Universitat Autònoma de Barcelona

Social Vulnerability, Adaptation and Conservation in the Calakmul Biosphere Reserve, Mexico

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Ph.D. dissertation

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Ph.D. Programme in Environmental Sciences and Technology

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Abstract

A deepening process of economic, social, political and cultural globalisation has contributed to increase the connection between rural and urban areas, and has resulted in an increased volatility of farm gate prices, an intensification of climatic changes, and an increased pressure over land and natural resources affecting rural households and rural environments around the world. At the same time, the proliferation of new "inclusive" protected areas and incentive-based conservation tools has modified the access to and use of natural resources and therefore rural livelihoods. This multi-faceted context has influenced rural households, which are undergoing rapid, irreversible and unprecedented changes. This research analyses how two communities part of Mexico's Calakmul Biosphere Reserve differ in their vulnerability patterns and adaptive processes to locally perceived stresses. Using a mixed-methods approach, this dissertation investigates, first, the environmental histories and livelihood activities to identify the most relevant locally perceived stresses on local livelihoods. Second, the thesis develops a Household-level Vulnerability Index (HVI) to analyse household sensitivity to such stresses and identify the communities' main adaptive capacity factors, as well as the main clusters of households. Third, the thesis explores the adaptive processes and responses to deal with these stresses, and investigates how conservation initiatives influence local agency for adaptation.

The analysis of environmental histories shows that land tenure and livelihood activities are essential for understanding past and present living conditions, as well as households' perceptions of vulnerability and adaptation. Rainfall variability, uncertainty about chilli prices and conservation regulations are perceived as the main stresses to local livelihoods. The HVI corroborates a wide range of sensitivity to conservation regulations, resulting from the impact of such regulations on people's tenure rights and access to forest resources. Adaptive capacity differs across household clusters because of distinct tenure rights and characteristics of community households, including health, age, knowledge, motivations and entrepreneurship. The research also shows that local people are adapting individually and collectively to climatic, market and conservation stresses by developing activities based on exchange or rationing, while diversifying their livelihood portfolio. However, the weak governance system of two studied communities, characterised by low

levels of trust, social cohesion and accountability, makes it difficult to engage in sustainable collective adaptive processes, e.g. community forest management plans.

The main contribution of this thesis is a critical analysis of the impact of conservation regulations on social vulnerability and adaptive processes through a political ecology perspective. The research shows that the studied conservation initiatives (the Calakmul Biosphere Reserve, the Payment for Ecosystem Services programme and the Environmental Compensation programme) enable, but also constrain, the local agency for adaptation. Such initiatives facilitate new subsistence and commercialisation practices by providing additional financial revenues to some households, but they also contribute to deepen the social differentiation across households, exacerbating internal conflicts, weakening collective action, and ultimately shaping households' vulnerability patterns and adaptive processes. By critically scrutinising the effects of conservation regulations, this thesis aims at informing rural development and biodiversity conservation policies so that they become more sensitive to the heterogeneity of rural societies, particularly to the lives and characteristics of the most vulnerable households.

Key words: adaptation, agency, biosphere reserve, conservation initiatives, globalisation, vulnerability index.

Resumen

El proceso actual de globalización económica, social, política y cultural ha contribuido al incremento de la dependencia entre las áreas rurales y urbanas, y ha resultado en un incremento de la volatilidad de los precios de los productores, una intensificación del cambio climático y un aumento de la presión sobre la tierra y otros recursos naturales afectando a los hogares y a los entornos rurales en todo el mundo. Al mismo tiempo, la proliferación de nuevas áreas de protección "inclusivas" y de instrumentos de conservación basados en incentivos ha modificado el acceso y el uso de los recursos naturales y, por ende, los medios de vida rurales. El presente estudio analiza cómo dos comunidades que forman parte de la Reserva de la Biosfera de Calakmul, en México, se diferencian en sus patrones de vulnerabilidad y procesos de adaptación a las perturbaciones localmente percibidas. A través de un enfoque que combina métodos mixtos, la tesis investiga, primero, historias ambientales y actividades de sustento para identificar las perturbaciones percibidas cómo más relevantes para los medios de vida locales. Segundo, la tesis desarrolla un Índice de Vulnerabilidad a nivel de Hogar (HVI en inglés) para medir la sensibilidad de los hogares a dichas perturbaciones e identificar los principales factores que afectan a la capacidad de adaptación de las comunidades y los grupos de hogares. Tercero, la tesis explora los procesos y respuestas para adaptarse a estas perturbaciones e investiga cómo las iniciativas de conservación influyen en la libertad de acción local para adaptarse.

El análisis de las historias ambientales muestra que la propiedad de la tierra y las actividades de sustento son esenciales para entender las condiciones de vida pasadas y presentes, así como la percepción de la vulnerabilidad y la adaptación de los hogares. La variabilidad en las precipitaciones, la incertidumbre sobre los precios del chile y las regulaciones de conservación son percibidas como las principales perturbaciones para los medios de vida locales. El HVI corrobora el alto rango de sensibilidad hacia las regulaciones de conservación, resultado principalmente del impacto de estas regulaciones en los derechos de propiedad y acceso a los recursos forestales. La capacidad de adaptación se diferencia a través de los grupos de hogares, debido sobre todo a diferencias en los derechos de propiedad y las características de los hogares, incluyendo la salud, la edad, el conocimiento, la motivación y el espíritu emprendedor. La presente investigación también muestra que la gente local se está adaptando individual y colectivamente a las

perturbaciones climáticas, del mercado y derivadas de la conservación. Sin embargo, el débil sistema de gobernanza de las dos comunidades analizadas, caracterizado por bajos niveles de confianza, cohesión social y responsabilidad, dificulta el desarrollo de procesos colectivos de adaptación sostenible, p. ej. Planes de manejo forestal comunitarios.

La principal contribución de esta tesis es el análisis crítico del impacto de las regulaciones de conservación en la vulnerabilidad social y los procesos de adaptación bajo una perspectiva de ecología política. La investigación muestra que las iniciativas de conservación estudiadas (la Reserva de la Biosfera de Calakmul, el programa de Pagos por Servicios Ambientales y el programa de Compensación Ambiental) posibilitan, pero también limitan, la libertad de acción local para adaptarse. Más concretamente, dichas iniciativas facilitan nuevas prácticas de subsistencia y comercialización debido a la provisión de ingresos económicos adicionales para algunos hogares, pero a su vez contribuye al incremento de las desigualdades entre los hogares, exacerbando los conflictos internos, debilitando la acción colectiva y, en última instancia, configura los patrones de vulnerabilidad y los procesos de adaptación de los hogares. A través del escrutinio crítico de los efectos de las regulaciones de conservación, esta tesis pretende informar las políticas de desarrollo rural y de conservación de la biodiversidad para hacerlas más sensibles a la heterogeneidad de las sociedades rurales, en particular a las condiciones de vida y a las características de los hogares más vulnerables.

Palabras clave: adaptación, globalización, índice de vulnerabilidad, iniciativas de conservación, libertad de acción, reserva de la biosfera.

Resume

El pronunciat procés actual de globalització econòmica, social, política i cultural ha contribuit a l'increment de la interdependència entre àrees rurals i urbanes, i ha resultat en un increment de la volatilitat dels preus de los productors, una intensificació del canvi climàtic i un augment de la pressió sobre la terra i d'altres recursos naturals, afectant les llars i entorns rurals d'arreu. Alhora, la proliferació de noves àrees de protecció "inclusives" i d'instruments de conservació basats en incentius ha modificat l'accés i ús dels recursos naturals i, conseqüentment, dels mitjans de vida rurals. Aquest estudi analitza com dues comunitats part de la Reserva de la Biosfera de Calakmul, al Mèxic, es diferencien en els seus patrons de vulnerabilitat i en els seus processos d'adaptació a les perturbacions percebudes localment. Mitjançant un enfocament que combina mètodes mixtes, la tesi du a terme una investigació, en primer lloc, d'històries ambientals i activitats de subsistència, per tal d'identificar les perturbacions que són percebudes com a més rellevants de cara als mitjans de manteniment locals. En segon lloc, la tesi desenvolupa un Índex de vulnerabilitat al nivell de la llar (HVI, de l'anglès) per a mesurar la sensibilitat de les llars a aquestes perturbacions i identificar els principals factors que afecten la capacitat d'adaptació de les comunitats i dels grups de llars identificats en l'estudi. En tercer lloc, la tesi explora els processos i respostes d'adaptació a aquestes perturbacions, analitzant de quina manera les iniciatives de conservació influeixen en la llibertat d'acció local.

L'anàlisi de les històries ambientals destaca la propietat de la terra i les activitats de subsistència com a fonamentals per a entendre les condicions de vida passades i presents, així com la percepció de la vulnerabilitat i la capacitat d'adaptació de les llars. La variabilitat en les precipitacions, la incertesa sobre els preus del xili i les regulacions de conservació són percebudes com les principals perturbacions dels mitjans de subsistència locals. L'HVI corrobora el ampli rang de sensibilitat envers les regulacions de conservació, resultat principalment de l'impacte d'aquestes regulacions sobre els drets de propietat i l'accés als recursos forestals. La capacitat d'adaptació és diferent en els diferents grups de llars, especialment a causa de les diferències en els drets de propietat i en les característiques de les llars, incloent salut, edat, coneixements, motivació i esperit emprenedor. La investigació present també demostra que la gent local està adaptant-se individual i col·lectivament a les perturbacions climàtiques, del mercat i de conservació.

No obstant, el dèbil sistema de de governança de les dues comunitats estudiades, caracteritzat per baixos nivells de confiança, cohesió social i responsabilitat, dificulta el desenvolupament de processos col·lectius d'adaptació sostenible tals com l'adopció de plans de gestió comunitària forestal.

La principal contribució d'aquesta tesi és l'anàlisi crític de l'impacte de les regulacions conservatòries en la vulnerabilitat social i en els processos d'adaptació, des d'una perspectiva que combina l'ecologia política amb la resiliència. La investigació mostra que les iniciatives conservatòries estudiades (la Reserva de la Biosfera de Calakmul, el programa de pagaments per serveis ambientals i el programa de compensació ambiental) possibiliten, però alhora també limiten, la llibertat d'acció local necessària per a l'adaptació. Concretament, aquestes iniciatives permeten l'adopció de noves pràctiques de subsistència i comercialització, sobretot gràcies a la provisió d'ingressos econòmics addicionals per a algunes llars, però alhora això contribueix a l'increment de les desigualtats entre llars, agreujant els conflictes interns, debilitant l'acció col·lectiva i, en última instància, condicionant els patrons de vulnerabilitat i els processos adaptatius de les llars. Mitjançant l'escrutini crític dels efectes de les regulacions de conservació, aquesta tesi doctoral té l'intenció d'informar les polítiques de desenvolupament rural i de conservació de la biodiversitat per tal de fer-les més sensibles a l'heterogeneïtat de les societats rurals, i en particular a les condicions de vida i característiques de les llars més vulnerables.

