and prices. Moreover, higher costs to commute to urban centres or nodal towns to buy substitute products might incentivize own production of desired goods. This would confirm that higher integration within markets reduces the likelihood that households grow a diversity of crops as substitute products become more accessible, both through availability but also through wider income opportunities that increase the opportunity cost of maintaining diversity on farm. This effect of market integration on crop diversity is especially relevant when we look at native species: while traditional maize is still grown by households both in urban and in more remote areas, it is minor varieties that are being replaced when households are closer to markets. All estimations on squash and legume species show that distance from main markets is strongly associated with their cultivation, which might pose challenges for their conservation. Squash and legume species are with maize the basis of the Yucatec diet, which is not only a source of nutrition and stability in consumption, but is also part of the cultural heritage of inhabitants of this region. The reduction of their availability from year to year, as fewer farmers cultivate them, is also associated with cultural loss, and the 'burden' of their conservation cannot be bore only by the farmers who are conserving them.

Finally, land heterogeneity, measured by the number of plots the farmer has access to, is a significant determinant of overall diversity as expected. Farmers seem to be adapting different crops to different types of land and exploiting the whole potential of environmental heterogeneity to address both consumption and marketing needs. In fact this happens in different forms throughout the region: farmers who cultivate traditional milpas and have

access to more than one plot often use one for maize, beans, and squash intercropping and the other for different uses. In the north they might plant henequen as a complementary cash crop, others, especially in the southern area, cultivate plots with lower stoniness and often with irrigation with permanent crops or vegetables both for family consumption and for marketing. Some farmers who have access to deeper soils and plant mechanized milpas also tend to plant secondary species on complimentary plots or even fruits. Few farmers who have access to three plots even cultivate one with traditional milpa, one with mechanization and one with permanent crops. Access to different agroecological conditions represents therefore a strong incentive for crop diversification, especially when one plot can be managed mainly for self-consumption while the other for marketing.

5.2.2 Proxies for capabilities

In terms of education capabilities, we don't find any significant association with the level of crop diversity managed nor with the decision to participate in the market and grow native varieties, except a feeble relationship with native squash varieties when the truncation is not taken into account. However, while there is not huge variation in the level of formal education attained by household heads, partly because of their age and lower education opportunities in youth, it makes sense to recall a feature of the area studied which is relevant when looking at agriculture and conservation through the lens of an Extended Capability Ecosystem Approach. We have seen in Chapter 4 that mechanized fields of the South, with lower overall crop diversity and loss of traditional maize varieties to commercial ones are often located in areas where the percentage of adults without completed primary education is significantly higher than in other localities. While their ability to achieve higher yields and income has been supported by government programmes, there have been marginal investments in improving access to services and overall opportunities outside agriculture in these areas. We have also seen that many of these farmers often conserve minor varieties for household consumption, while they take high advantage of ecosystem goods available in their area, therefore they are potentially conservationists of minor varieties.

The result for migration opportunities is quite intriguing: the coefficient is positive and significant for overall crop diversity, for diversification for consumption purposes, and for native diversity. We argue that this relationship might be mediated by a situation of overall

vulnerability of the majority of migrant households. This is not long-distance migration to the US or Canada, which is the type of labour movement that brings into households and communities higher remittances that can be used to substitute consumption goods, increase livelihood assets or reduce the value obtained from crop diversity. Instead, we have seen in Chapter 4 that families left behind my migrating members are older farming households where the young generation has left for lack of alternatives that satisfied their needs and aspirations. This is linked to low profitability of farming, lack of employment opportunities outside of agriculture in their communities and attractiveness of income generating activities in the city or in tourist areas. Money and in-kind donations sent by members who have migrated are small and quickly spent on basic daily needs that do not substitute completely their own production. The substitution of cultivated staples with commercial food does not seem to happen as the amount of money available for expenditure is small and households may choose to smooth market shocks through a diversified crop portfolio. Migration also reduces the pool of family (and village level) labour available for working on farm, but there might be enough disguised unemployment in agriculture to cover the labour input needed to grow a diversity of crops, which would reduce the effect of migration on labour availability. On a different level, an age effect, seeing that migrant households are older, might be linked to consumption preferences and custom that makes them maintain their crop diversity even when they receive cash relief from sons living in other communities.

Households affected by migration appear also more likely to grow traditional maize and squash varieties, with a partially different trend to the southern Yucatán peninsula studied for instance by Radel (2010), where migration of the head seems associated with cattle ranching and switching to cash crops. The fact that households affected by migration are more likely to cultivate traditional maize and squash varieties is likely to be associated with the same processes that we mentioned in the previous paragraph. One is that the money sent by individuals who change their community of residence is not so high to incentivize crop specialization. Then, the age factor might even be more important in contributing to maintenance of traditional varieties. As we argued, custom, tradition and culinary preferences might play a role in this association between migration and traditional maize diversity. An interesting line of research opens up with this association between regional migration and crop diversity, especially of native varieties, which will help understand the medium and

long-term effects of potential labour shortages and remittances on agrobiodiversity. As the cultivation of traditional maize and squash is meant in large part for home consumption and the surplus marketed does not provide attractive income for younger people, it might be one of the reasons for younger family members to look for opportunities off farm. This would point to the fact that more vulnerable households are those conserving traditional varieties, which is also supported by the positive and significant coefficient of the poverty indicator, discussed in the next section. The double turn of this process is that while today it is more likely that households affected by migration have higher crop diversity and are conserving native varieties, this cultural and crop genetic resources are likely to be lost tomorrow as fewer family members stay in the community and work on farm.

There is no significant association with off farm employment of the household head and overall crop diversity while it appears to be linked with lower market participation. Off farm labour opportunities are often seasonal, for instance during harvesting or burning season when farmers work on other plots to prepare them for burning and sowing, or occasional works in construction that provide additional income. This type of off farm work, while providing income relief to households that find it hard to survive only through subsistence or revenues from their plot, is not necessarily linked to lower diversity especially as farmers may choose crops and varieties that are planted or mature at different times to address time constraints. While they need to complement their agricultural activity with off farm labour to satisfy household needs, they might complement periods of lower labour intensity with off farm without reducing their own crop diversity. Therefore, while off farm work provides income to buy additional products it does not seem to compete highly with crop diversification for self-consumption nor with native diversity, except for squash species. Let us recall that several households look for employment off farm because their production is not sufficient to cover subsistence and other expenditure, while others maintain their plot despite their main occupation is off farm. This is also an important result of the analysis that provides evidence for a discourse being sustained by researchers in the region in recent years that many individuals who have taken advantage of off farm work opportunities, especially in urban or semi urban areas, keep maintaining agricultural plots mainly to satisfy consumption needs or 'for tradition', as some of our respondents said. In fact several people whose main activity is outside the farm are mainly working in petty commerce, tourism, construction or

public service posts, as the analysis in Chapter 4 shows. These people have decided not to abandon agriculture completely but to maintain it as a side activity for consumption rather than for marketing, often with other relatives working on the plot or by hiring seasonal labourers given their time constraints. These behaviour is not dissimilar to that observed in many rural areas of high-income countries.

5.2.3 Gender

An interesting result of our research that calls for further investigation is the strong significance of the gender dimension in overall and native crop diversity. Women have a central role in household's nutritional quality, house maintenance and overall health of its members but they also seem to influence the decision to plant specific varieties or diversify to address consumption needs. Spouses are knowledgeable about culinary properties and market values of the different crops and their contribution to farming provides family labour that might influence the planting of more varieties for instance for their culinary or storage characteristics. They are especially important during the harvesting season of secondary crops like squash and beans or other vegetables, as mentioned in farmer's responses.

From our estimations, where the spouse is working on farm the likelihood that the household grows a higher number of crops for consumption on the plot is significantly higher. This important result of the analysis provides direction for further research on gender roles not only for crop diversity in homegardens, which has been an important field of research in the region, but also for farming systems as a whole. Even when looking at the type of farming system, there is no significant difference between the proportion of households where women are working on the plot between those working on traditional (20%) or mechanized milpas (19%), therefore the gender effect is not mediated by the production system. From farmers' responses women have a fundamental role especially in weeding and during harvesting season. On the other side, their role doesn't appear associated with marketing decisions: other studies have found that their role decision making power might be more linked to spheres where they have more control, such as in family consumption, and less on those that are more often in control of the farmer, such as income decisions. However, apart from their role in providing quality labour, which can incentivize the maintenance of a wider portfolio of crops and varieties, women are also the household keepers and it is them who are in charge of preparing meals and taking care of the nutritional attainment of family members. If there is a

relationship between their role on farm and specific culinary, nutritional or storage characteristics that they favour, this has strong implications for agrobiodiversity conservation, as measures could be devised that take into account their role and reward them for this (Subedi et al., 2003).

In fact, the gender dimension results significant and positive also when we look at native diversity. The fact that the presence on the plot of farmer's spouses, in the large majority of cases the main caretakers of household member's well-being, nutritional attainment and quality, seems associated with higher diversity for consumption and especially with higher diversity of those crops that she is more likely to work on, especially squash, is of utmost relevance for policies and programmes aimed at improving food security and nutrition and for the conservation of crop genetic resources, especially of two staples of the Yucatec diet, squash and maize. Women seem especially to prefer local varieties: they might have better nutritional quality and taste, allow them to diversify culinary preparations and manage risk through management of a diverse crop portfolio during the year. Further research that focuses not only on the role of women in homegardens, but their contribution on farm is needed to understand incentives for de facto conservation of crop genetic resources on different farming systems in the region.

5.2.4 Economic poverty

There appears to be an association between the fact that the household is under the economic poverty line and the use of traditional maize varieties. Farmers who are economically better off might be more likely to experiment with new technologies and risk through specialization due to heir higher ability to smooth consumption shocks, in case these don't turn out as expected. They are considered more likely to specialize in higher yielding varieties and cash crops such as hybrids, citrus or chillies, because they can afford the input investment necessary. Poorer farmers are instead more likely to maintain traditional maize varieties that require low input investment, are adapted to seasonal agriculture, can be stored for the whole year without being infested by weevils, and can be grown in association with other staple crops. Poorer households are also more likely to grow legumes. Overall, the fact that poor households are the keepers of native crop genetic resources brings to light a common issue in the analysis of agrobiodiversity: the implications of economic well-being for conservation are

not straightforward and imply equity issues that are difficult to analyze. As long as risk management seems to drive farmers' concerns agrobiodiversity represents an important coping mechanism, while its value seems to be reduced once consumption needs can be smoothed through other activities and substitution with commercial goods.

5.2.5 Productive endowments

The area cultivated shows the expected signs: being a large-holder is negatively associated with diversification of crops for consumption, while it is positively associated with participation in the market. Farmers with access to large arable areas in the sample tend to produce a surplus or sometimes the entire harvest for the market therefore specialization is for them a more profitable strategy as it allows them to spread fixed costs of inputs. In fact there is a significant and high correlation between area cultivated and income generated from selling agricultural products, which reinforces this explanation. Diversification is labour intensive per se therefore larger areas are more easily managed with few crops. In fact, farmers who have access to larger areas for cultivation might prefer to specialize, however they might still leave aside parts of the plot for minor varieties, and in fact the variable does not appear associated with squash or legume diversity. Being a large-holder is instead associated with lower likelihood to plant traditional maize and in fact many larger-holders have access to deeper soils apt for mechanization and cultivation of hybrids. This interesting as it points to the fact that households with access to larger cultivated areas, which are more likely to be mechanized systems, are not switching completely to specialization, but are still likely to conserve some secondary crop genetic resources. On the other side, medium-holders don't appear to follow significantly different diversification strategies than small-holders in the sample area, but they are more likely to obtain a surplus from their harvest and sell it on the market. Inequality in access to land, even at smaller scales, has important consequences both in terms of income generation and crop diversification.

Another productive asset such as irrigation is associated with the likelihood to participate in the market but not necessarily with higher specialization: several farmers with irrigated land grow maize hybrids but others cultivate diverse fruit trees for marketing. Water rights and maintenance costs are quite high therefore once the farmer decides to cultivate an irrigated plot he tends to plant varieties that are easily marketed and provide sufficient profit. The

presence of an irrigation system results associated at the 10 percent significance level with a lower likelihood to grow squash and diversifying maize varieties. Many farmers who can afford irrigation are likely to grow hybrid maize varieties or commercial crops such as lemons and oranges or vegetables, while traditional maize is favoured among those who cannot irrigate as it is adapted to local climate, characterized by seasonal rains.