Paraules clau: *adaptació, globalització, índex de vulnerabilitat, iniciatives de conservació, llibertat de acció, reserva de la biosfera.*

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Acronyms

ACI	Adaptive Capacity Index
BR	Biosphere Reserve
CBR	Calakmul Biosphere Reserve
CDI	*Comisión Nacional para el Desarrollo de los Pueblos Indígenas* National Commission to the Development of Indigenous People
COMBIOSERVE	Community-based Management Strategies for Biocultural Diversity Conservation
CONAFOR	*Comisión Nacional Forestal* National Forestry Commission
CONAGUA	*Comisión Nacional del Agua* Water National Commission
CONAPO	*Consejo Nacional de Población* National Population Council
CRIPX	*Consejo Regional Indígena y Popular de Xpujil, S.C.* Indiginous and Popular Regional Council of *Xpujil,* S.C.
DIF	*Sistema Nacional para el Desarrollo Integral de la Familia* National System for the Integral Family Development
EC	Environmental Compensation
ECOSUR	*El Colegio de la Frontera Sur* The Southern Border University
FAO	Food and Agriculture Organization of the United Nations
HCA	Hierarchical Cluster Analysis
HVI	Household-level Vulnerability Index
IDESMAC	*Instituto para el Desarrollo Sustentable de Mesoamérica, A.C.* Institute for Sustainable Development in Mesoamerica
INE	*Instituto National de Ecología* Mexico's National Institute of Technology
IPCC	Intergovernmental Panel on Climate Change

NAFTA	North American Free Trade Agreement
PES	Payment for Ecosystem Services
PESA	*Proyecto Estratégico de Seguridad Alimentaria* Special Programme for Food Security
PROCAMPO	*Programa de Apoyos Directos al Campo* Programme of Direct Support to Countryside
PROCEDE	*Programa de Certificación de Derechos Ejidales y Titulación de Solares* Land Rights Certification Programme
PROFEPA	*Procuraduría Federal de Protección al Ambiente* Federal Attorney for Environmental Protection
PROGAN	*Programa de Producción Pecuaria Sustentable y Ordenamiento Ganadero y Apícola* Programme for the Sustainable Livestock Production and Livestock and Beekeeping Regulation
PROMAC	*Programa de Conservación de Maíz Criollo* *Programme for the Conservation of Creole Maize*
SAGARPA	*Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación* Secretary of Agriculture, Livestock and Rural Development
SEDATU	*Secretaría de Desarrollo Agrario, Territorial y Urbano* Secretary of Agrarian, Territorial and Urban
SEDESORE	*Secretaría de Desarrollo Social y Regional* Secretary of Social and Regional Development
SEDICO	*Secretaría de Desarrollo Industrial y Comercial* Secretary of Environment and Sustainable Development
SEMARNAT	*Secretaría de Medio Ambiente y Recursos Naturales* Secretary of Environment and Natural Resources
SES	Social-Ecological System
SI	Sensitivity Index

SMAAS	Secretaría de Medio Ambiente y Recursos Naturales de Campeche Secretary of Environment and Sustainable Development
IUCN	International Union for Conservation of Nature
UMA	*Unidad de Manejo Ambiental* Environmental Management Units
UNESCO	United Nations Educational, Scientific and Cultural Organization

1 Introduction

1.1 Overview

This thesis is about many yet diverse interrelated aspects of social vulnerability and adaptation and conservation governance. It is, above all, about rural households' and communities' livelihoods in Mexico evolving within large-scale social-ecological processes, such as market liberalisation, climatic changes and conservation policies. Therefore, this thesis is about complex, temporal and spatial experiences transforming the social structures of rural areas, which challenge vulnerability and adaptation of such rural societies.

> *The 31st January 2008, more than 200 thousand persons protested in the Ciudad de Mexico to claim for a renegotiation of the agrarian chapter in the North American Free Trade Agreement (NAFTA). The contingents arrived from all corners along the country, and in diverse states there were also demonstrations, assaults to secretaries and concentrations. During this afternoon, in the centre of one of the largest cities in the world, the rural system became visible. The column of tractors that started the trip from Ciudad Juárez, cows that were grazing next to the Revolution Monument, blankets placed along Paseo de la Reforma – all of that claimed for the protection of the land and the harvest that peasants are hardly able to produce.*
>
> (Padilla 2013: 9)

These words above illustrate the deepening process of economic, social, political and cultural globalisation that has accelerated the social-ecological transformation of rural societies worldwide during the last decades (Kay 2008; Dasgupta 2014). This process has increased the inter-dependency between rural and urban areas (Kay 2008; Black et al. 2013). Over the last three decades the Latin American rural sector has experienced a profound transition from a state-driven protectionist model to a neoliberal market-oriented economy (Kay 2008; Duran 2009; Harvey 2013). Specifically, the Mexican socio-economic and political transition was accompanied by land counter-reforms promoting the individual land ownership (Haenn 2006; Appendini 2008; Kay 2008), and

open-market policies triggering the interconnection of rural producers with national and international markets (Appendini and Liverman 1994; McMichael 1997; Baffes 1998). Hence both processes have stimulated the growing pressure over natural and human resources in rural areas (Stanford 1993; Harvey 2013).

Globalisation has thus had a remarkable impact on Mexican rural areas and livelihood activities (Eakin 2005; Schmook et al. 2013). Since 1990, rural studies already noted the increasing livelihood diversification (Ellis 1993; Borras et al. 2012), result of changes in rural cash crops to adapt the production to volatile market preferences worldwide (Eakin et al. 2009; Borras et al. 2016). Also the increased access to information and technology without previous precedent has allowed the intensification of livelihood practices (Eakin 2005; Thornton and Manasfi 2010; Borras et al. 2012), as well as the intersection of cultural values among rural and urban areas (Kay 2008). Rural households in this multi-faceted context have often developed and evolved their livelihoods towards the over-exploitation of the available natural resources, and the subsequent loss of biodiversity and degradation of ecological systems (Dietz et al. 2003; Sánchez-Núñez and Espinosa-Damián 2003). Hence, recent rural studies have highlighted the increased relevance of off-farm livelihood activities in employment and income rates (Eakin 2005; Kay 2008; Schmook et al. 2013).

Paradoxically, and despite the fact that rural areas play a key role feeding and maintaining the provision of goods and services to urban areas, the latter concentrate the world's socio-economic and political power. Rural areas in Mexico and other developing countries are generally identified by their high dependency on natural resources to make a living (Ellis 1993; CBD 2010), high poverty rates (UNCTAD 2015), and high marginalisation rates that undermine the socio-economic and political empowerment of those areas (Chambers 1983). Rural areas are highly sensitive to environmental stress at the same time that their limited economic and political capacities constrain their ability to deal with such damages (Dasgupta 2014). Thus, rural people are disproportionately receiving the adverse consequences of this social, economic, ecological and cultural globalisation process (Adger 2006; Dasgupta 2014), and consequently, they are likely to be more vulnerable to current environmental stresses than urban areas. In this context, it seems to be critical to understand how globalisation-related processes have impacted rural livelihoods, and what rural people are able to do to maintain or improve their well-being.

It is noted the spatial link at a variety of scales between rural poor communities and biodiversity ecosystems (CBD 2010; Porter-Bolland et al. 2011), which is also affected by globalisation processes. This relationship, however, is tied to the factors that characterise the particularities of the biodiversity and the rural system, which varies place to place. Generally, biodiversity conservation and rural development policies have been elaborated without considering local people, and especially to those who are less empowered (CBD 2010). Debates about the social impacts of conservation initiatives have then emerged to illustrate the institutional misfit of applying large-scale policies to lower scales, such as rural households and communities (e.g. Brown 2002; Adams et al. 2004; Adams and Hutton, 2007). The Madrid Action Plan (UNESCO 2008) pointed out the central role of biosphere reserves for encouraging inclusive governance systems to ensure conservation and sustainable development targeting vulnerable population. To date, there are 669 biosphere reserves in 120 countries, including 16 transboundary sites. However, there is still a lack of empirical evidence on how "inclusive" conservation governance systems and its related restrictive regulations influence rural vulnerability and rural people's adaptation to global change.

1.2 Research aim and questions

This thesis aims to understand how two local communities part of the Mexico's Calakmul Biosphere Reserve differ in their vulnerability patterns and adaptive processes to locally perceive institutional, environmental and economic stresses. This objective is fulfilled in turn through the exploration of three main research questions:

Research question 1: *How are land tenure regimes and livelihood patterns related to the locally perceived stresses in the two communities studied?*

In Chapter 4, I address this question by analysing the influence of large-scale land tenure reforms and open market policies in the environmental histories of the communities studied, and subsequently, their impact on governance systems. I also describe the main on-farm and off-farm livelihood activities of both communities and explore the influence of socially differentiated patterns on the development of such livelihood activities. Finally, I characterise the locally perceived stresses based on their influence on local livelihood patterns and the environmental governance system.

Research question 2: *How vulnerable are households and communities to locally perceived stresses?*

In Chapter 5, I address this question by, first, identifying the relevant factors determining the degrees of sensitivity of households and communities to each selected stress. Second, I note the relevant factors that determine households' adaptive capacity, which allow me in turn to cluster such households according to similar adaptive capacity profiles. Finally, I assess the relationship between sensitivity and adaptive capacity in order to understand households' vulnerability patterns and to interpret the evidence found through the Household-level Vulnerability Index (HVI).

Research question 3: *How are local adaptation and household agency influenced by conservation initiatives in a context of multiple stresses?*

In Chapter 6, I address this question by identifying household and collective adaptive processes and responses to multiple stresses across clusters of households and communities. I also explore household adaptive capacity based on human agency for understanding the similarities and differences of adaptive processes and responses across clusters of households. Specifically, I investigate the role that the Calakmul Biosphere Reserve and other overlapping conservation initiatives (i.e. Payment for Ecosystem Services and Environmental Compensation programmes) enable or constrain household and collective agency and adaptive capacities for adaptation to the locally perceived stresses.

1.3 Outline of the thesis

This thesis is divided into seven chapters, including this Chapter 1 as introduction. Chapter 2 presents the three dominant schools of thought in the field of vulnerability studies - i.e. hazard-risk, resilience and political ecology-, and defines the conceptual framework for this dissertation. Through a political ecology len, this thesis presents the theoretical principles to analyse social vulnerability to multiple stresses, defining exposure, sensitivity and adaptive capacity for rural households. It also explores the intersection of human agency and social structures, which influences household and collective adaptive capacity and adaptation processes. It then classifies adaptive processes and responses based on temporal and spatial scales, as well as the way in which households and collectives make use of their assets. Finally, the chapter lays the

theoretical and practical background of Biosphere Reserves and other "win-win" conservation initiatives, as well as reviews how such conservation initiatives can influence rural vulnerability and adaptation.

Chapter 3 presents the research strategy and methods employed to operationalise the three mentioned research questions by using a case study approach. The chapter presents the criteria for community selection and describes the main features of the Calakmul Biosphere Reserve. It then introduces the research strategy and the fieldwork methods, which include participatory observation, semi-structured interviews, focus groups, and household surveys. Data analysis procedures, including the development of the Household-level Vulnerability Index (HVI), are also described. Finally, the chapter reflects on how being a young Spanish female researcher in the field affected my fieldwork and contributed to my learning process.

Chapter 4 analyses the environmental histories of both communities for understanding current livelihood patterns, local governance systems, and social differentiation patterns. It analyses differences and similarities regarding tenure rights and legal status across communities to inform the current portfolio of livelihood activities (i.e. on-farm and off-farm activities). The chapter also identifies the three main locally perceived stresses: rainfall variability, uncertainty about chilli prices, and conservation regulations. The discussion of this chapter explores the influence of both land counter-reforms and conservation initiatives over local governance systems, livelihood patterns, and subsequently, people's perception of local stresses.

Chapter 5 analyses the household vulnerability patterns of the community studied based on the designed Household-level Vulnerability Index (HVI). It analyses household sensitivity to each perceived stress and to the overall stressful situation by interpreting the Sensitivity Index (SI). It also explores household adaptive capacity by analysing the Adaptive Capacity Index (ACI), and subsequently, identifies four household clusters, which diverge in their adaptive capacity levels, by using a Hierarchical Cluster Analysis (HCA). The clusters' analysis reveals significant differences regarding social status tied to tenure rights and personal skills, such as age, health status, motivations and entrepreneurship. Finally, the chapter uses the HVI to illustrate households' vulnerability to each stress and to their overall stressful conditions across communities. Specifically,

the chapter discusses the impact that conservation regulations over the management of natural resources exert on local livelihoods, and subsequently, household vulnerability.

Chapter 6 examines household and collective adaptive processes and responses across clusters and communities to the locally perceived stresses. Adaptation trade-offs are identified across households, as well as across stresses in a cascade of adaptive responses. This analysis makes evident that, contrary to what would be expected, households with different adaptive capacities develop the same responses to deal with the identified stresses. Thus, the chapter investigates the degrees of agency across clusters of households to explore their different ability gaining assets and mobilising them to confront climatic, market and conservation stresses. Specifically, the chapter characterises and discusses the double-edged influence of conservation initiatives as either enabling or constraining processes for household and collective adaptive processes.

Chapter 7 concludes the dissertation by providing, first, a synthesis of research findings. Second, it also presents the main theoretical and methodological contributions of the research derived from the integration of social vulnerability, adaptation and conservation governance issues. Third, it notes the theoretical and methodological limitations of this research. Fourth, the chapter draws a series of policy recommendations to improve conservation initiatives from the perspective of social vulnerability and adaptation to global changes. Finally, the chapter indicates a few areas of future research.

2 A social vulnerability framework for analysing rural areas

Vulnerability studies share an interest in analysing how a collective, a family or an individual are affected by stresses, and how they differ in their exposure, sensitivity and responses to such stresses (Adger 2006), which in turn affect their well-being (Miller et al. 2010). Rural societies rely on their natural resources and their ability to access and use those resources to live a "good life" (Chambers 1983; Ribot and Peluso 2003; CBD, 2010). “Inclusive” protected areas and other conservation initiatives that able to reduce social vulnerability while providing opportunities for adaptation are thus desirable and increasingly pursued in conservation policy and practice (WPC 2003; CBD 2010). As Ostrom (2001) points out, this is an opportunity to improve environmental governance systems for conservation, which might generate sustainable and adaptive processes across scales and over time.