An interesting result from the econometric analysis concerns indicators of trends linked to conversion of plots and forest to pasture in the study area. In our sample, there seems to be a feeble but significant at ten percent level association between ownership of pasture and lower likelihood to grow traditional maize and legume varieties. These findings are not dissimilar to those found by other authors in southern areas of the Yucatán peninsula, where reduction of traditional milpas is being associated with conversion to pasturelands through remittances or for maintenance of Procampo subsidies as we have seen in Chapter 4 (Dyer, 2010; Radel et al., 2010).

Finally, it is interesting to see that the coefficient for having received technical agricultural training is negatively correlated with overall diversity of crops and with the number of crops used for consumption: this kind of training by extensionists from the local agency for agricultural development is more often addressed to farmers with mechanized milpas and permanent croplands that are oriented to commercialization. These households are the objective of incentives to commercialization opting for more intensive and higher yielding production in order to bring higher quantities to the market. In fact, this is verified in the marketing regressions: households who received technical assistance are more likely to participate in the market as the positive coefficient of the variable shows. Resembling the set of regressions on overall diversity, having received technical assistance is negatively correlated with the decision to plant all three native crops, but among those who cultivate them it is only linked with fewer squash varieties, which might come through the effect of mechanized systems where when farmers grow squash varieties, they are more likely to only grow one. Households who have been trained to a more intensive or efficient use of chemical inputs are more likely to use higher chemical inputs and therefore produce for the market, which provides them with income to buy fertilizers and herbicides. But they are also more likely to grow hybrid maize varieties that perform better with more fertilizer application and

generate marketable surplus. According to farmer's responses an interesting initiative by the local government undertaken in the year previous to our survey, was the introduction of liquid organic fertilizer, herbicide and pesticide to some traditional milpa areas, especially in Tinum municipality. Farmers, who received these inputs for free and received basic training on their use, saved the money they usually use for fertilizers and welcomed the inputs when they were offered a second year. Research on the results of this local programme would be interesting, however even information on what the programme is and which government agency is providing it has been almost impossible to find.

5.3 Conclusion

The focus on conversion factors and capabilities through the Extended Capability-Ecosystem Approach allows us to take into account not only the different access of household to human, financial, physical and natural capital, but also their being part of a social and environmental setting that can impede or favour their well-being outcomes, but also influencing the conservation of crop genetic resources. What emerges from the econometric analysis is a picture of loss of diversity while households become more integrated in the market, with indicators of future threats especially for native varieties through the out-migration of people from rural areas and ageing of farmers. However, positive directions for future research and policy for conservation and development might lie in the role of women and access to land heterogeneity.

Geographic isolation seems to influence the conservation of native diversity of secondary crops, especially in remote Yucatec communities. The fact that households located in more remote areas, far from urban centres and markets and facing higher transaction costs, are more likely to grow a diversity of crops for consumption, especially squash and legume varieties suggests that changing demand patterns in urban centres might be associated with loss of overall and native diversity.

Regional migratory movements are affecting in particular households conserving traditional crops, which represent part of a coping strategy that provides food security and stability. These migratory movements have increased in recent years and even if abandonment of agriculture is not imminent, the ability of farmers to manage different crops will depend on

the availability of cheap labour in the communities, the transmission of associated knowledge and practices to the next generation of farmers, and the ability of households to achieve valued outcomes through agriculture. These trends are indirectly correlated among them and call for policy action to provide incentives for young people to stay on farm, through sustainable market development, capacity building and rewards for conserving crop genetic resources as public goods, but also on policies that can help maintain the associated public good that is the cultural value and knowledge transmitted to fewer and fewer young farmers as repeatedly mentioned during survey interviews.

A relevant insight only sketched by this analysis lies in the role played by women in the diversification strategy of households and in the conservation of crop genetic resources. Policies aimed at improving food security could benefit by creating synergies with on farm conservation strategies through understanding women's contribution on farm, how it affects nutritional attainments of household members and overall household food security, and how their contribution can be rewarded. Training of women in agricultural and culinary practices to maximize the uses of household's crop diversity or incentivize diversification by taking advantage of labour availability and knowledge of both the farmer and his spouse, might improve not only the quality of food consumed by family members but also their ability to produce marketable surplus or to storage harvest in effective way. While women have been the focus of research and interventions base on homegardens, it is time to take a more holistic approach to understand their contribution to farming household's well-being, especially as their ability to find employment outside the household remains low. However, it also appears that households better endowed in productive terms are significantly likely to reduce or abandon the cultivation of local maize varieties in particular. This is not a trend to overlook as it reflects an economic vulnerability of households who are conserving these varieties linked to loss of genetic resources, associated knowledge and the evolutionary power of conservation in the field.

This analysis provides evidence for the need of a complementary and synergetic action of conservation and development policies carried out by the different government organisms, agencies and administrative levels in the Yucatán. Household, village and regional characteristics are to be taken into account if a long-term strategy for the environment and

human development is to be successful. The opportunities open to people contribute in fact with productive resources to shape the costs of maintaining crop diversity by Yucatec households. This thesis provides a framework to define environment and well-being linkages through the lens of the Capability Approach, with an attempt at operationalization, which is much needed in this literature. While there are limitations in operational definitions of capabilities, agrobiodiversity and ecosystem goods and services, the scope was to provide insight for the development of an original framework while also deriving relevant policy implications for a centre of crop origin and domestication, where a large part of the population directly depends on nature for their well-being.

Table 5.3: Factors Influencing Overall Crop Diversity – Econometric Results

Set of Variableas	Explanatory Variables	Regression 1		Regression 2		Regression 3		Regression 4		Regression 5	
		Total plot varieties		Consumption varieties		Marketing Varieties		HH markets crops		Marketing varieties	
		Neg Bin		Neg Bin		Neg Bin		Probit		Truncated Poisson	
	Variable	coeff	t-ratio	coeff	t-ratio	coeff	t-ratio	coeff	t-ratio	coeff	t-ratio
Individual conversion factors	Age of HHH	0.00	0.35	0.00	0.26	-0.02	-2.2**	-0.03	-2.92***	0.00	0.21
	HH labour	-0.01	-0.31	0.01	0.48	-0.02	-0.46	0.04	0.68	-0.03	-0.93
Proxies for capabilities	Education HHH	0.02	1.09	0.01	0.65	0.00	-0.1	-0.03	-0.8	0.04	1.39
	Migration	0.23	2.3**	0.30	2.48**	-0.12	-0.65	0.03	0.12	-0.29	-1.59
	Off farm work	-0.03	-0.32	0.01	0.12	-0.45	-1.71*	-0.42	-1.45	-0.40	-1.75*
Gender	Wife works on farm	0.31	3.16***	0.38	3.66***	0.23	0.98	0.24	0.77	0.29	1.49
Economic poverty	Poverty indicator	0.10	0.7	0.20	1.18	0.18	0.74	-0.34	-1.05	0.39	1.46
Environmental conversion factors	Transaction costs	0.00	2.66***	0.00	3.01***	0.00	-0.68	0.00	-0.1	0.00	-0.52
	Land heterogeneity	0.36	3.93***	0.34	3.63***	0.40	2.13**	0.45	1.69*	0.25	1.23
Productive endowments	Medium-holder	0.01	0.13	-0.17	-1.46	0.77	3.38***	0.93	2.96***	0.15	0.6
	Large-holder	-0.12	-1	-0.30	-2.18**	1.00	4.43***	1.55	5.78***	0.20	0.76
	Irrigation	0.10	0.99	-0.18	-1.36	0.55	3.01***	1.14	3.52***	0.06	0.32
	Pasture	-0.06	-0.44	-0.15	-0.95	0.39	1.98**	0.28	0.91	0.28	1.29
Extension	Technical Assistance	-0.22	-2.18**	-0.28	-2.54**	0.39	1.92**	0.69	2.82***	-0.09	-0.5
	Constant	0.53	1.4	0.24	0.62	0.31	0.45	1.06	1.14	0.00	0.01
	F	4.66***		5.27***		5.79***		5.13***		2.18***	
	N	260		260		260		260		165	
	Linktest	0.407		0.116				0.938		0.24	
	Goodness of Fit Test							1.56			

*** p<0.01, ** p<0.05, * p<0.1

Table 5.4: Factors Influencing Maize and Squash Diversity – Econometric Results

Sets of Variables	Explanatory Variable	Regression 6		Regression 7		Regression 8		Regression 9		Regression 10		Regression 11	
		Traditional maize varieties		Traditional Maize HH		Traditional maize varieties		Squash varieties		Squash HH		Squash varieties	
		Normal Poisson		Probit		Truncated Poisson		Normal Poisson		Probit		Truncated Poisson	
	Variable	coeff	t-ratio	coeff	t-ratio	coeff	t-ratio	coeff	t-ratio	coeff	t-ratio	coeff	t-ratio
Individual conversion factors	Age of HHH	0.00	-0.04	0.01	0.76	-0.05	-3.17***	0.00	0.17	0.00	-0.13	0.01	0.42
	HH labour	-0.02	-0.53	-0.02	-0.27	-0.11	-0.88	-0.03	-0.74	0.02	0.33	-0.16	-1.7*
Proxies for capabilities	Education HHH	0.03	1.2	0.05	1.48	-0.07	-1.29	0.04	1.68*	0.05	1.15	0.07	1.23
	Migration	0.52	3.1***	0.60	2.11**	0.85	1.89*	0.17	1.4	0.57	2.03**	0.14	0.33
	Off farm work	-0.12	-0.65	-0.16	-0.63	0.17	0.37	-0.21	-1.52	-0.57	-2.07**	0.01	0.03
Gender	Wife works on farm	0.01	0.04	-0.28	-1.02	0.78	1.78*	0.47	3.4***	0.81	2.63***	0.74	2.06**
Economic poverty	Poverty indicator	0.55	1.99**	0.73	2.36**	-0.18	-0.29	0.05	0.31	0.12	0.33	0.30	0.6
Environmental conversion factors	Transaction costs	0.00	0.38	0.00	0.91	-0.01	-0.72	0.01	5.78***	0.02	3.12***	0.01	4.13***
	Land heterogeneity	0.38	2.4**	0.58	2.18**	0.19	0.4	0.22	1.65*	0.62	2.26**	0.00	-0.01
Productive endowments	Medium-holder	-0.21	-1.14	-0.23	-0.83	0.15	0.25	-0.09	-0.53	-0.41	-1.34	0.33	0.84
	Large-holder	-0.55	-2.28**	-0.83	-3.21***	0.75	1.49	0.09	0.54	-0.14	-0.43	0.46	1.03
	Irrigation	-0.36	-1.17	-0.40	-1.20	-1.04	-1.88*	-0.53	-2.37**	-0.58	-1.93*	-0.93	-1.09
	Pasture	-0.43	-1.51	-0.54	-1.73*	0.22	0.25	-0.18	-1.03	0.01	0.02	-0.34	-0.65
Extension	Technical Assistance	-0.67	-3.1***	-0.69	-2.99***	-0.91	-1.48	-0.35	-2.28**	-0.67	-2.75***	-0.06	-0.15
	Constant	-1.20	-1.94*	-1.38	-1.66*	1.81	1.21	-0.72	-1.5	-0.42	-0.44	-2.21	-1.63
	F	3.99***		3.20***		3.00***		4.87***		2.12***		4.86***	
	N	260		260		127		260		260		159	
	Linktest			0.587		0.365				0.327		0.062	
	Goodness of Fit Test			1.22						1.21			

*** p<0.01, ** p<0.05, * p<0.1

Table 5.5: Factors Influencing Legume Diversity – Econometric Results

Set of Variables	Explanatory Variables	Regression 12		Regression 13		Regression 14	
		Legume Varieties		Legume HH		Legume Varieties	
		Normal Poisson		Probit		Truncated Poisson	
	Variable	coeff	t-ratio	coeff	t-ratio	coeff	t-ratio
Individual conversion factors	Age of HHH	0.01	0.69	0.01	-0.1	0.02	1.9*
	HH labour	0.04	0.72	0.04	0.43	0.07	1.18
Proxies for capabilities	Education HHH	0.04	1.35	0.04	1.3	0.04	1.16
	Migration	0.26	1.12	0.26	0.51	0.20	1.12
	Off farm work	-0.08	-0.39	-0.08	-1.13	0.35	1.35
Gender	Wife works on farm	0.48	2.28**	0.48	1.56	0.41	1.58
Economic poverty	Poverty indicator	0.40	1.12	0.40	2.21**	-0.43	-2.22**
Environmental conversion factors	Transaction costs	0.01	3.83***	0.01	2.64***	0.00	2.64***
	Land heterogeneity	-0.04	-0.19	-0.04	-0.31	-0.19	-0.77
Productive endowments	Medium-holder	-0.18	-0.8	-0.18	-0.75	-0.07	-0.33
	Large-holder	-0.42	-1.53	-0.42	-1.27	-0.08	-0.26
	Irrigation	-0.11	-0.4	-0.11	0.03	-0.07	-0.22
	Pasture	-0.47	-1.44	-0.47	-1.97*	0.25	0.69
Extension	Technical Assistance	-0.58	-2.28**	-0.58	-3.75***	0.29	1.38
	Constant	-1.27	-1.5	-1.27	-0.61	-1.44	-1.84*
	F	3.76***		2.54***		2.10**	
	N	260		260		99	
	Linktest (hat-square p-value)			0.159		0.708	
	Goodness of Fit Test			0.95			

*** p<0.01, ** p<0.05, * p<0.1

CHAPTER 6. Discussion and Conclusions

Introduction

This research has started from the hypothesis that the application of an integrated and multidimensional human well-being - ecosystem approach can improve our understanding of agricultural biodiversity and the ecosystem services it provides in terms that are meaningful to the people that rely on them. This hypothesis was tested with the construction of an Extended Capability-Ecosystem Approach based on Duraiappah (2004) that links agrobiodiversity and human well-being through the capabilities, conversion factors and endowments that characterize different people and households. The framework was empirically applied to study the use and conservation of agrobiodiversity by rural Mayan households of the Yucatán, Mexico, a centre of crop origin and domestication. Through the development of this framework we have originally contributed to the recent literature on capabilities and ecosystems by extending the focus to biodiversity in agricultural landscapes. We also contribute to the research concerned with agrobiodiversity conservation on farm by including the lens of the Capability Approach. Under this theoretical approach, agrobiodiversity and the ecosystem services it provides can be devised as real opportunities that people are able to enjoy through availability and access, and that can contribute in achieving food security, stability, employment, cultural and spiritual well-being. Applying theoretical categories of the Capability Approach we take into account the fact that the degree of dependency and use these goods varies across individuals and/or groups depending among other things on the opportunities available to them, their characteristics but also ultimately their choices.

The theoretical foundations of the thesis lie in the debate on the conservation of genetic resources on farm, embedding it in a wider analysis on the reliance of rural households on the environment that takes into account also ecosystem services. Consensus in different disciplines on the relevance of understanding socio–ecological contexts when studying biodiversity and human well-being and the drivers that affect its loss is in fact increasing. These drivers include ethical, equity, distribution and spiritual issues that are often marginalized in conventional economic analysis. Biodiversity in agroecosystems and the well-being of rural households, especially those with lower economic endowments, are in

fact intimately tied in a multiple-provisioning/multiple-use relationship. Diverse crop, livestock, tree and wild species sustain diets, food security, income, employment, shelter, and cultural practices, representing a fundamental coping mechanism and safety net especially for poor people in rural areas. Centuries of local management of biodiversity have created invaluable knowledge shaping landscapes, diets, social habits and cultures. Land clearing, population pressures, overgrazing, environmental degradation and changing agricultural practices represent major drivers of the loss of genetic resources, but the communities that depend on them and allow their genetic evolution and conservation are seldom the object of wide and concerted conservation and development strategies.

The Extended Capability-Ecosystem Approach we develop allows us to understand pressures and trade-offs of the relationship between human well-being and agrobiodiversity by embedding it in a discourse on the real opportunities open to people. From the analysis emerges a strong need for conservation policies to recognize that people relying on the environment for their well-being differ in personal, social and environmental characteristics and that the opportunities available to them contribute to shape their use of ecosystems and the conservation of crop diversity on farm. Age, gender, education, employment opportunities, cultural identity, and aspirations contribute with endowments, agro-ecological conditions, access to different goods and services, government incentives, and so on to decisions concerning work in agriculture, conservation of on farm diversity, and use of ecosystem goods.

While the expansion of the capability set, or the real opportunities that people enjoy, can improve their ability to achieve valued well-being outcomes, the preservation of crop genetic resources on farm and in the wild may benefit or suffer strongly depending on local dynamics and drivers. On farm diversity but also forest ecosystem goods and services are fundamental elements not only for subsistence but also as a source of cultural identity, social organization and participation in the community life, especially in rural areas where the cycles of agricultural work strongly mark communal activities and organization. As an example, in our study we find that ancient Mayan ceremonies linked to the maize growth cycle, a source of participation in life of the community and a way to share duties and benefits of the harvest, are more often performed by farmers with traditional systems or in more isolated

communities.

Agricultural biodiversity and forest ecosystem goods in the area under study represent different aspects of ecological security: a diversity of crops allows the achievement of food security and stability in household consumption, linked with maintenance of cultural practices but also satisfaction of culinary preferences. Moreover, even in areas where specialization for the market has reduced the level of crop diversity managed by farmers, secondary crops, staples of the local diet but also favourites for consumption, are still being planted.

We asked farmers if they thought there were benefits in cultivating a diversity of crops and varieties and what were these benefits. The majority of them gave a positive answer, but 61 said that there is no benefit in diversifying crops. Their negative answer was motivated by the fact that it is expensive to manage different crops especially in terms of time, while the unpredictability of rainfall and lack of irrigation increase the opportunity cost of investing in crop diversity as harvests often fail. Half of them work off farm therefore they invest less time in the plot, stating that they focus on few varieties for consumption. Instead, 197 farmers gave a positive answer. The most representative ones include '*de ahi depende la vida de la gente de campo'* (the life of peasants depends on it) and *'pierdes en uno y ganas en otro*' ('if you loose in one you can gain in the other') and '*porque con eso comemos'* (because it allows us to eat). Their answers were strongly linked to the instrumental value of crop diversification for stability in consumption and risk management, their safety net, but also to a fundamental value as the roots of life, as the basic support to the life of people in the fields. The answer of one farmer includes several values of crop diversification: '*Me permite tener mi casa y mi dinero. Si hago solo un cultivo estoy sujeto al clima, a la lluvia, asi diversifico los riesgos. Me permite comprar ganado y si me sirve dinero lo vendo. Asi no tengo necesidad para que vaya a lo ajeno y me pongo solo en lo mio'*. (It allows me to have my own house and income. If I only have one crop I'm subject to climate, rain, in this way I diversify risk. It allows me to buy livestock so I can sell it if I need to. This way I do not need to go into the unknown (emigrate) and I can be independent, only working on my own)

Therefore crop diversity and more broadly ecosystem goods and services in agricultural landscapes and beyond represent also an instrument for insurance and a coping mechanism,

especially in marginal social and agronomic environments. This role is instrumental in achieving valued outcomes providing nutritional, productive and social opportunities but also protective security, or in Duraiappah's definition, ecological security.

6.1. Agriculture and conservation in the Yucatán

From our analysis we found that following global trends, younger and more educated individuals from rural households of the Yucatán most often look for alternatives to working on farm and in fact less than half of men excluding the household head are working in agriculture, while in younger families usually only the household head is dedicated to agriculture. Several young people who have a potentially larger capability set through education and alternative employment opportunities also have changing views of quality of life and are less likely to work on farm. It is also true that in many families one younger member is often a farmer, but overall the pool of people who are conserving crop genetic resources, especially in traditional farming systems, is narrowing. The benefits derived are strongly linked to consumption, but more commercially oriented systems allow the harvesting of a surplus that can be marketed when marketing channels are in place. However, even within these more specialized systems, farmers often have to work off farm to complement their income, while they are equally experiencing migration of younger members of the family to urban areas.

Many farmers feel a cultural bond to the land and a strong sense of place and identity that links them to their *milpas*, however they often acknowledge that not only tradition but also lack of education and other employment opportunities led them to work on the farm. This is also coupled with the ambition of many that their sons take advantage of these opportunities because work in agriculture is '*bonito, es lo que me gusta, de ahi vivo'* (it's beautiful, I like it, it's where I come from) but '*no da, es dificil salir adelante*' (it is difficult to survive on it). Many also acknowledge that if there was appropriate support, training, and financial incentives that allow higher harvests it could provide an alternative for younger people especially so they don't have to leave their own community.

This discourse also relates to the issue of migration: while it represents a potential

enlargement of opportunities open to people for those that can take advantage of them, it is often felt by farmers as a necessary evil because those alternatives can better satisfy the needs and aspirations of their sons taking them away from their roots. We stress that the migration we have encountered in the localities studied is not the type of international movement that brings in consistent remittances driving changes in the communities of origin. The type of migration that we found is linked to lack of substantial alternatives to agriculture in the communities of origin that drive several young adults to look for employment in the Caribbean coast or in the state's Capital, Merida, which have expanded to a large basin of cheap employment. The quality of life that these migrants find in these areas is beyond the scope of our research, but represents an interesting research development to understand how these opportunities shape their link with their communities of origin and the consequences for conservation of crop genetic resources but also land use change, as there appear to be indicators of trends in this direction. In fact, in line with other authors working in the southern tropical forest in bordering states of the Yucatán (Roy Chowdhury and Turner 2006; Dyer, 2010; Radel et al., 2010) we find some indication of links between families with migrating members and the acquisition or conversion of lands to pasture, which might put strains on local forest resources and ecosystem services if this turns into a trend. Moreover, pasture appears to be competing not only with forest conservation, but also with traditional maize cultivation, therefore with implications not only for carbon sequestration and other ecosystem services, but also for genetic resources conservation.

Studying maize varieties in central Mexico, Perales (1998) argued that urban migration and the increasing average age of farmers represented a threat for their conservation: we find that this process might be happening in the Yucatán. Our finding is that migrant households appear more likely to grow a higher number of crops for consumption and to plant traditional varieties of maize and squash because the remittances they receive are not enough to substitute completely cultivated diversity with goods from the market. This poses a threat for the conservation of crop genetic resources and associated knowledge if migrants from these households will not return to the fields, as they are not likely to. The direction of this relationship is a subject for further research, but it represents an important indicator of where the loss of genetic resources might likely occur. Moreover, rural-urban outmigration interrupts the transfer of associated knowledge between generations and disrupts social and

cultural practices among other things.

Geographical isolation also appears related to higher use of native squash and legume varieties and overall crop diversification for consumption, which poses important challenges for conservation in the area. This is not verified for traditional maize as farmers throughout the region maintain local varieties also close to urban centres, partly due to agro-ecological conditions. Van Dusen (2000) and Isakson (2007) find similar results for minor food crops in other areas of Mexico and Guatemala with strong indigenous presence such as the one studied in this dissertation. On the other, Perales et al. (2003) find different results for other areas, showing that the issues around agrobiodiversity conservation are strongly embedded in local contexts and processes. However, the modernization of rural economies and increasing employment opportunities outside of agriculture that come with higher market integration might be a threat to future conservation of local crop genetic resources if sustainable ways to make agriculture an attractive employment opportunity are not implemented.