This chapter introduces the theoretical background to address and respond to the three research questions highlighted in the introductory chapter. Section 2.1 describes the three main schools of thought in vulnerability studies - i.e. risk-hazard, resilience, political ecology - and clarifies the conceptual position of this research for analysing rural communities and households. Section 2.2 characterises the three components of social vulnerability- i.e. exposure, sensitivity and adaptive capacity - for its assessment in rural areas. Section 2.3 explains the influence of human agency and social structures in adaptive capacity for analysing adaptation. This section also classifies the adaptive processes and responses that rural households and societies may undertake to avoid and reduce harmful situations. Finally, section 2.4 describes the main features of environmental governance for biodiversity conservation and rural development highlighting its interrelationship with local vulnerability and adaptation.

2.1 Conceptual approaches in vulnerability studies

To date, a myriad of studies from different fields have explored the impact of global change on human systems. Within such expanding research, analyses of climate change and their impacts have become dominant (Wisner et al. 2004; Adger 2006). Vulnerability studies encompass a wide variety of research approaches, with distinct theoretical and methodological frames. Among the former, risk-hazard, resilience and political ecology

perspectives are the most common approaches (Eakin and Luers 2006), which differ in three main issues: first, in the understandings of human-nature relationships; second, the role of human agency focusing on the degrees of freedom in decision-making processes; and third, the influence of social structures rooted in power relations that shape the relationships across individuals and collectives and with their surrounding environment (McLaughlin and Dietz 2008). The understanding of these issues and their relations determines a different interpretation of what vulnerability is, why it is originated, and how it operates at place. A summary of the three main schools of thought on vulnerability is presented in Table 2.1, and the information is further analysed in the next sub-sections.

Table 2.1: Summary of the main conceptual differences among the three principal schools of thought on vulnerability

	Risk-hazard	**Resilience**	**Political Ecology**
Human– nature relationship	Cause - effect	Inherently condition in the co-evolution of social-ecological systems	Result of the intersection between the social and the ecological system
Human agency	Humans are passive	Growing support among scholars	Humans are active
Social structure	Often neglected	Little consideration (barriers for adaptation)	Core (power relations)
Unit of analysis	Large scale geographical areas (e.g. countries, regions, etc.)	Social-ecological system	Cross scalar analysis focusing on households and communities

2.1.1 Risk-hazard

A risk-hazard perspective interprets human vulnerability as a consequence of environmental degradation (Liverman 1990), and the lack of human capacity to avoid or reduce such adverse situation (Eakin and Luers 2006). As a predominant agent-oriented perspective, it focuses on measuring the impact of harmful situations on individuals at different government administrative scales. This impact is predominantly assessed in economic and material terms, being biophysical factors easier to measure than social factors (McLaughlin and Dietz 2008). As Brooks (2003) notes, this perspective is concerned with ‘measuring risk’ - i.e. the probability of being damaged by natural hazards triggering undesirable outcomes. Adaptation is, on the contrary, considered as a positive outcome. Adaptation should be facilitated by different actors across scales, where the

state has a critical role for coordinating these cross-scale responses, as illustrated by National Adaptation Plans of Actions (NAPASs) (Adger 2006). Conversely, vulnerable people are mostly observers and passive victims in these environmental degradation processes (McLaughlin and Dietz 2008).

Over time, risk-hazard studies have combined the concern for natural risks with human-induced damage. This concern has motivated the study of possible avenues to mitigate anthropogenic environmental change and to foster technocratic, top-down adaptive responses (Eakin and Luers 2006). Early IPCC reports have been a clear example of this risk-hazard perspective (Brooks 2003) but critiques to these technology-based options (Chambers 1983) and the overall top-down planning focus in detecting, analysing and implementing adaptive responses have contributed to include insights from other vulnerability perspectives.

2.1.2 Resilience

A resilience approach to human vulnerability considers that change is the natural state of any system (Berkes et al. 2000; Nelson et al. 2007). Holling (1973: 4) defines resilience as the "*ability to absorb change and disturbance and still maintain the same relationship*". Since then, and increasingly since the 1990s, vulnerability research has navigated the boundaries of both social and natural sciences, emphasising the co-evolution of social-ecological systems (SESs) (Folke et al. 2010), being the definition of SES boundaries often arbitrary or subject to the scholars' own judgement (Adger 2006; Folke 2006). Thus, a system under a harmful situation may undertake actions to maintain or achieve a new state in the overall SES.

Human vulnerability studies based on resilience theory often look at community scale as the main unit of analysis embedded in a particular SES. Individual and collective adaptive processes are founded upon changes in human behaviour and the opportunities that changes in social structures may generate within the studied SES. From this perspective, vulnerability is widely understood as a limited capacity of human systems to manage and adapt to changing environmental conditions (Eakin and Luers 2006; McLaughlin and Dietz 2008). Hence, resilience and vulnerability are considered opposed but not contradictory concepts (Nelson et al. 2007). Most recent studies on vulnerability within a resilience perspective highlight the importance of adaptive governance and flexibility in natural resource management to enhance adaptive capacity (Folke 2006). Particularly,

new insights have emphasised the role that bottom-up processes can play in modifying governance systems at larger administrative and political scales (e.g. Folke 2006; Berkes 2009), as well as the relevance of learning dynamics to improve flows of knowledge across governance systems (Berkes et al. 2000).

Critiques to vulnerability studies grounded in resilience, however, emphasise the overall tendency to underplay the importance of social structures to explain the vulnerability of SESs (Eakin and Luers 2006; Norris et al. 2008; Miller et al. 2010). For example, equity and justice considerations around the access and distribution of natural resources and the recognition of multiple values and worldviews are often overlooked in resilience-informed vulnerability studies (Adger 2006; Miller et al. 2010).

2.1.3 Political ecology

A political ecology perspective of human vulnerability focuses on the intersections of one or multiple environmental drivers of change with the social structures where individuals and societies are living across temporal and spatial scales (Eakin and Luers 2006; Scoones 2009). Thus, social structures are a core issue in this perspective understanding them as the roles, routines and decisions developed within the different social units of a given system (e.g. individuals, households, organisations, state, etc.). In particular, this perspective engages with notions of social vulnerability to recognise that ecological and social change may disrupt people's livelihood activities (Adger 1999). Early insights from Sen (1980) and Blaikie and Brookfield (1987) allow for understating how famine and land degradation respectively, are both result and cause rooted in the features of social systems. Thus, power relations, culture or social differences (gender, ethnic, age, etc.) become critical explanatory factors of social structures framing social vulnerability (Cutter et al. 2003; Eakin 2005; Smit and Wandel 2006). Questions such as who are the losers and winners, resulting from these social-ecological relationships, and what enables or constrains people's ability to overcome their vulnerable condition, are major issues of concern in this perspective (Adger 2006; Eakin and Luers 2006).

Influenced by constructivist thinking, political ecology scholars have also explored the role of human agency in vulnerability and adaptation, paying attention to peoples' values and perceptions regarding what should be considered a stress or an adaptive process (Grothmann and Patt 2005; O'Brien and Wolf 2010). Moreover, social vulnerability understood that actors are active agents undertaking adaptive responses and generating

with these actions harmful situations to them and to the surrounding environment (O'Brien and Leichenko 2000; Adger 1999).

For political ecologists, the dynamic co-evolution of social-ecological systems can be translated in changes of vulnerability patterns over time (Adger 1999), which are in turn the result of past experiences and adaptations (Adger et al. 2004; Nelson et al. 2007). Such perspective highlights also the influence of institutional changes in enhancing or undermining social vulnerability (e.g. McMichael 1997; Borras et al. 2012; Navarro-Olmedo et al. 2015). These studies have particularly focused on the transformation of natural resources regimes and its consequence to households and societies (Adger and Kelly 1999; Lemos and Agrawal 2006; Ruiz-Mallén et al. 2015a). Also, there is a long tradition to analyse the influence of top-down, policy processes in triggering adjustment in the governance systems across individuals, households or communities (e.g. Corbera et al. 2009; Navarro-Olmedo et al. 2015).

Very often, however, the main weakness of political ecology as regards vulnerability and adaptation studies lies in the lack of adequate mechanisms to reflect the dynamic relationship between social and ecological processes (Adger 2006; Miller et al. 2010). Recent studies in this regard have focused on vulnerability trade-offs to exemplify the interaction between social and ecological systems, as well as across scales. For instance, Eakin, Winkels and Sendzimir (2009) make evident the existing 'tele-connections' between Mexican and Vietnamese coffee farmers, who see their vulnerability conditions and adaptation opportunities geared towards opposite directions as a result of changing marketing conditions in the global coffee market.

2.1.4 A research informed by political ecology

This research is informed mostly by a political ecology perspective and, in doing so, it adopts Adger's definition of social vulnerability as "*the exposure of groups or individuals to stress as a result of social and ecological change, where stress refers to unexpected changes and disruption to livelihood*" (Adger 1999: 249). I also draw on a constructivist approach of vulnerability as advocated by O'Brien and Wolf (2010), to place attention on 'local' voices and identify which locally perceived stresses are triggers of vulnerability and adaptation in Chapter 4, section 4.3. The research acknowledges that rural areas are exposed to multiple environmental harmful influences (e.g. O'Brien and Leichenko 2000;

Eakin and Bojórquez-Tapia 2008), and aims to understand the relationship among them for vulnerability and adaptation, in Chapter 5 and 6 respectively.

Specifically, this chapter contributes to the growing body of research exploring through a political ecology lens the influence of conservation on vulnerability and adaptation. I then engage with the notion of "bundle of powers" by Ribot and Peluso (2003), to analyse the way in which individuals and collectives gain, control and maintain access to human and natural resources across scales and over time. Hence, the environmental governance for biodiversity conservation has altered the powers that natural resource-dependent societies have to access and use the resources targeted by such governance approaches and, subsequently, affected the ways in which local users relate to their environment (Brown 2002; Himley 2009; Ruiz-Mallén et al. 2015a). Following the most recent studies integrating human agency and social structures (e.g. Chowdhury and Turner 2006; Brown and Westaway 2011), I understand that decision-making processes are not independent of the social structures where individuals are embedded. Both the human cognition and the social-political and economic characteristics of such social structures are key for analysing social vulnerability and adaptation in rural areas (see section 2.3 for further details). Moreover, my research attempts to identify possible positive and negative trade-offs dynamics derived from the interaction of these three studied theoretical elements – vulnerability, adaptation, and conservation.

Throughout this thesis, the household is the main unit of analysis because it is considered the smallest organised social unit directly influenced by the interdependency between social and ecological systems. Critical factors to consider when studying rural households include their composition (Notenbaert et al. 2012), their ways to make a living (Chambers and Conway 1992; Bebbington 1999; Eakin 2005), and their set of rights and opportunities, or entitlements, to access, control and use resources, including land, tools and labour (Sen 1981; Adger and Kelly 1999; Leach et al. 1999), as well as, their responsibilities or daily experiences (Crehan 1992). Rural households are interconnected in small social and relational identity groups such as a community, which involves all individuals living within a shared territory (Smit and Wandel 2006). The relationships that these households establish between them and with outsiders are influenced by the governance system within which households are living (Young 2013). Households and communities are then not isolated from their economic, political, social and ecological

contexts, which span multiple geographical, administrative and spatial scales, from local to global levels (Adger 1999; Eakin 2005).

Figure 2.1 represents the relationship between social vulnerability, adaptation and environmental governance in a context of social-ecological stressful situation. The following sections in this chapter will provide a detailed description of each of these components, as it is noted in Figure 2.1.

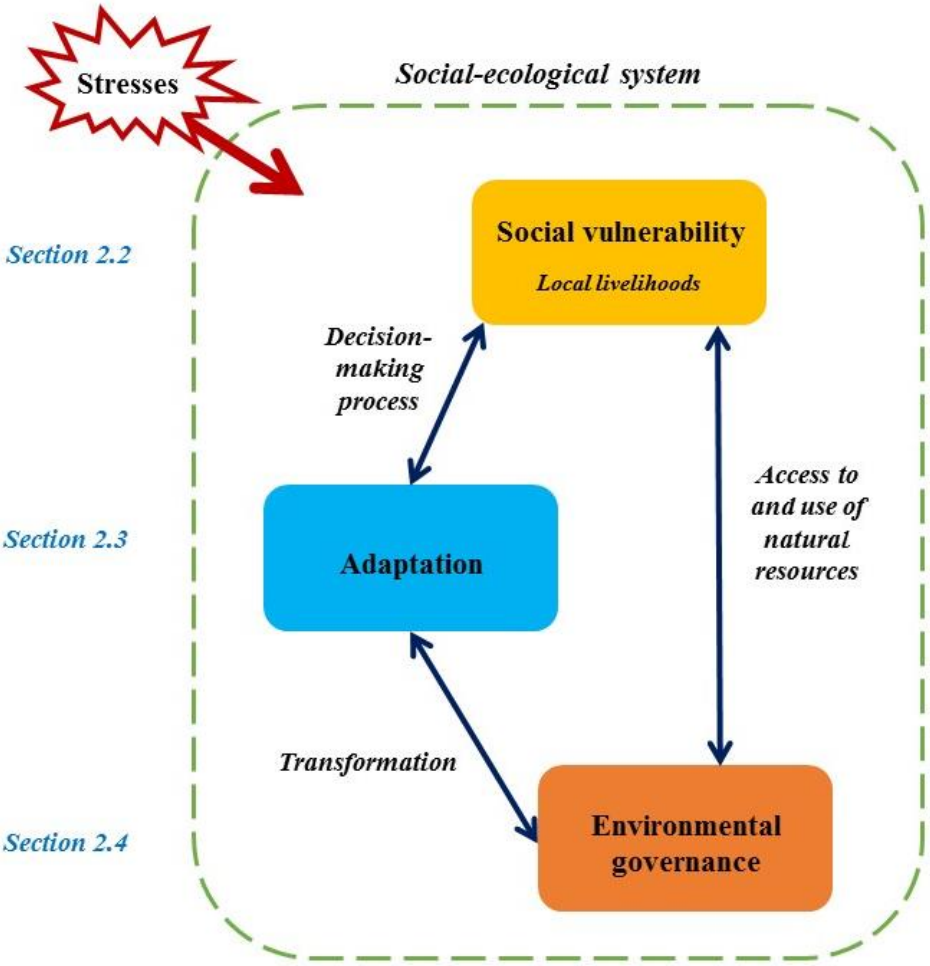

Figure 2.1: Conceptual framework for analysing social vulnerability and adaptation rural areas informed by a political ecology approach

2.2 Assessing social vulnerability

The assessment of social vulnerability of rural areas encompasses the study of the three recognised components of vulnerability (Figure 2.2): 1) the exposure of households and communities to the identified stresses; 2) the sensitivity of these households and

communities to the identified stresses; and 3) the household and collective adaptive capacity to overcome adverse situations derived from the identified stresses (Adger 2006). In a rural system, the critical factors to understand how exposed, sensitive or adaptive capacity to deal with stresses are related to households' assets – i.e. those resources that can be potentially deployed to pursue a living -, and their portfolio of livelihood activities (Chambers and Conway 1992; Bebbington 1999; Leach et al. 1999).

2.2.1 Exposure

Exposure is "*the nature and degree to which a system experiences environmental or socio-political stress*" (Adger 2006: 270). This component is key for understanding the direct link between a harmful situation and the properties and functions of the social-ecological system studied (Figure 2.2). Such a harmful situation has been referred in the literature as a stress (or stressor), a disturbance, a shock and a hazard, which have been also often used indistinctively or without an accompanying definition. In this thesis, I focus on the idea of stress as a more generic term that represents a threat to the functioning of a social-ecological system, and then, to the maintenance of human well-being (Norris et al. 2008; Ruiz-Mallén et al. 2015a). Exposure reflects the degrees of impact of a stress over the system studied, including its magnitude, frequency, and duration (Adger 2006).

Particularly in rural areas, exposure is largely reflected by the effect that a stress exerts over a portfolio of livelihood activities. This subsequently impacts on households' ways of consumption and production, both for subsistence and commercial purposes. Climate variability and market price volatility are often considered key stresses on rural vulnerability studies (e.g. O'Brien and Leichenko 2000; O'Brien et al. 2004; Eakin and Bojórquez-Tapia 2008). To illustrate such idea, O'Brien and Leichenko (2000) note the double exposure that individuals and societies face to climatic and market stress, and they highlight who loses and who wins under such circumstances. This demonstrates that rural vulnerability and adaptation are simultaneously influenced by multiple ecological and social changes (Hilhorst and Bankoff 2004; O'Brien et al. 2004; Eakin and Luers 2006).

Moreover, social and ecological systems are subjected to continuous changes adjusting their processes and functions to such new environmental conditions. In this dynamic context, societies may be exposed to a stress today that may be not be relevant tomorrow, challenging the identification of stresses to human well-being. In this thesis, I endorse the idea that rural households and communities are exposed to a myriad of stresses of

different nature and changing impact. In fact, local people may not perceive a given stress as harmful, or even perceive past and devise stresses as current harmful conditions. This issue is addressed in this manuscript in Chapter 4 by identifying locally perceived stresses and by accepting that people are unlikely to adapt to stresses they do not identify.

2.2.2 Sensitivity

Sensitivity means "*the degree to which a system is modified or affected by perturbations (stresses)*" (Adger 2006: 270). This definition acknowledges that a system may be exposed but it may be not sensitive to a specific stress in a specific time (Figure 2.2). For instance, a household that is not involved in the commercialisation of a cash crop should theoretically be insensitive, at least directly, to the volatility of market prices of this crop. Moreover, social vulnerability sheds light on the relevance of individuals' perceptions about its own harm and control over their actions (Grothmann and Patt 2005; Adger 2006), which may in turn increase households' sensitivity to one or multiple stresses.

In rural areas, the degrees of damage experienced by households and communities are closely related to socio-economic profiles and the nature and diversification of rural livelihoods. For example, O'Brien and colleagues (2004) assess rural Indian villages' sensitivity to climate change and market instability by analysing the dependence of their agricultural production to dryness and monsoon, as well as the crop diversification and their access to market. Similarly, Eakin and Bojórquez-Tapia (2008) explore Mexican rural communities' sensitivity to climate change processes by estimating the percentage of income from agriculture and the percentage of land affected. Moreover, Hann and colleagues (2009) explore the sensitivity to climate change and variability in of rural households in Mozambique by analysing household socio-demographic profiles. Insights from the latter study also show the relevance of social networks buffering sensitivity.

Despite of how relevant it is to explore such degrees of damage, the truth is that there are very few studies including the sensitivity component in vulnerability assessments at different scales (e.g. Vincent 2004; Notenbaert et al. 2013). Additionally, few are the research articles addressing the synergistic effect that two or multiple stresses may exert over a given SES (O'Brien and Leichenko 2000; O'Brien et al. 2004).

2.2.3 Adaptive capacity

This research understands adaptive capacity as "*the preconditions necessary to enable adaptation, including social and physical elements, and the ability to mobilize these elements*" (Nelson et al. 2007: 397). Differently from exposure and sensitivity, adaptive capacity is not subjected to the influence of stresses (Figure 2.2) (e.g. O'Brien et al. 2004). Households' varying degrees of adaptive capacity are a consequence of first, their specific natural, human, social, physical and financial assets (Adger 2006; Eakin and Luers 2006), and second the individual and collective agency to deploy freely their assets within, or contesting, the social structures of the system (Chowdhury and Turner 2006; Brown and Westway 2011). In this regard, resilience scholars have productively engaged in assessing adaptive capacity in order to identify which assets and processes are needed to adjust the system to new conditions (Adger 2006). Very often, however, these studies have overlooked the social structures and the people's agency for analysing adaptive capacity (McLauling and Dietz 2008). Thereby adaptive capacity is mostly understood as a picture of present conditions of the studied system (Adger et al. 2004).

Mostly based on assets theory, vulnerability studies across different rural societies emphasise the role of a well-balanced pattern of financial, educational, social-political, material and natural assets for local well-being, and thus for adaptation. Although adaptive capacity is widely considered context-specific, important efforts have been made to identify common individual and collective assets worldwide that favour adaptation, trying to point out common baselines for advising international policies (Miller et al. 2010). For instance, many scholars point out the relevance of a stable and diversified source of income, savings or insurances in dealing with overall contingencies (Adger 1999; Ellis 1999; Eakin 2005). Financial assets have the advantage of being easily transformed into other kind of assets. A widespread educational system acknowledging the value of both local and expertise knowledge has also been considered critical in order to adjust livelihood practices and management of natural resources (Berkes et al. 2000; Ruiz-Mallén and Corbera 2013). The advantages of accessing information, such as weather forecasts or climate projections, to deal with risks and anticipate adaptation are also well known sources of adaptation (Wood et al. 2014). Additionally, the quality of social networks and the level of political empowerment have been acknowledged also as key determinants of adaptive capacity across individuals and societies (e.g. Adger et al. 2004; Notenbaert et al. 2012; Wood et al. 2014). Social assets are then key for converting

one type of assets into another through networks and social negotiations. Finally, natural resources such as land, water, forests or biodiversity, and the quality of those resources, are also key elements conditioning rural livelihood activities and thus influencing adaptation (Chambers and Conway 1992; Ellis 1999; Notenbaert et al. 2012).

The assessment of adaptive capacity is challenged by the complexity for capturing and quantifying the multiple dimensions of these assets (Vincent 2004). Finding ways to monitor and measure factors referring to human agency (e.g. values, perceptions or cultural expectations) or social structures (e.g. power relations for accessing to benefits and opportunities) is yet a major challenge for vulnerability and related issues assessments (Dietz et al. 2003; Adger 2006). These issues make evident the limitations involved in understanding and assessing adaptive capacity as only a set of biophysical variables. Therefore, throughout this thesis, I acknowledge that both access and use are influenced by human agency and social structures (Chowdhury and Turner 2006), and even that the presence of some assets is not a guarantee for individuals and collectives use them.

To conclude, the analysis and measurement of household vulnerability patterns is carried out in the Chapter 5 of this dissertation following the theoretical insights detailed here. I designed and developed a Household-level Vulnerability Index to analyse the sensitivity to the locally perceived stresses at household level (see section 5.1), and the potential adaptive capacity of the two studied communities and across households (see section 5.2). Regarding the exposure of households to the adverse situation, I draw on others' work (e.g. O'Brien et al. 2004; Notenbaert et al. 2013), to assume that each of the locally perceived stresses affect households equally and I do not attempt to quantify the impact exerted by identified stresses separately or together. For further methodological considerations in the design and analysis of the HVI see section 3.4, in Chapter 3.

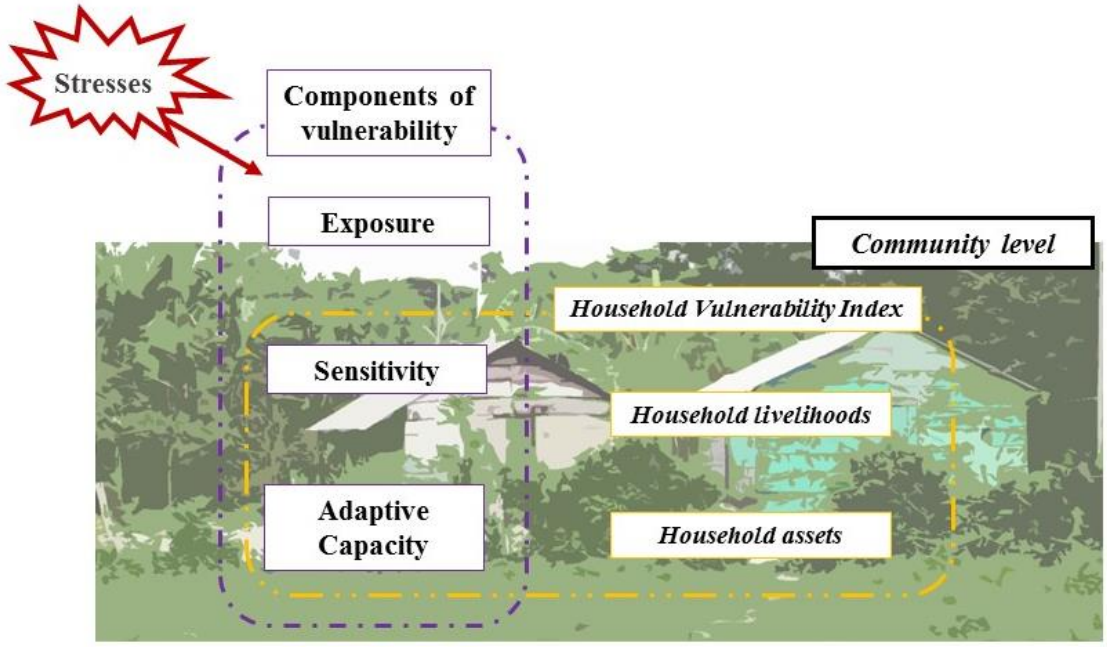

Figure 2.2: Relational schedule of the components of social vulnerability

Note: the figure highlights the two components (i.e. Sensitivity and Adaptive Capacity) included in the designed Household-level Vulnerability Index (HVI), in which households livelihoods and assets are the main explanatory factors at household level.