An important result of our research is the confirmation of a significant relationship between crop diversity and women working on farm, which seems to indicate an influence in decision-making related to what crops and how many are being cultivated. Lope Alzina (2007) finds similar results in a traditional community of the Yucatán. Their role appears especially important for their post-harvest knowledge and labour, in particular of minor crops, and their presence on farm is significantly associated with higher maize and squash diversity and with the cultivation of a higher number of crops for consumption. On the other side, no significant relationship seems to arise with the choice to market and to diversify production for marketing, which might indicate a stronger influence on varietal selection for consumption purposes rather than on income generating activities. These dynamics offer room for further research to inform policies aimed at on farm conservation and women empowerment: while projects in the region are starting to focus on their role in homegardens, there is need for further research to create reward mechanisms for the role of women for the conservation of local crop genetic resources on farm as an instrument to enlarge their opportunities and decision-making power. Harvesting and storage characteristics, resistance to pests and diseases, and culinary traits might be linked to their influence on crop diversity and offer space for further research. Moreover, research on dietary diversity and quality is further

needed to understand links between on farm conservation, gender roles and food security in the area.

The difficult generalization of what influences the conservation of crop diversity on farm stresses the importance for local analysis and local solutions that address the different characteristics, opportunities and endowments of stakeholders in diverse socio-economic and environmental systems. Better synergies among government agencies devoted to agricultural development and conservation might bring about improvement of rural livelihoods if they take upon a participatory approach contrary to the measures that have been implemented in the region. In our interviews with different stakeholders the fundamental problem that emerges is the isolation of farmers, especially smallholders, from the development and implementation of programmes and policies that directly or indirectly affect their livelihoods. While they are subsidized to maintain the status quo, they lack the assets and capacity building to innovate and incorporate new research outcomes that might improve their ability to support consumption and income. Distributive inequality and access to information and knowledge that allows poorer farers to manage their resources in the most economically efficient and ecologically sustainable manner appears linked to the lack of interest from agricultural development agencies.

The fact that farmers who are maintaining traditional *milpas* have lower access to productive endowments, seem to be economically poorer and able to satisfy mostly self-consumption with low income generation, and more likely to be affected by outmigration due to the unattractiveness of this livelihood to younger people, poses important questions on the future of conservation of native crops in the Yucatán. While outmigration might reduce disguised unemployment in agriculture and reduce pressure to forest resources, we find that it is strongly linked to traditional farming systems that are repositories of crop diversity and associated knowledge. If means to make conservation on farm an attractive alternative, a real employment opportunity, for younger people who are more educated and integrated in the 'modern' economy, the pool of farmers that are stewards of this genetic diversity will strongly reduce. Despite this is a trend that has been going on for decades in the area, we argue that the strong reduction seen today in young people working especially in traditional *milpa* agriculture and the fact that many of them have not been working on farm as did their

parents, will have important consequences for future conservation on farm but also for the loss of associated knowledge that this entails. However, because many farmers who are taking advantage of employment opportunities and are more integrated in the markets are still conserving native varieties it is important to recognize what are the incentives for different groups in the society to conserve local varieties. The challenge is therefore to provide instruments to achieve valued well-being outcomes while conserving agrobiodiversity and maintaining relevant ecosystem services, especially in areas where tropical forests are threatened by different driving forces, including among others traditional *milpa* farming. Strategies for innovating these systems should take into account local knowledge of agroecosystems and ecosystem functioning.

6.2. Policy Implications

Household decisions leading to crop diversification and conservation are affected by agroecologial conditions, productive endowments and constraints to production but also by individual, social and environmental conversion factors and opportunities open to the farmer and other family members. Conservation programmes must therefore take into account the embeddedness of rural households into the social, environmental and political context: gender roles and decision-making, changing life-styles and consumption preferences, geographical isolation, inequality of endowments, and heterogeneity of agro-ecological conditions can all favour or constrain the conservation of crop genetic resources and use of ecosystem goods.

Research and information on agricultural biodiversity and the ecosystem services it provides is extremely relevant to understand local mechanisms for action. Altieri (1999) recalls for instance agroecological initiatives where traditional crop and animal systems could be adapted to increase productivity, while research on traditional and peasant agriculture in Latin America suggests that despite constrains in producing marketable surplus, it ensures food security, more stable levels of total production per unit area, soil protection and conservation and enhances biodiversity.

The pool of people who are maintaining genetic crop resources on farm in the region appears

to get narrower by the day. The abandonment of agriculture to off farm employment and outmigration implies a loss of associated knowledge and diversity of genetic resources, especially of maize, beans, squash and local fruits that have provided subsistence, income and cultural values for thousands of years and are still valued for their agronomic traits, for specialty dishes, for cultural ceremonies and as the basis of the local diet. Several farmers also grow different varieties of landraces to face the uncertainties of rainfall, for their resistance to pests and diseases and their endurance to poor storage conditions. Moreover, local varieties of beans, squash and especially maize have an undeniable role in the culinary tradition, the preferences, and the cultural and spiritual life of the heirs of Mayan civilization. The fact that there are different tortillas during the year according to the harvesting time of maize varieties, and they all have specific culinary and cultural functions is a cultural heritage that many people, including young people, still value (Birol et al., 2007; Jarvis et al, 2011).

Developing mechanisms and procedures that recognize the value of environmental goods and services provided by ecosystems is fundamental in the area, in order to be able to share the cost of their preservation with the society, and not only burdening the direct users of these resources. A fundamental problem with the conservation of biological resources and valuation of ecosystem services is that the relationship between problems linked to local context, institutions, and environment can have wider repercussions from the local to the global level. The creation of financial mechanisms to compensate, support or encourage owners and users of ecosystem goods and services to guarantee biodiversity conservation in agricultural ecosystems can only come with the recognition that they also provide public goods (Wise, 2007; Kontoleon et al., 2009).

As one of the main constraints of Yucatec farmers is their inability to reach markets and the low prices they receive once they do, effective policies aimed at on farm conservation and livelihood improvement could be focussed on incentivizing a production strategy aimed at both subsistence and commercialization through capacity building on the management of diversified systems not only focussed on *milpas* but also on exploiting market demand and niches in urban areas and tourist spots. Organic market niches are appearing especially in the state Capital and a price premium for native varieties could be incentivized. While the Yucatán region has been experiencing high economic growth, many consumers are starting to

ask for this type of products, but farmers are not able to enter these channels without infrastructure, financial support and training. Revaluing the culinary and cultural values of these varieties could come through incentives to their culinary use in urban areas and for society in general, increasing the consumption and demand for local and traditional preparations, fundamental components of the Yucatec diet, for which the region is renown for. Without demand from society, this diversity would be highly threatened even if incentives for on farm conservation were in place. In particular, changing consumption patterns are favouring industrialized products and imported fruit and vegetables found in supermarket, forgetting the local diet. The focus might be on exploiting local possibilities, switching to a reviewed strategy of incentives and capacity building on alternative practices such as agroforestry, minimal dependence on agrochemicals and increasing complexity of farming systems, which is already a strategy implemented by several farmers. Payments of Agrobiodiversity Conservation Services have been for instance suggested as market-based instruments aimed at alleviating market failures through individual-based or community-based reward mechanisms (monetary or non-monetary); and increasing the competitiveness of certain species, varieties or breeds (Narloch et al., 2011).

Recognizing the value of agrobiodiversity as an instrument for nutritional, economic and cultural well-being, rewarding farmers for its conservation and providing further evidence of the different ecosystem services it provides could provide the basis for a conservation strategy aimed at increasing human well-being.

6.3. Limitations of the study

This dissertation provides a first step into integrating analysis of on farm conservation and ecosystem goods and services in agricultural landscapes with analysis of human well-being under the Capability Approach perspective. Given the developing country and rural context where direct benefits from agroecosystems are particularly important and given the socio-economic nature of this research, we focused on provisioning services, mainly crop diversity and off farm ecosystem goods, and in part on the cultural value of agriculture and biodiversity. We acknowledge the narrow view that this focus on provisioning services entails and that the services provided by crop diversity in particular are diverse and a thriving

research field. However, our aim was to provide a first empirical application of an original framework linking the Capability Approach to agrobiodiversity and ecosystem services. A wider analysis was beyond the possibilities of a three years time-bounded research and would better be addressed by a multidisciplinary team. This approach would greatly improve through the study of these relationships in a team including economists, agriculturalists, ecologists, economists, anthropologists, biologists and so on, that could find biodiversity-based solutions for sustainable agricultural production and improvement of human well-being.

Another limitation of the study partly derives by the framework taken as a basis and is related to the choice of human well-being dimensions studied. What appears to come out in studying the relationship between ecosystem services and human well-being through the lens of the Capability Approach is that an important element is not only opportunities open to people but also the agency and personal choices, the personal value judgements that might have an influence precisely because of different values that this relationship entails. Taking further concepts of agency and choice could shed wider insight on the link between biodiversity and human well-being.

Finally, an initial objective proposed for this research was to take into account also the value of crop diversification to improve dietary diversity and quality. Data on frequency of consumption of different food groups was recorded in order to measure dietary diversity through the use of the Food Consumption Score (World Food Programme, 2008). The index is frequency weighted diet diversity score calculated using the frequency of consumption of different food groups consumed by a household during the 7 days before the survey. What emerged during the analysis of data is that as the rural diet of Yucatec people is based on the combination of maize, beans, squash seeds, fruits and vegetables but also by a moderate to frequent consumption of meat, very few households appeared as 'borderline' according to the score. The rural diet is based on consumption of many own crops from the plot and the garden that provide some diversity, but also by low variation in consumption patterns for the majority of rural households. On the other side, it appeared that higher levels of the Food Consumption Score were consistently associated with lower crop diversity on farm: it appeared therefore that while crop diversification was clearly providing stability in

consumption and equal income saving ability as less diversified system, the income gained from the latter contributed to increase the frequency of consumption of the different food groups, even fruits and vegetables. This finding was interesting and puzzling at the same time and led us to caution in large part because we felt after collection of data that the instrument was not appropriate to measure dietary diversity in an area where the local diet is already quite diverse and probably amounts of different food groups would have provided a clearer picture. We acknowledge this limitation and will develop it for further research.

6.4. Directions for future research

The Yucatán region as a centre of crop diversity and close to one of the last tropical forests in Mexico is especially interesting while new waves of rural out-migration produce mixed results for ecosystem and agrobiodiversity conservation. While they might reduce pressure from traditional farming practices, there are also incipient indicators of new types of pressure through acquisition or conversion of lands to pasture and increasing cattle-ranching. Further research is also needed to understand the role of migration to touristic spots of the coastal Riviera Maya and the conservation of native varieties.

Other trends linked to tourism are candidates for further research: for instance while reduction of the slash and burn farming lowers pressure on forest areas in the central *milpera* region close to the Mayan site of Chichen Itzà, increasing pressure on secondary vegetation is coming from artisanal production for the tourism market, while land acquisitions create conflicts with local farmers. This area is among those where highest diversity of local varieties of maize, squash and beans is preserved, and this repository of genetic resources becomes threatened with the expansion of the services sector, but also migration, which we found strongly associated with households cultivating native varieties, posing issues of future loss of genetic resources, cultural value and associated knowledge.

Understanding the relationship between agrobiodiversity and food security represents one of the most important aspects of research over on farm conservation and is part of the fundamental challenge of how to make agriculture sustainable while improving the quality of life of farmers. Moreover, studying the role of women in maintaining native varieties and

diversifying production for consumption, which can be linked to nutritional outcomes, is priority for researchers interested in conservation and human well-being in the Yucatán region (and beyond). The creation of better conditions in rural areas, expansion of local opportunities, and also the use of conservation as a strategy to contribute to the achievement of these objectives are subjects that merit further research.

6.5. Final Comment

What is at stake in the Yucatán as in other parts of the world where cultural identity is an heritage from ancient civilizations that have managed and changed their environment, putting it at the centre of nutritional, organizational, ecological, and spiritual values, is not only the survival of fundamental genetic resources, but also of the rich associated knowledge and cultural diversity that they entail. The fundamental question is if the valorisation of this cultural identity can become the instrument for improving the real opportunities open to people in rural areas. The willingness of policy makers to value this cultural identity and for society at large to appreciate it as an instrument for improving the well-being of its poorest members are of course fundamental. This is particularly difficult in an area where indigenous people are among the most marginalized groups in the society and where 'modern' life-style often rejects this identity. Some steps are being taken in the Yucatán to give value to Mayan language, culinary traditions and even recognize the value of agricultural ceremonies. Through a coherent effort the conservation of agrobiodiversity and the ecosystem services it provides could become instruments for improving well-being of rural households and conserving the cultural and genetic resources heritage of the region.