2.3 Human adaptation in rural areas

As mentioned above, adaptation is not a result of only uni-linear combination of assets (Nelson et al. 2007). The degrees of agency that individuals in rural areas have within the structures of their socio-economic and political context play a remarkable role in how individuals and collectives adapt to the multiple stresses that they experience over their lifetime (Chowdhury and Turner 2006; McLaughlin and Dietz 2008; Brown and Westaway 2011). Why do people with similar assets develop different responses? And *vice versa*, why do people with different assets develop similar responses? These are both relevant questions shedding light onto the critical influence of social differentiation in terms of adaptation for exploring power relations between those who concentrates benefits and those who do not. Powers are then mechanisms, processes and social relations by with people's ability to benefit from resources and opportunities are established (Ribot and Peluso 2003).

2.3.1 Human agency for analysing adaptation

Exploring human agency is to consider individuals and societies as active agents selecting between their adaptive options and being able to implement such adaptive responses in a particular time and space (McLaughlin and Dietz 2008). Thus, to talk about human agency is to talk about socio-economic and political structures, and to acknowledge that adaptation is a context-specific response (Adger et al. 2005). As Chowdhury and Turner (2006) assert, human decision-making to implement adaptation is not independent of the social context where individuals or collectives are living, and nor of the cultural and historical experiences that enable or constrain their adaptive responses (Adger et al. 2012). The work of Brown and Westaway (2011) establishes connections to interpret adaptive capacity as something else than a balance of human assets. Adopting a human agency perspective, they categorised human adaptive capacity as the set of socio-cognitive factors, the bundle of assets and the ability to deploy them, as well as the influence of external agents facilitating and inhibiting adaptive responses (Figure 2.3).

Socio-cognitive factors determine the extent to which a given individual or collective is able to perceive vulnerability and act upon it. The recognition of being damaged, the self-assessment of adaptation as a feasible and desirable options, and the willingness to adapt are three relevant socio-cognitive themes linking adaptive capacity with adaptation (Brown and Westaway 2011). In this regard, Grothmann and Patt (2005) draw on behaviour economics and psychology literature to present basis for including both risk perception and perceived adaptive capacity as two major perceptual processes for human adaptation. Recent studies have provided additional insights regarding the relationship between different socio-cognitive factors and adaptive processes. Kuruppu and Liverman (2010) show how the level of 'perceived' adaptive capacity is critical to manage and respond to water stress in Kiribati, Central Pacific, whereas Frank and colleagues (2011) remark the influence of social identity in the adaptation of coffee producers in Mexico. Also among coffee producers in Mexico, as well as in Guatemala and Honduras, Tucker and colleagues (2010) highlight the relevant influence of structural factors in shaping risk perception for adaptation.

Socio-cognitive factors are thus also related to the availability of assets and the human ability to mobilise them for implementing adaptation. Once individuals and collectives recognise the damage and reflect over their possibilities for implementing adaptation,

they assess the set of assets they have and their ability to deploy them adequately. In rural areas, for example, land tenure is a key determinant of vulnerability and adaptation, since tenure regimes are not only linked to the distribution of rights and access to natural resources, but also to socio-economic and political power (Ribot and Peluso 2003; Tucker et al. 2010). In this regard, Ribot and Peluso (2003) have shown that tenure regimes should be better conceptualised as 'bundles of powers' (i.e. power relationships rooted in the socio-economic and political context that determine the access to benefits among across individuals and societies) rather than as 'bundles of rights' alone –as in classic property theory. In doing so, this perspective engages with social structures beyond rights to investigate who has a legal or an illicit access to resources, why, and therefore what is influencing one's vulnerability condition and adaptation. Ribot and Peluso (*ibid*.) further argue that such 'bundles of powers' are dynamic. Rights-based mechanism change over time result of the interaction between the social and ecological system. Actors across scales therefore aims at maintaining and controlling access to benefits through structural and relational mechanisms, determining access to capital, technology, markets, labour and labour opportunities, authority and information, social identity or social networks.

Finally, external agents are identified as enablers and constraints of human adaptive capacity and adaptation because they can influence the availability of assets and the degree of agency to deploy them (Chowdhury and Turner 2006; Brown and Westaway 2011). Agrawal and Perrin (2008) note the role of external agents in future adaptation of natural resources-dependent households to climate change. Particularly, they reveal the remarkable role of civic organisations facilitating the generation of common pool resources management and household's engagement in market exchange mechanisms. Similarly, sustainable livelihood policies are articulated in rural areas through several development and conservation initiatives (Brown 2002), which play a key role orienting farmers' adaptive processes and responses. Conservation initiatives can thus be considered as 'external agents' that create both opportunities and barriers for adaptation (Ruiz-Mallén et al. 2015a). As noted earlier, rural households often rely on natural resources for their livelihoods, and therefore, conservation regulations might either enhance their opportunities for adaptation, for example through the maintenance of ecological conditions or through the provision of new income-generating activities (e.g. eco-tourism). However, they can also deepen people's vulnerability and constrain their adaptation options, for example through increased restrictions in the access to and use of

land and other resources. The role of conservation initiatives in fostering and limiting adaptation is further explored in section 2.4.

To conclude, socio-cognitive factors assessing adaptation opportunities, barriers and desires, the availability of assets and the ability to mobilise them, as well as the influence of external actors, are inter-related and changing over time. In this sense, this research aims to go further in the understanding of how and why individuals and socially differentiated groups implement one and no other adaptive process and response (Figure 2.3).

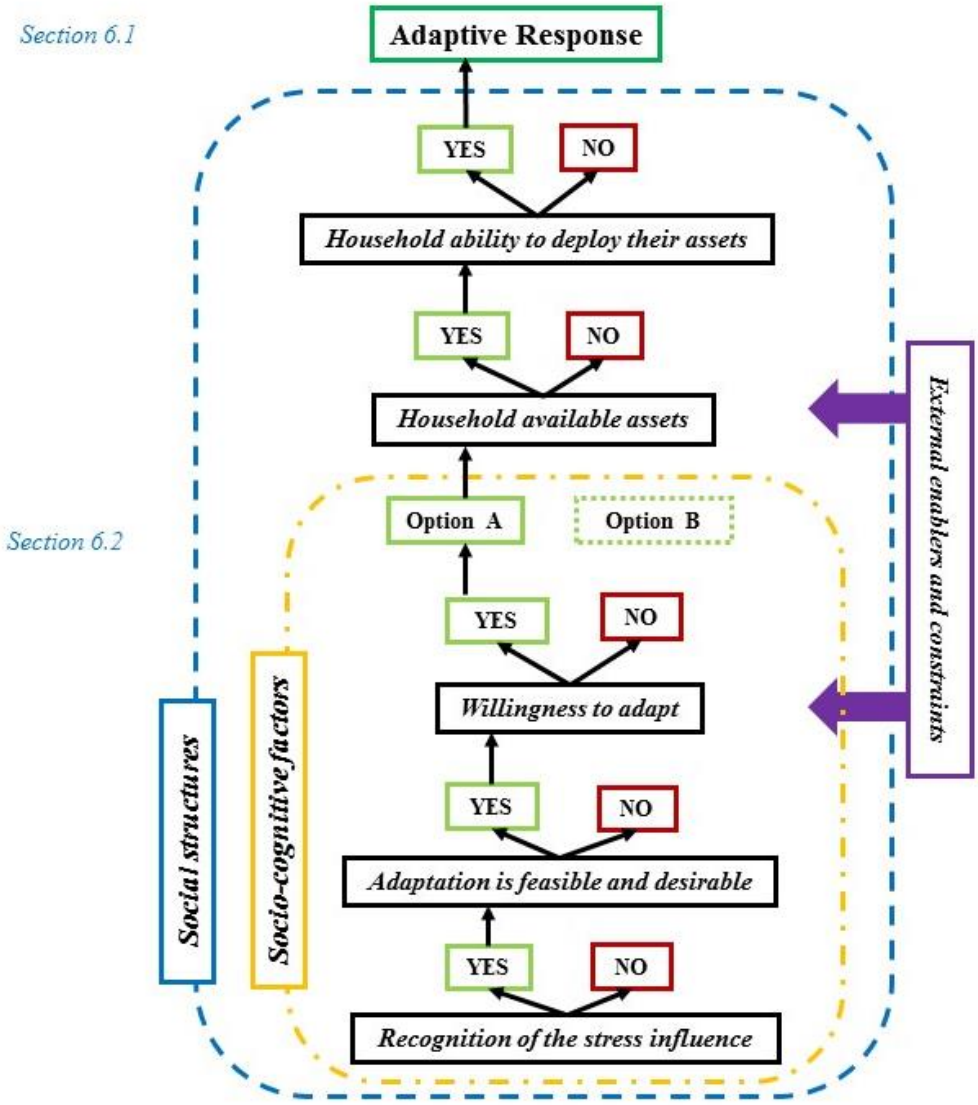

Figure 2.3: Determinats of an adaptive response at household level focusing on household agency within the social structures

Note: Option A and Option B reflect the different adaptive responses that a household would like to develop, e.g. livestock rearing and beekeeping.

Thus, the above-mentioned influence that both social structures and people's agency exerts for mobilising household potential adaptive capacities into an adaptive response has been very often overlooked or partially addressed in risk-hazard oriented vulnerability studies (Chowdhury and Turner 2006). In Chapter 6, section 6.2 of this thesis, I aim to fill this gap by demonstrating that the degrees of freedom to decide (i.e. human agency) are influenced by social structures, as well as by personal preferences, and that together play a key a role in human adaptive processes (McLaughlin and Dietz 2008; Brown and

Westaway 2011). Specifically, in Chapter 6, section 6.3, I investigate the role of the studied conservation initiatives influencing household and collective agency for undertaking adaptation.

2.3.2 Classifying and assessing adaptive processes and responses

Individuals, households and societies response to harmful situations in order to avoid and manage any experienced risk and damage. There are three main ways to interpret adaptation. A first approach emphasises the temporal scale of such responses. It describes coping responses as reactive actions developed in a short-term to reduce the damage of a stress. When these responses are developed strategically to provide a solution in the medium-long term or prevent future damage they are considered adaptive responses (Smit and Pilosova 2001). A second approach focuses on the spatial scales at which adaptive responses are undertaken, differentiating between responses at individual, household, social group, national or global level. Brown and Westaway (2010) integrate both temporal and spatial perspectives to differentiate between individual responses, and those that required a collaborative effort within and across social groups and societies in the short and long-run. The combination of both temporal and spatial scales generates four main categories of adaptive responses (Figure 2.4). At individual level, this classification refers to coping and adaptation categories above explained. At collective level, self-help responses reflect the collaboration between individuals, households or societies to provide a common short-term solution to an identified problem without substantial changes in social and/or ecological systems. Transformational responses emphasise the substantial change on the structure and functions of the social and/or ecological systems. Interestingly, this categorisation implies that individual transformation responses do not entail a transformation of the collective, as Adger and Kelly (1999) earlier argue.