An important recommendation from this research for the Yucatán and beyond is that the decoupling of policy aimed at development and environmental conservation is a strategy deemed to fail. There are close associations between deprivation of opportunities, lack of endowments, specific personal characteristics such as gender and age, and geographical isolation that must be taken into account to achieve both conservation and development outcomes. Environmental policy alone would be insufficient to conserve biodiversity and ecosystem goods as these appear linked to social and cultural drivers such as migration, education, employment and changing societal values. Environmental conservation,

agricultural and rural development policies must be part of a coherent framework taking into account these links. The preservation of different values, linked to food security, women empowerment, identity but also culinary practices and knowledge associated to local varieties, might provide an umbrella for these policies. Creating incentives for privates to conserve these public goods could be a strategy to provide real opportunities to people to live a kind of life they have reason to value, favouring the enlargement of their capability set while achieving conservation outcomes. These values will only be properly recognized if we apply what Doña Rosy, a local stewardess of conservation in Tzucacab, repeatedly said: "*Conocer de nuevo lo que hemos dejado que se perdiera*[1]"

[1] 'Learn once again what we have allowed to be lost'

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ANNEX I – Sampling Strategy

A complex sampling strategy was chosen to have an adequate number of households with diverse productive resources, socio-economic and environmental conditions, which could contribute to determine the level of agricultural diversity managed and the use of ecosystem goods.

The population was divided in two strata based on ownership of irrigation, according to the list of farmers available from the government programme Procampo. To determine the value of n, that is, the sample size, taking N as the total population in the two strata and assuming a confidence level of 95%, the following formula was applied:

$$n = \frac{Z^2 \cdot p \cdot q \cdot N}{(N-1)e^2 + Z^2 \cdot p \cdot q}$$

where n is the size of the representative sample; N the size of the population in each stratum; Z=1.96 for a confidence level of 95%; e = 0.05 the estimation error; p = 0.5 the expected prevalence of the estimated parameter, and $q = p - 1$. The total population without irrigation in the four municipalities is 5469 households, which produces a sample size of 185 households, while the population with irrigation is 184 households, which produces a sample size of 94 households.

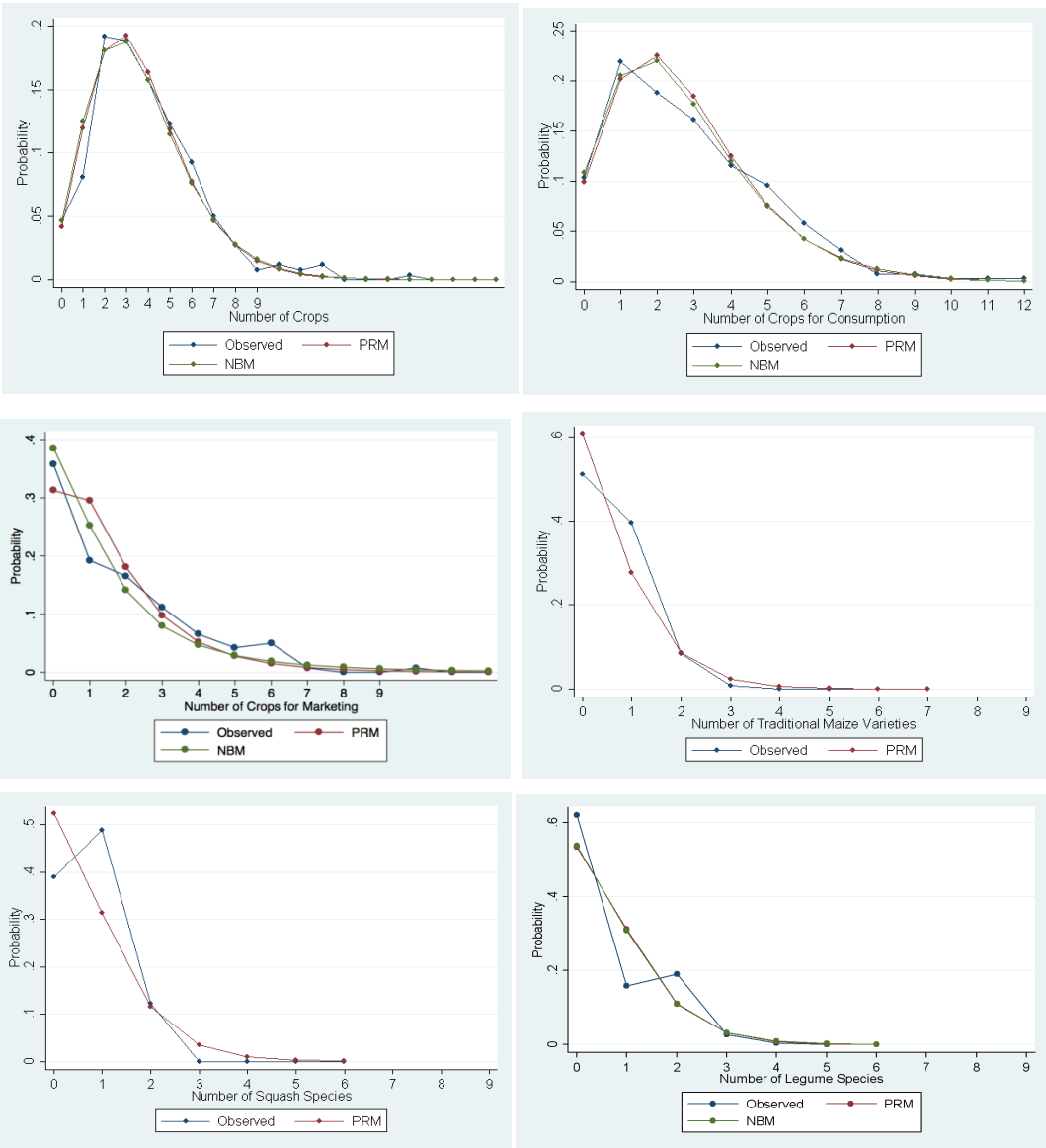
After the total sample size for the two strata was estimated, we applied the sampling formula to the two strata in each municipality to derive a more equi-distributed proportion of households to interview in each municipality. The representative sample size for each community according to the two strata would have been: 145 in Motul, 158 in Tinum, 180 in Tekax, and 163 households in Tzucacab without irrigation; and 0 in Motul, 0 in Tinum, 83 in Tekax, and 31 households in Tzucacab with irrigation. This gave us a proportion of 0.22, 0.24, 0.28, and 0.25 in each municipality respectively for the population without irrigation; and 0.73 and 0.27 for the population with irrigation in Tekax and Tzucacab. The final sample size in each municipality was therefore 42, 45, 51, and 47 households without irrigation in Motul, Tinum, Tekax, and Tzucacab respectively; and 68 and 26 households with irrigation

in Tekax and Tzucacab. However, the final number of households interviewed was 260 instead of 279 because there were no more farmers to interview in some villages, particularly in Sudzal Chico in the Southern Cone and in Motul, despite being enlisted in public support programmes.

This disproportionate sampling introduces a bias in the sampling frame by over or under-representing some groups of the population. Because this is done on purpose in order to be able to take into account key variables of interest, sampling weights are applied in the estimation of means, variances, standard errors, and confidence intervals. The survey command in STATA 12 (svy) is used to declare survey design and sampling weights. Sampling weights are the inverse of the likelihood of being sampled and compensate for unequal probabilities of selection by inflating the impact of those groups that are under-represented, and deflating the impact of those that are over-represented so that the original population is approximated. This reduces bias induced by the sampling design as it takes into account the number of individuals in the population that a sampled individual represents. The weighted sample distribution is therefore adjusted for the key variables of interest to conform it to the known population distribution. The "subpop" command is applied to analyze subpopulations in the dataset. The advantage of this command is that the calculation of estimates is based only on the cases defined by the subpopulation, but all cases are used in the calculation of the standard errors. Cochran (1997) shows the importance of correcting mean values for design effects when simple random sampling is not applied. An example of correction for stratification and weighting in the analysis of crop diversity can be found in Benin et al. (2004).

ANNEX II – Graphic Analysis for Model Selection

Heeringa (2010) suggests that for complex sample survey data, graphical techniques that compare the modeled distribution of counts (e.g., 0, 1, 2) with the observed distribution from the survey can be extremely useful in gauging the quality of the model fit. The figures below provide graphical analysis for each of the regressions specified and justify the choice of the regression models for our analyses. While for the overall number of crops the Poisson and Negative Binomial regression models provide similar model fit, the value of the dispersion parameter was slightly higher than zero and therefore the Negative Binomial was preferred. For regressions on the number of native varieties, accounting for the two processes, the zero-generating one, and the count process, the Poisson distribution provides the best model fit.



ANNEX III – Household Survey

Università degli Studi Roma Tre & Universidad Autónoma de Yucatán

Proyecto: "Explorar los vínculos entre el bienestar humano, la biodiversidad y los servicios de los ecosistemas"

Nombre encuestador:	Fecha:	Encuesta Número:
Nombre entrevistado:	Localidad:	Municipio:
Dirección de la vivienda:		Idioma utilizado en la entrevista:

Sección I. Encuestador, la sección I la deberá preguntar Mujer con Mujer

A. Demografía

Nombre completo	D1. Relación con el jefe del hogar: 1. Jefe 2. Cónyuge 3. Hijo 4. Yerno / Nuera 5. Nieto(a) 6. Padre / Madre 7. Hermano 8. Suegro 9. Primo 999. Otro.	D2. Sexo: 1. Hombre 2. Mujer	D3. Edad (años)	D4. Cual es su ocupación?		D5a. Habla Maya? 1. Si 2. No	D5b. Habla Español? 1. Si 2. No
				D4a. Principal *(La que contribuye mas a los ingresos familiares)*	D4b. Secundaria		
[1]							
[2]							
[3]							
[4]							
[5]							
[6]							
[7]							
[8]							
[9]							
[10]							

Demografia (concluye)

CODIGO MIEMBRO	D6. Sabe leer y escribir? 1. Si 2. No ***(15 o más años)***	D7. Cual fue su ultimo grado de estudio? 1. Primaria 2. Secundaria 3. Preparatoria/ Bachillerato 4. Técnica Comercial 5. Profesional 6. Maestría/ Doctorado 7. Sin instrucción.	D8. Recibió la beca de Oportunidades en 2011? 1. Si 2. No	D9. Cuántos años hace que ha recibido la beca? (CALCULAR numero años)	D10. Cuántos hijos ha dado a luz?	D11. Su salud en 2011 fue: 1. Buena 2. Regular 3. Mala	D12. Si fue mala, porqué?	D13. Dejó de trabajar en 2011 por motivos de salud?	
								1. Si 2. No	Tipo de trabajo
[1]									
[2]									
[3]									
[4]									
[5]									
[6]									
[7]									
[8]									
[9]									
[10]									

CODIGO MIEMBRO	D14. Trabaja en el campo (diariamente o ocasionalmente)? *(PREGUNTAR PARA TODOS LOS MIEMBROS, INCLUSO MENORES)* 1. Si >> 2. No	D15. Trabaja en: 1. Terreno propio 2. Otro terreno (jornalero/ empleado)	T8. Cuantos dias por semana o mes trabaja en el campo?		T9. Cuantas horas por dia?	T10. Durante los últimos tres años ¿ha sufrido algún accidente o enfermedad trabajando en el campo? 1. Si 2. No	D17. Y durante el último año ¿cuántos accidentes o enfermedades ha tenido?	D20. Qué sucedió?	D21 Como consecuencia del accidente o enfermedad, ¿Cuántos días tuvo que interrumpir su actividad laboral?
			DIAS/ SEMANA	DIAS/ MES					
[1]									
[2]									
[3]									
[4]									
[5]									
[6]									
[7]									
[8]									
[9]									
[10]									