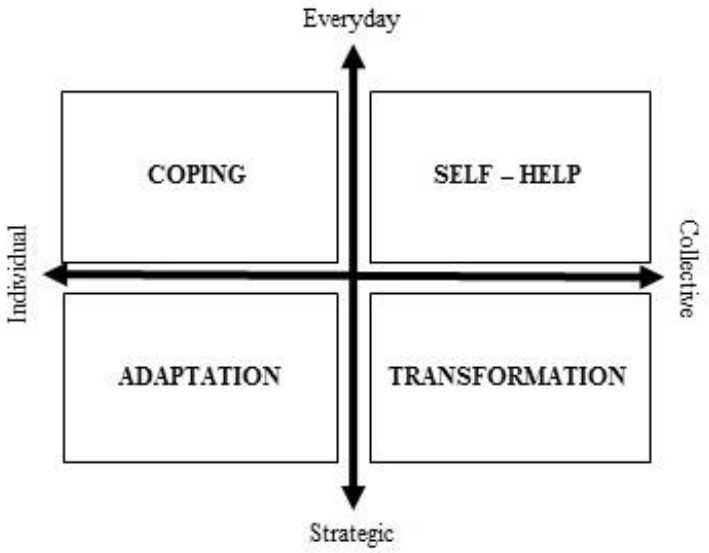

Figure 2.4: Temporal and spatial classification of adaptive responses

Note: Adapted from Brown and Westaway (2011: 336)

Finally, there is a third approach to understanding adaptive responses that focuses on the ways in which individuals or collectives make use of their assets to manage current or future damage (e.g. Chambers and Conway 1992; Agrawal and Perrin 2008; Gómez-Baggethun et al. 2012). This approach identifies a series of adaptive processes such as mobility, storage, diversification, pooling, exchange, intensification, innovation and revitalisation (Table 2.2). It also recognises that some adaptive responses may be undertaken at different temporal and spatial scales and that human adaptation should be understood as a process imbued in specific social, political, economic and ecological circumstances (Thornton and Manasfi 2010).

Table 2.2: Classification of adaptive processes *(Source: Thronton and Manasfi (2010: 137)*

Adaptive processes	Description
Mobility	Changing the spatial location of assets and/or livelihood activities to avoid risk across space
Storage	Building infrastructures to keep assets across time
Diversification	Increasing the variety of assets and/or livelihood activities to reducing risk across them
Pooling	Sharing ownership of assets and/or livelihood activities to reduce risk among the whole joint members
Exchange	Gaining cash or assets by the conversion of assets with other assets' owner
Intensification	Increasing the production through an increase in input for a livelihood activity within a certain space or time
Innovation	Creating new methods and/or techniques regarding livelihood activities
Revitalisation	Renewal and reconfiguration of ideology and cultural practices

Assessing adaptation success, or maladaptation, requires being attentive to temporal and spatial dimensions, as well as to culturally context-specific factors, such as values and worldviews (Adger et al. 2005). Four major principles are often applied for assessing policy success – i.e. effectiveness, efficiency, equity and legitimacy – alike for adaptation success (e.g. Adger et al. 2005; Thomas and Twyman 2005). First, effectiveness is related to the achievement of an expressed objective, such as reducing the exposure to a particular stress. Second, efficiency reflects the cost-benefit balance resulted from such adaptive responses. Third, equity is often assessed considering who wins and loses from the undertaken adaptive responses (distributional justice), and who decides such actions (procedural justice) (Eakin and Luers 2006). Fourth, and last, legitimacy reflects the sense of fairness in the way that decisions are made and implemented under unequal distributional and procedural conditions considering the web of powers within every social system (Adger et al. 2005). Equity and legitimacy are deeply rooted social-cultural and political factors, which means that no universal rules for their evaluation actually exist (Adger et al. 2003).

Successful adaptation is therefore one that "*balances effectiveness, efficiency and equity through decision-making structures that promote learning and are perceived to be legitimate is an ideal from which much adaptation inevitably diverges*" (Adger et al. 2005: 83). Subsequently, unsuccessful adaptation is one that does not achieve a reasonable effectiveness, efficiency and equity, in which legitimacy is not achieved. Similarly, the term maladaptation has been mainstreamed in vulnerability and adaptation research to specifically refer to adaptive responses that, unexpectedly, increase the vulnerable condition of a whole or part of a society (Barnett and O'Neil 2010). There is a growing interest in identifying adaptation trade-offs across time and space susceptible of generating maladaptation (e.g. Adger et al. 2005; Thomas and Twyman 2005; Meyfroit et al. 2014). However, we still know little about the bi-directional relations between adaptive responses and vulnerability patterns across scales and over time.

Through this thesis I consider adaptation as a complex and dynamic process in which rural communities are enrolled to face uncertain and changing social-ecological circumstances. By focusing on the social system, I further argue that there is a need for understanding processes and factors that contribute to overcome social vulnerability through adaptation policies and practices, instead of generating maladaptation. Further considerations to such issues are developed in Chapter 6, and particularly in relation to the role of conservation initiatives enhancing and undermining local agency and adaptive capacities for adaptation (section 6.3).

2.4 Social vulnerability and adaptation in a conservation context

As noted earlier, rural people rely on natural resources for their living (Sen 1981; Chambers and Conway 1992; Bebbington 1999). However, rural people have also seen the proliferation of a wide range of biodiversity conservation initiatives over the last few decades, from protected areas to more recent incentive-based programmes of Payments for Ecosystem Services (PES), which have also had varying degrees of impact on people's livelihoods (e.g. Adams et al. 2004; Bunce et al. 2010; Ruiz-Mallén et al. 2015a). This final section of the theoretical chapter reviews the role played by biodiversity conservation initiatives in shaping vulnerability patterns and adaptation options to multiple stresses in rural areas. Inspired by Ostrom (2001), I consider how diverse governance systems may enhance local capacities and abilities to overcome their vulnerable condition.

2.4.1 Environmental governance for biodiversity conservation

Human relations to each other and with our surrounding environment are guided by a set of behavioural prescriptions or institutions, which may be formal (i.e. obligations, rights and prohibitions structured through legal instruments) or informal (i.e. conventions and codes of behaviour) (North 1990). Ostrom defines (2005: 3), institutions as the "*prescription that humans use to organise all forms of repetitive and structured interactions including those within families, neighbourhoods, markets, firms, sports, leagues, churches, private associations and government at all scales*". Institutions are then embedded in the specifics of SESs, which vary substantially across societies (Adger 2006).

Institutions may regulate the access to, use of and control over natural resources (Nelson et al. 2007), the social and political participation (Adger 1999) or even the establishment of different roles or other socially differentiated groups (Navarro-Olmedo et al. 2015), including between women and men (Crehan 1992). Institutions are thus central to understand how social groups that differ in decision-making, power and resources relate to each other and why (Adger and Kelly 1999), as well as with their environment (Dietz et al. 2003).

The institutional landscape, in which individuals and societies gain access to and use of natural resources, has been a focus of debate because of rampant environmental degradation worldwide (Dietz et al. 2003; Acheson 2006). Hardin (1968) argued that common natural resources open to all have led to the overexploitation of those resources. Thus, he advocated clear property rights systems under the assumption that local resources users are unable and unwilling to manage them collectively (Ostrom 2005; Haller et al. 2013). Hardin's thought was contested by later studies on common pool resources (e.g. fishers, wildlife or forest, among other), which suggested that collective management may success in establishing regulations in the interest of long-term preservation of those resources (e.g. Schlager and Ostrom 1992, Ostrom 2005).

Environmental regimes provide then a regulatory frame to manage common pool resources across scales, influencing local livelihood practices and adaptation (Young et al. 2013). These regimes define the property rights system that determines who has access to natural resources through holding a title, licence or permit, and a set of institutions establish how those who have access should use such resources (Leach et al. 1999;

Ostrom 2005). For example, land tenure regimes determine who has access to land through land tenure rights, while bundled institutions at different administrative scales can make prescriptions about how land and resources should be managed.

These considerations have guided environmental governance systems to reframe human-nature relations toward common desirable goals (Young 2013), such as poverty eradication or wildlife preservation. This manuscript draws on Lemos and Agrawal (2006: 298) to understand environmental governance as "*the set of regulatory processes, mechanisms and organisations though which actors influence environmental action and outcomes*". Thus, an environmental governance system is composed by 1) a set of formal and informal institutions that regulates access to and use of natural resources, 2) the rule-making system to structure social interactions, and 3) the diversity of actors that are embedded in the design and implementation of such regulations (Ostrom 2005; Young 2013). In particular, environmental governance for biodiversity conservation and rural development, here known as conservation governance, refers specifically to the set of institutions, involved actors and the rule-making system that aim to ensure biodiversity conservation while promoting an equitable and long-term human development.

Since the formalisation of the International Union for Conservation of Nature (IUCN) in 1962, governments have been largely the main officially recognised actor ensuring environmental governance for biodiversity conservation (Reyes-García et al. 2013). Thus, governments have engaged in the designation of protected areas defined as "*geographical spaces, recognised, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values*" (IUCN 2013: 8). Initially, the loss of biodiversity and land deforestation encouraged governments to establish high restricted top-down exclusionary protected areas, neglecting the role of local communities as direct users of natural resources (Brown 2002). In particular, this model has received numerous critiques of the forced displacement of local communities from conserved target areas breaching local Human Rights in the name of conservation (West et al. 2006; Adams and Hutton 2007; Himley 2009). Paradoxically, such governmental protected areas have had an historical limited impact in protecting biodiversity in remote areas such as tropical forests (Kaimowitz et al. 2003) or marine ecosystems (Acheson 2006), where open-access and mismanagement have resulted in resources abused (Dietz et al. 2003; Acheson 2006).

In this context of failure of governmental protected areas, the debate around conservation governance has moved on, being decentralisation the focus (Lemos and Agrawal 2006). Thereby in a growing recognition of the diversity of actors engaged in environmental governance issues, IUCN has defined since 2008 four main types of governance system for designing, regulating and implementing protected areas, which include those regulated by the state or the private sector, those relying on the local communities, and those based on a shared governance alliance between the state and communities. The two latter governance systems have been the focus of recent debates because of the challenge of developing participatory and collaborative governance systems for both effective biodiversity conservation and rural wellbeing (e.g. Brown 2002; Berkes 2007; Plummer and Armitage 2010).

An example of shared governance in protected areas is likely the form of Biosphere Reserves (BR), which emerged from the Man and Biosphere programme led by United Nations Educational, Scientific and Cultural Organization (UNESCO) in 1968 as 'laboratories of sustainable development' (Batisse 1982; Folke et al. 2011). Since then, the promotion of BR has aimed to make indirectly compatible conservation and local communities' development with a model of areas of high and low restricted regulations (Brown 2002; UNESCO 2008). Thus the spatial configuration of a BR includes a well-protected core area of strict conservation (i.e. IUCN categories I to IV) surrounded by a buffer area allowing traditional land uses in a controlled manner (Maciver and Wheaton 2005; Lourival et al. 2011). As Batisse (1982) earlier note, BRs differ from traditional top-down and exclusionary protected areas by their openness, which aim to integrate local land-uses and even inspire natural resource management system beyond their boundaries.

Nevertheless, recent studies have highlighted the challenges that BRs face to fully achieve such participatory and adaptive governance principles. Similar to high restricted protected areas, the establishment of BRs has triggered the displacement of local communities (e.g. Sunderlin et al. 2005; Ruiz-Mallén et al. 2015a). In other cases, local communities within and around BRs have claimed the lack of information previous the establishment of BRs (e.g. Reyes-García et al. 2013; Speelman et al. 2014), and the overall lack of involvement of their representatives in BRs rule-making system (e.g. Ruiz-Mallén et al. 2014). Moreover, recent studies evidence that BR restrictions in the use of natural resources are exacerbating local people's vulnerabilities (e.g. López-Carr et al. 2012; Reyes-García et al. 2013; Speelman et al. 2014). The fact that very often BRs rest on national protected

areas systems may explain why, in practice, BRs are guided by restrictive top-down management approaches rather than being examples of collaborative management with local communities (Ruiz-Mallén et al. 2015a). BRs are then identified by local communities as a source of stress to local livelihoods due to the implementation of top-down of decision-making rules, which have often resulted in conflicts leading to environmental degradation and poverty (e.g. García-Frapolli et al. 2009; Porter-Bolland et al. 2013; Ruiz-Mallén et al. 2015a).

To reverse this situation, conservation practitioners, scholars, and policy makers have increasingly advocated guaranteeing local communities with economic compensations associated to conservation initiatives (Adams et al. 2004), and creating incentives for compliance (Dietz et al. 2003). Thereby, complementary to protected areas, "win-win" conservation initiatives, also known as "pro-poor" conservation initiatives (Adams et al. 2004). These encompass incentive-based tools addressed to local communities and designed under the assumption that conservation should not compromise poverty reduction (Walpole and Wilder 2008; Muradian et al. 2013). In 1997, Costa Rica became in the first national PES programme for forest conservation (Borras et al. 2012; Börner et al. under review), and since then, it has spread worldwide (Fairhead et al. 2012).