B. Migración PREGUNTAR TAMBIEN POR MIEMBROS QUE SE FUERON A VIVIR EN OTRO LADO

MI1. Hay algunas personas que **NO** han vivido habitualmente en este hogar en los últimos 12 meses y **HAN APORTADO** dinero al hogar? *(PREGUNTAR LAS SIGUIENTES PREGUNTAS TAMBIEN SI VIVEN EN OTRO LUGAR)*		MI2. A dónde se va usualmente? 1. Mérida 2. Cancún 3. Otro lugar de la Península 4. Resto de México 5. EE.UU.	MI3. Por cuánto tiempo se va? (PUEDE SER DIAS O MESES)		MI4. Por qué se va del pueblo?
1. Si >> 2. No	**CODIGO MIEMBRO**	LEER OPCIONES	DIAS	MESES	

MI5. Usualmente envía o trae dinero/en especie al hogar? 1. Si 2. No		MI6. En total, cuanto dinero/ en especie envió o trajo en 2011?			MI7. Cómo invirtieron este dinero en el hogar? ***(PUEDESER MAS DE UNA)*** 1. Comida 2. Ahorro 3. Educación de los hijos 4. Salud 5. Compra de animales 6. Compra de químicos o maquinaria para la milpa/parcela 7. Mejoramiento de la casa 999. Otro: esp
1. Si >> 2. No	**CODIGO MIEMBRO**	PESOS	DOLARES	ESPECIE	LEER OPCIONES

C. Bienestar

Imagine una escalera de diez escalones que representa el Bienestar de su familia, donde en la parte de abajo, en el primer escalón, están las personas que tienen un Bienestar bajo, y en el escalón más alto, el ultimo, están los que tienen un Bienestar alto: ***Mostrar Tarjeta 1***

B1a. ¿En qué escalón está su familia actualmente?	B1b. Por qué lo considera así?	B2a. ¿En qué escalón está la mayor parte de la gente del pueblo?	B2b. Por qué lo considera así?	B3a. ¿En qué escalón estaba su familia hace 5 años?	B3b. Por qué lo considera así?	B4a. ¿En qué escalón estaba la mayor parte de la gente del pueblo hace 5 años?	B4b. Por qué lo considera así?

B5. ¿Le gustaría cambiar algo en la vida de su familia hoy en día? 1. Si 2. No → **Pase a hoja siguiente** 888. No sabe/ No responde	B6. Mencione las tres cosas más importantes que le gustaría cambiar actualmente en la vida de su familia (no necesariamente debe especificar 3)	B7. ¿Quién le parece que contribuirá más a estos cambios en la vida de su familia? 1. Usted mismo 2. Sus familiares 3. Su comunidad 4. El gobierno del Estado 5. El gobierno Federal 999. Otro: esp 888. No sabe	B8. ¿Ud. cree que personas como Ud. pueden cambiar cosas en su comunidad si quisieran? 1. Si, fácilmente 2. Si, pero con dificultad 3. No, para nada 999. Otro: esp 888. No sabe
	1. 2. 3.		

D. Consumo de alimentos

ALIMENTOS	C1. Cuántos días en la última semana comió estos alimentos?	C2. **Cuales alimentos especificos consiguen del Solar, Milpa o Parcela?** *(las cantidades se preguntan en la seccion agricultura)*	C3. Donde consiguen los otros alimentos?				
	Número de días (0-7)		1. Mercado o tienda en el pueblo	2. Mercado o tienda en otro pueblo	3. Merida	4. Tienda diconsa	5.Vecino Pariente
a. (Cereales) maíz, pan, arroz, trigo, tortillas hechas, tostadas…							
b. (Tubérculos y raíces): papas, yuca…							
c. (Leguminosas): frijol, lentejas							
d. (Verduras): zanahoria, lechuga, tomate, rábano, acelga, col…							
e. (Frutas): naranja, papaya, mango, sandia, limón…							
f. Huevos, pescado y carnes (vacuno, bovino, res, cerdo..)							
g. Leche y productos lácteos (yogurt, queso…)							
h. Azucares: dulces, azúcar, miel de abeja, refrescos							
j. Aceite, mantequilla, grasas (chocolate, margarina…)							

C3. Durante el año pasado, hubo alguna época del año en la cual la alimentación para su familia fue insuficiente? 1. Siempre es insuficiente para toda la familia 2. A veces no alcanza 3. No 888.No sabe/ No responde	C4. Si fue insuficiente, en qué?	C5.Cuanto tiempo fue insuficiente?		C6. Qué pasó para que no alcance la alimentación en aquella época?
		DIAS	MESES	

E. Solar

SO1. Si tiene solar, qué tamaño de área tiene?	SO2. Me puede decir los diferentes tipos de cultivos y árboles frutales que tuvieron en su solar en los últimos doce meses? ***(AYUDAR CON LISTA TARJETA 2)***	SO3. Cuántas matas, plantas, área tiene de cada cultivo?	SO4. Quién cuida el cultivo en el solar?	S05, Durante cuántos meses hubo produccion el año pasado?	SO6. En 2011 cuánto consumaron de cada cultivo al mes/año?		SO7. En 2011 ¿vendieron alguna parte de la cosecha?	SO8. Cuánto vendieron de cada cultivo?		SO9. Qué precio recibió por Kilo, Jícara, Pieza, Almud, etc.?	SO10, Quien maneja el dinero de la venta?
	Nombre	Numero ESP MEDIDA	1. Hombre 2. Mujer 3. Ambos 999. Otro: esp	Numero meses	Cantidad por mes ESP MEDIDA	Cantidad por año ESP MEDIDA	1. Si >> 2. No	Cantidad	ESP: Kilo Jícara Almud Pieza	Pesos	1. Hombre 2. Mujer 3. Ambos 999. Otro: esp
	1.-										
	2.-										
	3.-										
	4.-										
	5.-										
	6.-										
	7.-										
	8.-										
	9.-										
	10.-										
	11.-										
	12.-										
	13.-										
	14.-										
	15.-										

F. Características físicas de la vivienda

V1. La casa dónde viven es…? 1. Propia 2. Rentada 3. Prestada	V2. Cuántas habitaciones tiene en total la vivienda, incluyendo los dormitorios, (sin contar cocina ni baño)? (Numero)	V3. En el cuarto donde cocinan, también duermen? 1. Si 2. No	V5. Que material predomina en las paredes de la vivienda? 1. Block / ladrillo 2. Piedra / adobe 3. Madera y/o lámina 4. Varas 5. Paja con barro 6. Mampostería 999. Otro: esp	V6. Que material predomina en los techos de la vivienda? 1. Huano 2. Losa / block 3. Lamina Cartón 4. Palma o Paja. 999. Otro: esp	V7. Que material predomina en los pisos de la vivienda? 1. Tierra 2. Cemento o Firme 3. Madera o Duela 999. Otro: esp	V8. El baño de la vivienda es… ? 1. Sumidero 2. Letrina 3. Espacio en el solar 999. Otro: esp

V9. El baño lo comparten con otra vivienda? 1. Si 2. No	V10. En esta vivienda tienen: **(PUEDE SER MAS DE UNA)** 1. Agua entubada dentro de la vivienda 2. Agua entubada fuera de la vivienda pero dentro del terreno 3. Agua entubada de llave pública (o hidrante) 4. Agua entubada que acarrean de otra vivienda 5. Agua de pipa 6. Agua de un pozo dentro de la vivienda 7. Agua que acarrean de un pozo fuera de la vivienda, río, lago, arroyo u otra	V11. Cuántas veces a la semana falta el agua a esta vivienda? 1. Nunca 2. De vez en cuando 3. Una vez por semana 4. Dos veces por semana 5. Cada tercer día 6. Diario	V12. El desalojo de las aguas residuales se hace mediante….? 1. Red pública 3. Fosa séptica 4. Sumidero 5. Infiltración libre 999. Otro: esp	V13. Tienen luz electrica en la vivienda? 1. Si 2. No	V14. En el hogar cocinan con: **(PUEDE SER MAS DE UNA)** 1. Estufa de Gas 2. Con fogón abierto y leña 3. Ambos (gas y leña) 4. Estufa ahorradora de leña 999. Otro: esp.

G. Servicios

SE1. A qué sistema de salud pertenece su familia? 1. Seguro Popular 2. IMSS 3. ISSTE 4. Ninguno 888. No sabe/ No responde	SE2. A cuáles de los siguientes servicios tiene usted, o algún miembro de su familia, acceso en la comunidad o centro de población cercano?		SE3. Usted paga para este servicio? 1. Si >> 2. No	SE3. Es barato o caro para Usted? 1. Barato 2. Caro 3. No paga
	SERVICIO	1. Si 2. No		
	a. Clínica Oportunidades (solo asistencia)			
	b. Centro de salud (medicinas etc)			
	c. Hospital			
	d. Participación en la planificación de proyectos de desarrollo que involucran a su comunidad			
	e. Asistencia técnica agrícola para sus cultivos			
	f. Servicio veterinario para sus animales			

H. Crédito para el Hogar

C1. Usted o algun miembro de su familia solicitó préstamos en 2011? *(Incluye dinero prestado por familiares)* 1. Si 2. No	C2. Razones para el préstamo	C3. Lo pudo conseguir? 1. Si 2. No	C4. Si C3 = No Porque no lo pudo conseguir?	C5. Quién le dio el préstamo? 1. Banco 2. Prestamo mujeres 3. Mutualista 4. Parientes 5. Compradores de maiz 6. Produccion bajo contrato 7. Conocidos 999. Otro: esp	C6. Cuanto consiguió de préstamo? (Pesos)	C7. Cuál es el interés que paga mensual?
	e. Para comprar comida					
	f. Para necesidades de salud					
	g. Para educación de los hijos					
	h. Para pagos de renta					
	i. Construcción y mejoramiento de vivienda					
	j. Para la milpa o parcela					
	k. Otra (esp)					

I. Activos del hogar

H1. En el hogar tienen...?		H2. En 2011 ¿Cuántos activos de estos hay en la familia? Número	H4. En caso de tener vehículo, o motocicleta ¿Cuánto gasta de gasolina en promedio a la semana o mes?	
Activo	1. Si 2. No		Pesos/ Mes	Pesos/ Semana
a. Automóvil particular				
b. Camioneta o camión				
c. Motocicleta				
d. Triciclo				
e. Bicicleta				
f. Televisión				
g. Refrigerador				
h. Radio				
i. Teléfono fijo				
j. Teléfono celular				
m. Computadora				
n. Estufa de Gas				

L. Gastos del Hogar

G1. Comunmente cuánto gastaron el año pasado en…? (*Responder en la columna apropriada)*	Al dia: $	A la semana: $	Al mes: $
a. (Cereales) maíz, pan, arroz, trigo, tortillas hechas, tostadas…			
b. (Tubérculos y raíces): papas, yuca…			
c. (Leguminosas): frijol, lentejas			
d. (Verduras): zanahoria, lechuga, tomate, rábano, acelga, col…			
e. (Frutas): naranja, papaya, mango, sandia, limón…			
f. Huevos, pescado y carnes (vacuno, bovino, res, cerdo..)			
g. Leche y productos lácteos (yogurt, queso…)			
h. Azucares: dulces, azúcar, miel de abeja, refrescos			
i. Aceite, mantequilla, grasas (chocolate, margarina…)			
l. Cerveza y Licor			

CODIGO MIEMBRO (ver seccion demografia)	G2. En 2011: cuánto gastaron a la semana para los estudios de sus hijos en transporte para ir a la escuela?	G3. Cuánto gastaron para los estudios al mes en hospedaje?	G4. Cuánto gastaron para los estudios de sus hijos en inscripción y colegiaturas?	G5. Cuánto gastaron para los estudios de sus hijos en útiles escolares?	G6. Cuánto gastaron para los estudios de sus hijos en uniformes?	G7. Cuánto gastaron a la semana para los estudios de sus hijos en alimentos escolares?	G8. Cuánto gastaron en otro tipo de gastos escolares de sus hijos , por ejemplo internet, fotocopias, etc.?
	Pesos/Semana	**Pesos/Mes**	**Pesos año**	**Pesos año**	**Pesos año**	**Pesos/Semana**	**Pesos/Semana**