PES programmes have been identified as hallmark of such incentive-based instruments due to the direct economic revenue to the producers of ecosystem services by the opportunity cost of conserve these services (Adams et al. 2004; Corbera et al. 2009; Börner et al. under review). Theoretically, the goodness of PES is based on the idea that valuing and paying for ecosystem services may deal with externalities result of human actions without the involvement of the public sector (Costedoat et al. 2016; Börner et al. under review). Moreover, high biodiverse areas and most forest cover lands are located in rural areas of developing countries (Potter-Bolland et al. 2011), where such payments are expected to contribute to poverty alleviation of these marginalised populations (Adams et al. 2004; Muradian et al. 2013). Thus, PES is theoretically a cost-effective instrument, which means that for a giving budget PES induces positively the provision of ecosystem services in comparison to the situation before its implementation (Börner et al. under review). However, several studies on PES have already documented both positive and negative socio-economic, institutional, or cognitive influences (Muradian et al. 2013; Costedoat et al. 2016; Börner et al. under review). Specifically, Börner and colleagues (under review) have found that PES induced both positive and negative outcomes

depending on the PES design and the characteristic of the SESs in which PES is implemented.

In conclusion, there are multiple evidences of the controversial role that conservation initiatives such as BR and PES, despite their inclusivity or "win-win" principles, have over local systems of environmental governance. However, as I show in the next section, few studies have explored the linkages between these conservation initiatives and local vulnerability and adaptation.

2.4.2 The role of conservation initiatives for local vulnerability and adaptation

Conservation initiatives can support local adaptation and reduce vulnerability to climatic hazards (van de Sand et al. 2014). However, conservation initiatives may also reframe local governance systems and livelihoods in a way that local vulnerability patterns may be exacerbated, becoming a stress to local livelihoods (Bunce et al. 2010; García-Frapolli et al. 2009; Porter-Bolland et al. 2013). Positive and negative influence of conservation initiatives depend on the specific social-ecological circumstances where they take place (Sandström et al. 2004; Muradian et al. 2013; Börner et al. under review). The following paragraphs describe the influence of conservation initiatives, and specifically BRs and incentive-based tools, on local vulnerability and adaptation by focusing on social structures and human agency (Figure 2.5). As mentioned before in section 2.3, both are key elements in understanding human decision-making to implement adaptation influences by the social context where individuals or collectives are living (Chowdhury and Turner 2006). In doing so, I examine how local environmental governance systems are challenged by the effective involvement of local people in rule-decision making on natural resource management (Brown 2002).

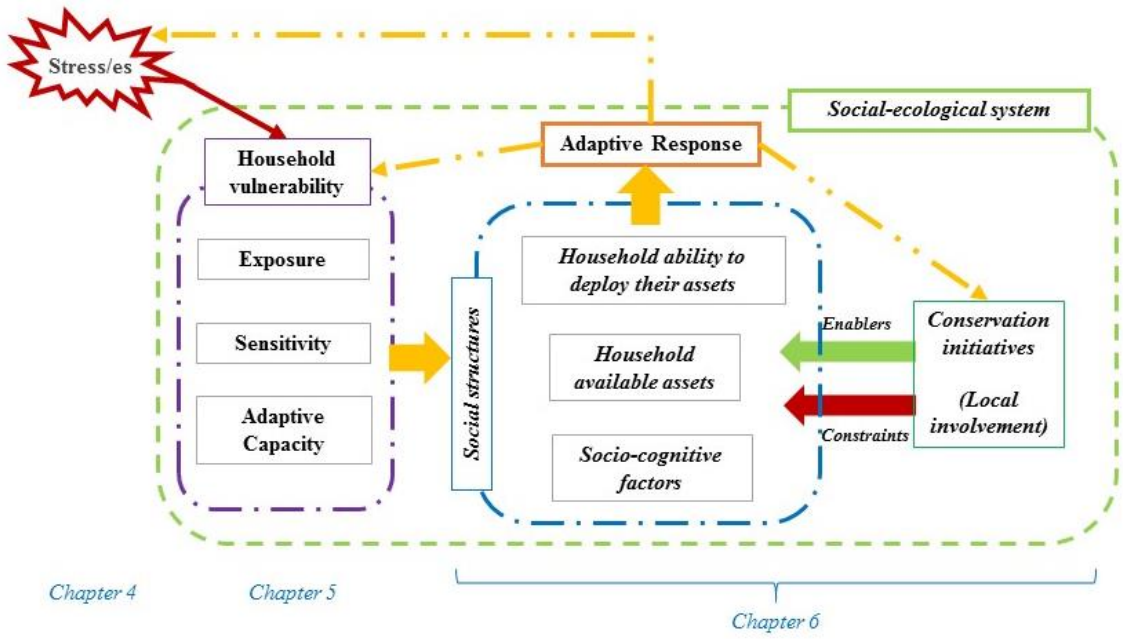

Figure 2.5: Overall conceptual framework establishing the relationships between vulnerability, determinats of adaptation and conservation initiatives

Local engagement in conservation enforcement is a positive incentive for sustainability and to ensure conservation governance legitimacy and ensure local conservation compliance (Dietz et al. 2003; Adger et al. 2005). However, Brown (2002) notes it is still a challenge to develop effective participation mechanisms to engage local people across scales, which very often are involved in passive forms of consultation. Moreover, effective participatory decision-making implies that government, as traditional custodian of natural resources, should transfer power to the communities (Ribot 2002; Olsson et al. 2004) often against their willingness (Acheson 2006; Lund 2015). In doing so, local resources users and communities can be empowered increasing their ability to adapt their livelihoods and governance system to the social-ecological conditions. Insights from studies on participatory environmental governance cross-scale suggest that collaborative structures needs of trust to avoid conflicts and ensure legitimacy (Olsson et al. 2004), whereas its lack is a major barrier (Sandström et al. 2004). Nonetheless, the time needed to reach trust among different actors is costly, increasing the transaction costs (i.e. negotiation over shared values, objectives and consensus) of participatory processes of decision-making (Adger et al. 2005).

Moreover, Brown (2002) highlights how "inclusive" and "win-win" conservation initiatives interact with social hierarchies within communities assuming that they are

representative and democratic. This ultimately facilitates the participation of richer and more powerful individuals (Navarro-Olmedo et al. 2015) and triggers inequalities in the effective involvement of marginalised sectors of the population within decision making processes (Adger et al. 2005; Navarro-Olmedo et al. 2015). It also highlights that conservation initiatives do not recognise that communities are socio-economic and political heterogeneous, leading to aggravate existing or potential conflicts among community members (Adger and Kelly 1999). Thereby, local differences in their involvement in conservation initiatives decision-making relate inherently to unequal distribution of potential benefits (Chakraborty 2001; Ribot and Peluso 2003; Adger et al. 2005). This means that conservation rules and enforcement exert a dual influence enabling and constraining households' available assets and ability to deploy them based on these flow of benefits. In consequence, conservation initiatives may exacerbate vulnerability patterns and marginalisation of the disempowered sectors of the community despite their "inclusive" principles (Ruiz-Mallén et al. 2015a).

Particularly for BRs, positive examples have highlighted how the recognition of local people and communities as legitimate resources users has triggered the devolution of land and resources rights enhancing their adaptation options (e.g. Kaimowitz et al. 2003; Kaimowitz and Sheil 2007; Ruiz-Mallén et al. 2015a). Also, Speelman and colleagues (2014) note how the effective involvement of local users into the BR governance structures promotes the legitimacy of conservation regulations (see also Sandström et al. 2014). This fact empowers local resources users and enhances their agency geared toward more strategic adaptive responses rather than short-term and reactive responses. There are also evidence of the positive influence of BR in providing and reinforcing local adaptive capacities, such as improving training and educational skills of local resources users (Batisse 1982), organisational capacities (Speelman et al. 2014; Ruiz-Mallén et al. 2015a), or increasing household income (Speelman et al. 2014), which is likely to positively influence local adaptation, and ultimately, reduce individual, and even collective, vulnerability patterns. BRs may also influence socio-cognitive patterns among local resources users by increasing their perceived value of forest conservation to local livelihoods, and well-being (Reyes-García et al. 2013). This, in turns, is likely to incentive the generation of individual and collective adaptive processes and responses related to conservation practices to confront their social-ecological stresses.

Conversely, other studies show how communities' vulnerability has increased as a result of being displaced due to the establishment of BRs (García-Frapolli et al. 2009; Ruiz-Mallén et al. 2015a). Others suggest that local people living within or around BRs are hardly informed nor involved in the design and implementation of BR regulations (Ericson et al. 2001; Reyes-García et al. 2013). This lack of involvement triggers detrimental consequences in terms of their access and use of natural resources, and ultimately increases local vulnerability patterns. Insights have revealed that women are especially vulnerable since they remain out of the conservation governance system (CDB 2010; Reyes-García et al. 2013) because participation in decision-making processes are very often tied to tenure rights (Velázquez-Gutierrez 2003). This suggests that as more conventional conservation governance systems, that BRs may also reinforce social hierarchies within communities. Moreover, BR regulations may also impact negatively rural livelihoods, which are mostly high dependent of rules over the access to and use of natural resources (Reyes-García et al. 2013; Ruiz-Mallén et al. 2015a), which ultimately impact on local adaptive capacities and agency for adaptation. This relation is well illustrated regarding the restrictions over the use of land which may increase the scarcity of available land for subsistence and commercial purposes, and lead to internal conflicts for the access to and control of land (Speelman et al. 2014). In sum, BR restrictions in the access to land in context of high marginalisation and few livelihood opportunities have pushed local users to develop adaptive responses to confront their negative impact, including to migrate abroad (López-Carr et al. 2012; Ruiz-Mallén et al. 2015a).

PES programme, as incentive-based tools, substantially differ from BRs because they are voluntary initiatives that have to be demanded by local communities (Southgate and Wunder 2009). As Corbera and colleagues (2009) note, this voluntary engagement facilitates the legitimacy of their related conservation regulations and avoid conflicts with external agents. This implies that PES may increase human agency and reduce the vulnerability of those who are benefited from the conservation rewards. Specifically, recent studies provide further evidence focusing on the substantial increase of financial support to local livelihoods to compensate local user for regulating the access and use of conserved target area (Muradian et al. 2013). As Christensen (2004) argues, PES revenues generate new opportunities for adaptation due to this new household income, improve access to basic services and equally address rights and local interest in the use of conserved areas. Similarly, van de Sand and colleagues (2014) further argue that PES

increase local adaptive capacity and local agency for implementing adaptation, which ultimately, may reduce local vulnerability to climatic hazards. Conservation payments may also be oriented to improve collective infrastructures or respond to collective claims (Corbera et al. 2009), in which it may help to overcome individual and collective vulnerability patterns. PES programme has then may influence positively over conservation enforcement, or willingness for training on natural resources management as Corbera and colleagues (2009), enhancing local agency for adaptation.

However, as Börner and colleagues (under review) note, PES programme may also generate negative outcomes to actors that are not directly involved by triggers inequalities in the effective involvement of the most disempower members of a community, often landless members and women (see also Corbera et al. 2009). Social hierarchies are then easily reinforced though an unequal distribution of costs and benefits within the community (Corbera et al. 2007; Bulte et al. 2008; Börner et al. under review). As Ruiz-Mallén and colleagues (2015a) further show, the lack of involvement of landless households may weaken conservation compliance and erosion of social cohesion and trust among actors, fuelling internal conflict. Indeed, as Corbera and colleagues (2009) further show that local attempts to engage landless dwellers in PES programme by, for example, reforesting or rewarding them with only half of the carbon income allocated to formal right-holders can trigger internal conflicts. PES programme therefore may exacerbate individual and collective vulnerability patterns and undermine adaptation options of those less empowered, as well as that may constraint collective adaptive responses. Moreover, insights from the influence of incentive-based instruments for conservation do not always strengthen social and ethical motives, and they may actually undermine such motives in some situations (e.g. Navarro-Olmedo et al. 2015). As Kosoy and Corbera (2010) argue, PES programme reduces ecosystem values to a single exchange-value measure, which has promoted the assessment of nature values based on market rationale (Harvey 2013). In doing so, conservation revenues may erode intrinsic motivations and other institutions (Muradian et al. 2013), mostly based on social and cultural values (e.g. Navarro-Olmedo et al. 2015). Therefore, conservation regulations might influence the belief in adaptation as desired and feasible option, as well as re-orient individual and collective's willingness for adaptation.