G9. En el 2011 ¿algún miembro de su hogar compró algunos de los siguientes bienes?	G10. ¿Cuánto pagaron por ...?
a. Licuadora	
b. Plancha	
c. Muebles (sala)	
d. Ollas, vajillas, platos, vasos etc.	
e. Artículos de limpieza del Hogar (Jabón, Pinol, Cloro)	
f. Artículos de limpieza Personal (Papel, Shampoo, cremas)	
g. Otros artículos para el Hogar	
h. Ropa y Zapatos (no uniformes escolares)	
i. Otros artículos personales: Aretes, perfumes, desodorantes	

G11. En el 2011 ¿Algún miembro del hogar pagaron algunos de los siguientes servicios?	G12. Cuánto pagaron en el 2011 por ...?
a. Cortes de cabello	
b. Dentista	
c. Médico	
d. Cuidados de salud (Nutrición)	
e. Un viaje de vacaciones fuera del Pueblo	
f. Fiestas (bautizo, boda, XV años, bailes	
g. Gremios:	
h. Otro:esp	

G13. Gastos del Hogar en 2011 ¿En promedio cuánto gasta en…? *(Responder en la columna apropriada: semana, mes etc)*	A la semana: $	Al mes: $	Al bimestre: $	Al semestre: $	Al año: $
1. Gas					
2. Leña					
3. Luz eléctrica					
4. Agua potable					
5. Agua embotellada					
6. Teléfono					
7. Teléfono celular					
8. Caseta de Teléfono					
9. Transporte (no para el trabajo ni escuela)					
10. Gasolina					
11. Internet en casa					
12. Internet en el Cyber Café.					
999a. Otros:					

G14. En 2011 ¿Cuánto pagó para tramites públicos?	a. Acta de Nacimiento registro Civil	b. Acta de Defunción en registro Civil	c. Pago de impuesto predial	d. Pago de IVA	e. Acta de Matrimonio	f. Gastos en Mejoras de la casa	g. Gastos en construcción casa	h. Compra casa	i. Gastos reparación casa	j. Otro
(Valor Anual)										

Sección II. Encuestador, la sección II deberá preguntarla Hombre con Hombre

M. Agricultura

A1. Usted sembró Milpa, Parcela o Plantel en 2011? 1. Si > 2. No	A2. Codigo de la Milpa, Milpa Mecanizada, Parcela o Plantel	A3. Qué tamaño en área tiene cada, Milpa, Parcela, Plantel o Monte? 1. Mecates 2. Hectáreas 3. Legua (5 Km) 999. Otra medida: esp	A4. Es ejido, comunidad agraria o privada? 1. Ejido 2. Comunidad Agraria 3. Privada	A5. La milpa/ parcela/ plantel es de riego o temporal? 1. Riego 2. Temporal	A6. Qué tipo de suelo hay en la parcela? 1. K´ANKANB 2. TSEKÉL 3. YAAX HOM 4. AK´ALCHÉ 5. PUSLÚUM 6. KAKAB 7. Otro	A7. La calidad del suelo es? 1. Buena 2. Regular 3. Mala	A8. Pedregosidad 1. Mucho 2. Regular 3. Poco 4. Nada	A9. Después de la cosecha usa la Milpa/ Parcela para: 1. Siembra 2. Ganado 3. Pasto 4. Descanso 999. Otro: esp
	CODIGO							
	[1] Milpa 1 año							
	[2] Milpa 2 año							
	[3] Milpa 3 año							
	[4] Milpa mecanizada							
	[5] Parcela							
	[6] Plantel							

	A10, Cuántas horas trabaja en la Milpa/Parcela por dia?	A11. Cuántos días por semana trabaja en la Milpa/ Parcela?	A12. En 2011 invirtieron en la compra y mantenimiento de maquinaria, de sistemas de riego o pozos para ..? 1. Si >> 2. No	A13. *(Si A12=Si)* Cuánto gastaron?	A14. Cómo financiaron las inversiones que hicieron ? 1. Apoyo publico 2. Ingresos propios 3. Prestamo 4. Remesas 999. Otro: esp
CODIGO			CODIGO	PESOS	CODIGO
[1]					
[2]					
[3]					
[4]					
[5]					
[6]					

N. Químicos, Suelos, Agua para actividades productivas

CODIGO	Q1. Químicos (Ejemplos en Listado 2)	Q2. Usted usa ...? 1. Si 2. No	Q3. Cuántas veces por año?	Q4. Cuánto … usa? ESP MEDIDA	Q5. Cuál es el precio por unidad?	Q6. De dónde los obtiene? 1. Ayuntamiento 2. Gobierno 3. Tienda 999. Otro: esp	Q6a. Estos productos, ¿llevan información acerca de su peligrosidad (fichas de seguridad, etiquetas, instrucciones de uso...?	D6b. Usted ha recibido capacitacion o istruccion acerca del uso y peligrosidad de estos productos?	Q7. Qué sistema utiliza para realizar los tratamientos preferentes? 1. Manualmente o pulverizador tipo mochila 2.Atomizador 3. Nebulizador 999.Otro: esp	Q8. Cuánto ha cambiado el uso de... en los últimos 5 años? 1. Usa mas 2. Igual 3. Usa menos	Q9. Qué cree usted que ha llevado este cambio?
Milpa [1	Fertilizantes										
	Herbicidas										
	Insecticidas										
	Otro: esp										
Milpa [2	Fertilizantes										
	Herbicidas										
	Insecticidas										
	Otro: esp										
Milpa [3	Fertilizantes										
	Herbicidas										
	Insecticidas										
	Otro: esp										
MecAN 4	Fertilizantes										
	Herbicidas										
	Insecticidas										
	Otro: esp										
Parcela [5	Fertilizantes										
	Herbicidas										
	Insecticidas										
	Otro: esp										
Plantel	Fertilizantes										
	Herbicidas										
	Insecticidas										
	Otro: esp										

Q9a. Respecto a la manipulación y aplicación de estos productos químicos ... :	1. Siempre o casi siempre 2. A veces 3. Nunca o casi nunca 888. No sabe/ No responde
Realizo la dosificación, preparación y tratamiento de caldos y mezclas conforme a las instrucciones que aparecen en el envase	
Utilizo ropa impermeable	
Utilizo ropa transpirable (algodón, algodón y nylon etc)	
Utilizo ropa exclusiva para este tipo de trabajo	
En algún momento puedo llegar a quitarme parte de la ropa durante el tratamiento (por calor, etc.)	
Evito comer, fumar y beber	
Evito tocar los ojos, heridas, etc.	
Me baño tras la aplicación del tratamiento	
Echo a lavar la ropa utilizada o la desecho, tras la aplicación del tratamiento	
Elimino los residuos, restos y envases conforme a las normas y/o por separado	

Q9b. Después de aplicar alguno de estos productos, ¿con qué frecuencia suele sentir...?	1. Siempre o casi siempre 2. A veces 3. Nunca o casi nunca 888. No sabe/ No responde
Irritación o enrojecimiento de la piel, ojos, nariz	
Tos o irritación de vías respiratorias	
Náuseas, vómitos o diarrea	
Mareos, cefaleas, pérdida de conciencia	
Sensación extraña en los labios, lengua o en la cara	

CODIGO	Q10. Comparado con hace 5 años ha cambiado la fertilidad de su Milpa o Parcela? 1. Mejor 2. Igual 3. Peor 888. No sabe/ No responde	Q11. Si ha cambiado, cuál cree Usted que es la causa que ha llevado a este cambio?	Q12, Tenía problemas de erosión de suelo, hace 5 años? 1. Si 2. No	Q13. Tiene problemas de erosión actualmente en su Milpa/ Parcela? 1. Si 2. No	Q14. Cuál cree usted que es la causa de dicho problema?	Q15. Qué cambios ha tomado para solucionar este problema?	Q16. Se ha presentado algún cambio positivo? 1. Si 2. No
[1]							
[2]							
[3]							
[4]							
[5]							
[6]							

CODIGO	Q17. Tenía problemas con la calidad del agua de su Milpa/ Parcela hace 5 años? 1. Si 2. No	Q18. Cuál cree usted que eran las causas del problema?	Q19. Qué hizo para solucionar este problema?	Q20.Tiene problemas con la calidad del agua hoy en dia? 1. Si 2. No	Q21. Qué problemas tiene con la calidad del agua? 1. Contaminación 2. Salinización 3. Escasez	Q22.Qué hace para solucionar este problema actualmente?	Q23.Se ha presentado algún cambio positivo? 1. Si 2. No
[1]							
[2]							
[3]							
[4]							
[5]							
[6]							

O. CULTIVOS

[1] MILPA 1 - [2] MILPA 2 - [3] MILPA 3

CODIGO	C1. Qué cultivos tuvieron en 2011 en..? **(Diferenciar variedades según TARJETA 3)**	C2. Estos cultivos fueron sembrados solos o asociados? 1. Solo 2. Asociado o mezclado con otro	C3. Qué superficie sembró en la parcela? 1. Mecates 2. Hectáreas 999. Otro: esp	C4. Cuánto cosecharon? C4a. Número de Unidades	C4b.ESP MEDIDA 1. Kilo 2. Admul 3. Caja 4. Tonelada 5. Atado 6. Piezas 7. Otra: esp	C4c. Cuántos kilos tiene esta medida?	C5. Qué cantidad de semilla sembraron de cada cultivo?	C6. Usaron semilla mejorada (hibrida) o criolla (país)? 1. Híbrida (de bolsa) 2. Criolla (país)	C7. Porqué utilizaron esta semilla?	C8. Esta semilla es: 1. Comprada 2. De su cosecha 3. Regalada por el gobierno 999. Otro: esp	C9. Si compró la semilla, de dónde? 1. Familiar 2. Amigo 3. Veterinario (tienda) 4. Mercado 5. Asociación Organización 999. Otro: esp
[1] MILPA 1	*A)*			*A)*	*A)*	*A)*					
	B)			*B)*	*B)*	*B)*					
	C)			*C)*	*C)*	*C)*					
	D)			*D)*	*D)*	*D)*					
	E)			*E)*	*E)*	*E)*					
	F)			*F)*	*F)*	*F)*					
	G)			*G)*	*G)*	*G)*					
	H)			*H)*	*H)*	*H)*					
[2] MILPA 2	*A)*			*A)*	*A)*	*A)*					
	B)			*B)*	*B)*	*B)*					
	C)			*C)*	*C)*	*C)*					
	D)			*D)*	*D)*	*D)*					
	E)			*E)*	*E)*	*E)*					
	F)			*F)*	*F)*	*F)*					
	G)			*G)*	*G)*	*G)*					
	H)			*H)*	*H)*	*H)*					
[3] MILPA 3	*A)*			*A)*	*A)*	*A)*					
	B)			*B)*	*B)*	*B)*					
	C)			*C)*	*C)*	*C)*					
	D)			*D)*	*D)*	*D)*					
	E)			*E)*	*E)*	*E)*					
	F)			*F)*	*F)*	*F)*					
	G)			*G)*	*G)*	*G)*					
	H)			*H)*	*H)*	*H)*					

[4] MILPA MECANIZADA - [5] PARCELA - [6] PLANTEL

CODIGO	C10. Qué cultivos tuvieron en 2011 en..? **(Diferenciar tambien variedades según TARJETA LISTADO 3)**	C11. Estos cultivos fueron sembrados solos o asociados? 1. Solo 2. Asociado o mezclado con otro	C12. Qué superficie sembró en la parcela? 1. Mecates 2. Hectáreas 999. Otro: esp	C13. Cuánto cosecharon? C13a. Número de Unidades	C13b. ESP MEDIDA 1. Kilo 2. Admul 3. Caja 4. Tonelada 5. Atado 6. Piezas 7. Otra: esp	C13c. Cuántos kilos tiene esta medida?	C14. Qué cantidad de semilla sembraron de cada cultivo?	C15. Usaron semilla mejorada (hibrida) o criolla (país)? 1. Híbrida (de bolsa) 2. Criolla (país)	C16. Porqué utilizaron esta semilla?	C17. Esta semilla es: 1. Comprada 2. De su cosecha 3. Regalada por el gobierno 999. Otro: esp	C18. Si compró la semilla, de dónde? 1. Familiar 2. Amigo 3. Veterinario (tienda) 4. Mercado 5. Asociación Organización 999. Otro: esp
[4] MILPA MECAN.	*A)*			*A)*	*A)*	*A)*					
	B)			*B)*	*B)*	*B)*					
	C)			*C)*	*C)*	*C)*					
	D)			*D)*	*D)*	*D)*					
	E)			*E)*	*E)*	*E)*					
	F)			*F)*	*F)*	*F)*					
	G)			*G)*	*G)*	*G)*					
	H)			*H)*	*H)*	*H)*					
[5] PARCELA	*A)*			*A)*	*A)*	*A)*					
	B)			*B)*	*B)*	*B)*					
	C)			*C)*	*C)*	*C)*					
	D)			*D)*	*D)*	*D)*					
	E)			*E)*	*E)*	*E)*					
	F)			*F)*	*F)*	*F)*					
	G)			*G)*	*G)*	*G)*					
	H)			*H)*	*H)*	*H)*					
[6] PLANTEL	*A)*			*A)*	*A)*	*A)*					
	B)			*B)*	*B)*	*B)*					
	C)			*C)*	*C)*	*C)*					
	D)			*D)*	*D)*	*D)*					
	E)			*E)*	*E)*	*E)*					
	F)			*F)*	*F)*	*F)*					
	G)			*G)*	*G)*	*G)*					
	H)			*H)*	*H)*	*H)*					

[1] MILPA 1 - [2] MILPA 2 - [3] MILPA 3

CODIGO	CULTIVO (Preguntar igualmente por variedades)	C19. Quién maneja estos cultivos?	C20. En el 2011 ¿cuánto consumieron por dia o en todo el año?		C21. En cuáles meses?	C22. En el 2011, vendieron alguna parte de la cosecha?	C23. Cuánto vendieron? *(Si no se acuerda cantidades preguntar por porcentaje vendido de la cosecha)*	C24. Qué precio recibieron por unidad o por toda la venta?	
	Nombre	1. Hombre 2. Mujer 3. Ambos	Dia	Año	Nr. Meses	1. Si 2. No	Cantidad	Precio unidad	Precio total
[1] MILPA 1	*A)*								
	B)								
	C)								
	D)								
	E)								
	F)								
	G)								
	H)								
[2] MILPA 2	*A)*								
	B)								
	C)								
	D)								
	E)								
	F)								
	G)								
	H)								
[3] MILPA 3	*A)*								
	B)								
	C)								
	D)								
	E)								
	F)								
	G)								
	H)								

[3] MILPA MECANIZADA - [4] PARCELA - [5] PLANTEL

CODIGO	CULTIVO	C25. Quien maneja estos cultivos?	C26. En el 2011 ¿cuánto consumieron por dia o en todo el año?		C27. Durante cuántos meses?	C28. En el 2011, vendieron alguna parte de la cosecha?	C29. Cuánto vendieron? *(Si no se acuerda cantidades preguntar por porcentaje vendido de la cosecha)*	C30. Qué precio recibieron por unidad o por toda la venta (especificar)?	
	Nombre	1. Hombre 2. Mujer 3. Ambos	Dia	Año	Nr. Meses	1. Si 2. No	Cantidad	Precio unidad	Precio total
[4] MILPA MECAN.	*A)*								
	B)								
	C)								
	D)								
	E)								
	F)								
	G)								
	H)								
[5] PARCELA	*A)*								
	B)								
	C)								
	D)								
	E)								
	F)								
	G)								
	H)								
[6] PLANTEL	*A)*								
	B)								
	C)								
	D)								
	E)								
	F)								
	G)								
	H)								

C31. Hay algunos cultivos o árboles que cultivaba hace 15 años y que ahora los ha dejado?			C32. Por qué lo dejó de sembrar?	C33. Le gustaria volver a sembrarlo? 1. Si 2. No	C34. Porqué?	C35. Por qué no lo hace?
C31a. Cultivo	C31b. Variedad	C31c. Dónde? 1. Solar 2. Milpa 3. Parcela				

P. Percepción sobre diversidad agrícola y hábitat

B1. En su opinión, tiene beneficios de disponer de una Milpa, Parcela y Monte con muchos cultivos? 1. Si 2. No	B2. Porqué?	B3. De lo que puede recordar ¿cuándo era niño estaban en la comunidad algunas variedades o cultivos que hoy no están? 1. Sí 2. No	B4. Usted cree que esta perdida es mala? 1. Si >> B5 2. No	B5. Porqué?

B8. Hay áreas **sin cultivar** en su terreno que ayuden al medio ambiente de animales y plantas? 1. Si 2. No	B9. Hace 5 años como ha cambiado esta area? 1. Hay mas 2. Igual 3. Hay menos 888. No sabe/ No responde	B10. Qué cree usted que ha llevado a este cambio?	B6. Desde hace 5 años, cómo ha cambiado la vegetación en el monte, allí donde hace su milpa? 1. Hay mas 2. Igual 3. Hay menos 888. No sabe/ No responde	B7. Qué cree usted que ha llevado a este cambio?

Q. Ceremonias tradicionales

Tradición	CE1. Conoce la tradición de..? 1. Si 2. No	CE2. La práctica? 1. Si >> 2. No	CE3.En torno a qué la realiza? 1. Milpa 2. Solar 3. Apicultura 4. Ganadería 999. Otro: esp	CE4. Utiliza sus propios productos para esta ceremonia? 1. Si 2. No	CE4.La organización de esta ceremonia es colectiva? 1. Si 2. No	CE5.Quién la organiza?
a. WAJIL KOOL						
b. CH´AA CHAAC						
c. JET´S LU´UM						
d. T´ZA UK´UL						
e. JETS ME´K						
f. PA II´K SANTIGUAR						
g. Otro: esp						

Q. Otros recursos agropecuarios

Actividad	O1. Tiene Usted o realiza? 1. Si 2. No	O2. Número de colmenas/ animales que tuvo en 2011	O4. Cuánto consumieron en 2011?	O5. Cuanto vendieron en 2011	O6. Cual fue el ingreso para toda la venta en 2011?	O7. Qué les da de comer?	O8. Cuánto les da de comer al dia? (ESP MEDIDA)	O9. Donde obtiene el alimento
a. Apicultura (abejas europeas)								
b. Xunancab (abejas nativas)								
c. Cultivo pastos								
d. Ganado:								
1. Cerdos								
2. Gallinas/ Pollos								
3. Pavos o guajolotes (totol)								
4. Carneros								
5. Cabras								
999. Otro: esp								

R. Recursos naturales del Monte

R1. Durante 2011 algún miembro de la familia aprovechó recursos naturales del Monte?		R2. Qué cantidad usaron en 2011?	R3. Qué cantidad vendieron en 2011?	R4. Que precio recibieron por unidad o en total?	
				UNIDAD	TOTAL
1. Árboles maderables (tablas, muebles)					
2. Leña					
3. Carbón					
4. Frutos silvestres					
5. Plantas medicinales					
6. Tierra para plantas (abono)					
7. Animales:	a. Pavo de monte				
	b. Armadillo				
	c. Iguana				
	d. Venado				
	e. Jabalí				
	f. Otros (esp):				
8. Huano					
9. Forraje					
999. Otro: esp					

S. Trabajo en el campo

T1. En sus terrenos trabajan otras personas ?		T2. Cuantos?	T3. Cuantos días/horas por semana o actividad?			T4. Qué tipo de negociación aplica? (LEER OPCIONES) 1. Empleado asalariado 2. Mano vuelta 3. Ayuda/ No remunerado
Quien:	1. Si 2. No		Dias / semana	Días / actividad	Horas / dia	
a. Esposa						
b. Hijos/as						
c. Parientes						
d. Vecinos						
e. Trabajadores empleados						

T5. Los ingresos que tiene de su trabajo en el campo son: 1. Muy buenos 2. Buenos 3. Regulares 4. Malos 5. Muy malos	T5a. Con qué recursos piensa vivir su viejez? 1. Ahorros 2. Ingresos de los familiares 3. Apoyo publico 999. Otro: esp 888. No sabe/ No responde	T6. En su opinión, el trabajo en el campo es una buena oportunidad de empleo? 1. Si 2. No 888. No sabe/ No responde	T7. Por qué?	T7a, La productividad del campo es suficiente para ocupar a todos los miembros de la familia interesados en la produccion agricola? 1. Si 2. No	T8. Usted toma vacaciones durante el año? 1. Si 2. No	T9. *(Si T7 = Si)* Cuánto tiempo se toma de vacaciones?	T10. Cuándo?	T11. Según Usted cuales son los riesgos de trabajar en el campo?

T12. Porqué Usted se dedica a esto?	T13. Quién le enseñó a trabajar en el campo? 1. Sus familiares 2. Organización campesina 3. Ejidatarios 999. Otro: esp. 888. No sabe/ No responde	T14. Sus hijos se dedican al campo? 1. Si 2. No	T15a. Ud. les ha enseñado lo que sabe del trabajo en el campo? 1. Si 2. No	T16b. Porqué?	T17. Le gustaria que sus hijos se dedicaran al campo? 1. Si 2. No 888. No sabe/ No responde	T18. Porqué?	T19. En su opinión, quién podría contribuir mas en mejorar las condiciones de trabajo en el campo? 1. Usted mismo 2. Las organizaciones de productores 3. El gobierno estatal 4. El gobierno federal 999. Otro: esp 888. No sabe/ No responde

Trabajo fuera del campo

T20. Usted la semana pasada trabajó al menos una hora por salario? 1. Si 2. No	T21. Aunque no trabajó hizo alguna actividad: 1. Que le pagaran 2. Que le dieran apoyo del gobierno 3. Para ayudar algun familiar o amigo 4. No	T22. Ha trabajado usted fuera del campo **en 2011?** 1. Si 2. No						T27. Usted ha buscado trabajo en el ultimo mes? 1. Si 2. No
		T23. Tipo de empleo	T24. Tiempo que trabajó			T25. Cuando terminó	T26. Por que terminó	
			DIAS	SEMANAS	MESES			

T. Redes Sociales

R3. Usted o algun miembro de su familia pertenece a una o mas organizaciones (agropecuaria, de mujeres, cooperativa etc)? 1. Si 2. No	R2. De qué tipo es? 1. Ejidatarios 2. Cooperativa 3. Organización para mujeres 4. Organización productores. 5. Asociación. 888. No sabe/ No responde	R4. Desde que año pertenece a esta organ.?	R5. Cada cuánto se reúnen? 1.Una vez por semana 2.Dos veces por mes 3.Una vez por mes 4. Cada 2 meses 5. Cada 3 meses 6. Cada 6 meses 7. Una vez al año 999. Otro:	R6. Para qué se reúnen? 1. Toma de decisiones 2. Capacitación 3. Planificación 4. Subsidios	R7. Qué tipo de servicios recibe de la organización? 1. Entrenamiento y capacitación 2. Servicios financieros (como prestamos) 3. Educación 4. Acceso a insumos como fertilizantes 5. Acceso a maquinaria o herramientas 8. Servicios médicos 999. Otros (especifique):	R8. Usted considera que esta organización es importante para la toma de decisiones? 1. Si 2. No	R9. Por qué?
1.							
2.							
3.							
4.							

U. Programas de Gobierno en 2011

P1. Encuestador, preguntar para cada *Programa*	P2. Usted recibió o algún miembro del hogar recibió algún programa de Gobierno? 1. Sí 2. No	P3. Quién recibió? (CODIGO MIEMBRO)	P4. Por cuántos años ha recibido el programa?	P5. Cuánto dinero le dan?	P6. 1.Mes, 2.Bimestre, 3.Semestre, 4.Año
			Años	Pesos	Código
1. Reconocer (Lentes)					
2. Cobijar (Chamarras y cobertores)					
3. Compartir					
4. PROCAMPO					
5. 70 y +					
6. Piso firme (piso de cemento)					
7. Programa de Empleo Temporal (PET)					
8. Opciones productivas					
9. Programa para la adquisición de activos productivos					
10. Proyecto Estratégico para la Seguridad Alimentaria					
11. Apoyos para costura (maquinas de cocer)					
12. Programa DIF, apoyo alimenticio					
13. PROGAN					
14. PROARBOL					
15. Otro programa. ¿Cuál? : esp					