In sum, participatory and collaborative conservation initiatives, such as BR and incentive-based conservation tools, may play a double-edge role enhancing and undermining rural

livelihoods (e.g. Muradian et al. 2013; Speelman et al. 2014; Costedoat et al. 2016). In this regard, studies have highlighted on the effectiveness of conservation initiatives engaging local resources users in decision-making processes (e.g. Corbera et al. 2009; García-Frapolli et al. 2009; Ruiz-Mallén et al. 2015a), which is also related to studies on conservation legitimacy (e.g. Sandström et al. 2014; Speelman et al. 2014), and local values towards conservation rules and practices (e.g. Muradian et al. 2013; Reyes-García et al. 2013). Recent studies have also provided insights on the reinforcement of social hierarchies as an unexpected outcome result of the unequal level of local involvement in these "inclusive" and "win-win" conservation initiatives (e.g. Corbera et al. 2007; Bulte et al. 2008; Börner et al. under review).

In doing so, most of the related conservation governance studies have addressed several strings, but not a fully integrated view of rural vulnerability patterns and adaptation options in a context of conservation. In this dissertation I aim at filling this gap through the integration of conservation governance as a transversal theme influencing vulnerability patterns and adaptation options of the socially differentiated rural households in a case study. Therefore, the influence of conservation initiatives, together with land counter-reforms, over local governance systems, livelihood patterns, and subsequently, people's perception of local stresses is addressed in Chapter 4. Once that conservation rules and enforcement is identified as a source of stress to these studied communities, Chapter 5 discusses the impact that conservation regulations over the management of natural resources exert on local livelihoods, and subsequently, households' vulnerability patterns. Finally, Chapter 6 characterises and discusses the double-edged influence of conservation initiatives as either enabling or constraining processes for household and collective adaptive processes.

3 Research strategy: case study selection and methods

This methodology chapter explains how the theoretical research framework has been operationalised in a case study located in the Calakmul Biosphere Reserve (CBR). The research strategy combines inductive and deductive reasoning to collect the needed information to answer the questions raised in Chapter 1. Collected data broadly allowed for an examination of the social-ecological system and households' living conditions to address vulnerability and adaptation in the two communities studied. This facilitated an understanding of how local livelihoods are embedded within a conservation context.

This chapter is divided into five sections. Section 3.1 justifies the selection of the two studied communities to carry out this research, and describes contemporary land tenure reforms and economic policies influencing rural livelihood along the country and at local scale. Section 3.2 explains the fieldwork research schedule. Section 3.3 describes the research methods applied during fieldwork. Section 3.4 describes the procedure for analysing the qualitative and quantitative data, including a detailed description of the steps undertaken to develop a Household-level Vulnerability Index (HVI). Finally, section 3.5 describes aspects of my interactions with the communities and civil society organisations during the research.

3.1 Case study selection

The research was carried out in two rural communities following a case study approach. This approach allowed for comparing and contrasting local vulnerability patterns by observing what made these communities similar, and what made each of them special (Newing et al. 2011). I chose the CBR territory in Mexico as my case study, as it was one of the three case studies already selected in the COMBIOSERVE[1] research project within which I developed this research. Within this project, I collaborated as a partner with a grassroots organisation called Consejo Regional y Popular de *Xpujil* C.S. (CRIPX in Spanish), which facilitated my entry into and interaction with the communities.

[1] Community-based Management Strategies for Biocultural Diversity Conservation (COMBIOSERVE) is a FP7 EU-funded research project aims at assessing the effectiveness of community-based management in biocultural conservation initiatives located within protected areas.

The selection of the two Mexican communities (Figure 3.1), Once de Mayo (hereafter *Once*) and Santo Domingo-El Sacrificio (hereafter *Sacrificio*), correspond to three research criteria. The first criterion is the presence of conservation institutions influencing local vulnerability patterns and adaptation responses, such as the CBR and 'win-win' conservation initiatives. Second is the existence of a collaboration agreement between local inhabitants and COMBIOSERVE researchers based on Free Previous and Informed Consent (FPIC). Third is the different land tenure rights status of both communities (i.e. *Once* with land rights and *Sacrificio* without them), which I hypothesise exerted a heavy influence over local vulnerability patterns and adaptation options.

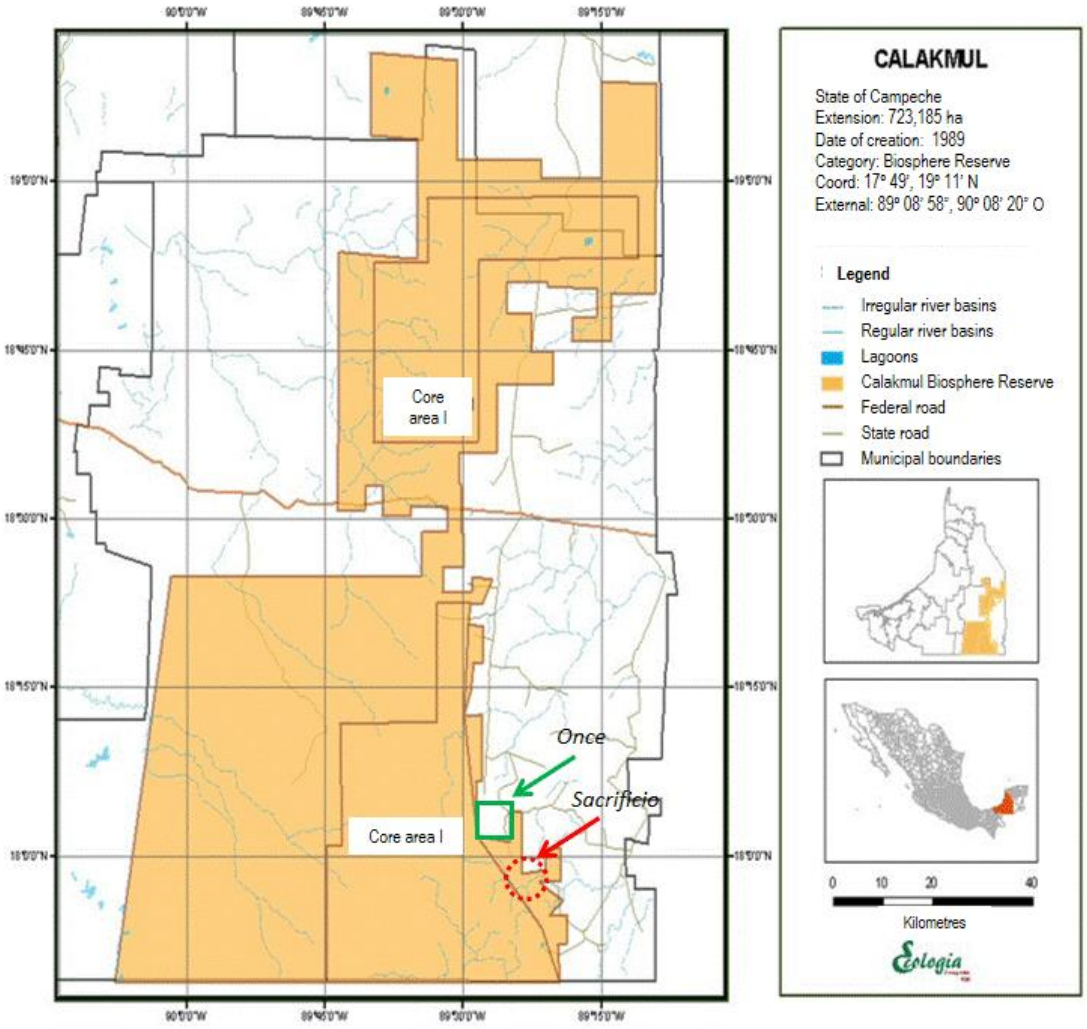

Figure 3.1: Official land tenure in the region of the Calakmul Biosphere Reserve

Note: This map was facilitated by IDESMAC, and adapted for this dissertation. In a green continuous line I have indicated the perimeter of the ejido Once, within the buffer zone and next to the core area I of the CBR. In a red discontinuous line I have indicated the

approximate perimeter of the still illegal community of small private properties of Sacrificio, within the buffer zone and core area I of the CBR.

Additionally CRIPX, as the local civil society organisation, prioritised the selection of communities in the Southern region of Calakmul to provide support to one of the most marginal areas in this municipality. Yet, their historical relationship with both communities was deeply unequal and, subsequently biased the information that this NGO provided me with. *Once* and CRIPX have been maintaining a constant steady relationship over the last decade, whereas the relationship between CRIPX and *Sacrificio* was almost broken after internal conflicts resulting from the community´s relocation in 1999. Recently, some inhabitants have reinforced *Sacrificio* representatives' participation in CRIPX decision-making processes, which explains why CRIPX allowed them to collaborate in the COMBIOSERVE project.

3.1.1 Land reform and economic policies in Mexico

In Mexico, the foundations of land tenure regimes as currently found were laid in Article 27 of the country's 1917 Constitution. It identifies three types of land tenure regimes (detailed below) (Appendini 2008; Rentería and Delgado-Serrano 2014). To illustrate the contemporary Mexican agrarian evolution, I differentiate between four historical periods by their relevance to current configurations of land distribution and tenure regimes.

The first period ran from 1857 to 1910. Federal agrarian regulations facilitated land accumulation by Spanish colonial *haciendas* (i.e. system of large land holdings) through the appropriation of *terrenos baldíos* (i.e. lands belonging to the state). These lands often overlapped with indigenous territories lacking official recognition, which meant that such regulations became in practice an instrument for indigenous land expropriation (Durand-Alcántara 2009 2009). This conflicting context was the precursor for future revolutionary and agrarian claims led by the *Zapatismo* movement over the next period.

The second period ran from 1910 to 1934 and was known as *agrarismo revolucionario*. In 1911 the *Plan de Ayala*, developed by Emiliano Zapata and Otilio Montaño, created the foundations of the current agrarian system in Mexico based on communal traditions and indigenous rules and conventions (Durand-Alcántara 2009; Harvey 2013). However, it was not until the mid-1930s that the agrarian revolution was operationalised.

The third period, from 1934 to 1988, was characterised by state-driven protectionist policies supporting the rural sector (Durand-Alcántara 2009). Federal government land reform re-distributed 51.4% of the Mexican territory in form of common land properties (i.e. *comunidades* and *ejidos*) (Appendini 2008). Simultaneously, the government subsidised local exploitation of natural resources and protected rural farmers' sales through guaranteed crop prices (i.e. regulated prices by the government which considered the costs of production and the international market prices) (Moreno-Brid and Ros Bosch 2010). At the end of this period, however, the Mexican economy experienced a transition to a neoliberal economic model. The Mexican President De la Madrid (1982-1988) encouraged an open-market policy reducing market restrictions while increasing exports at an annual rate of over 5% (Moreno-Brid and Ros Bosch 2010). Still, some federal restrictions were maintained in agricultural production, though commercial liberalisation was the long-term objective (Durand-Alcántara 2009; Harvey 2013).

During the fourth period, from 1988 to present, the ongoing neoliberal economic model was encouraged by President Salinas de Gortari (1988-1994), who had attributed Mexico´s economic backwardness to high public investment during the previous five decades, and the economic inefficiency characterising the *ejidal* model. In 1992, the land counter-reforms (i.e. the modification of Article 27 of the Mexican Constitution and the new Agrarian Law) abolished the *ejido* regime (i.e. communal land tenure rights) neglecting the opportunity for rural communities to claim lands under a collective regime. The counter-reforms gave *ejidatarios* (i.e. individual, mostly man, granted collective land titles in an *ejido* regime, see further description below) the rights to renting and selling their *ejidal* granted lands to third parties (Appendini 2008; Rentería and Delgado-Serrano 2014; Navarro-Olmedo et al. 2015). To achieve this, the federal government promoted the Land Rights Certification Programme (PROCEDE in Spanish) through which *ejidatarios* could legalise the practice of dividing communal land into family-owned and managed plots (Durand-Alcántara 2009; Navarro-Olmedo et al. 2015).

International private investment was promoted through a National Development Plan (1988-1994), which reduced public investment in the agricultural system and abolished price guarantees for agricultural products (Appendini and Liverman 1994; Baffes 1998; Harvey 2013). The hallmark of these changes in national economic policy was the signature in 1994 of the North American Free Trade Agreement (NAFTA), which resulted in the opening of the Mexican economy to global trade, with the USA becoming the

country's reference market (Appendini and Liverman 1994; Baffes 1998; Durand-Alcántara 2009). Over the following years, many farmers' associations across the country were dissolved, being unable to deal with market price volatility, and to compete with large farms and imported products (Stanford 1993; Harvey 2013).

At present, the end of the Mexican land reform and the establishment of a neoliberal economic model have resulted in three land tenure regimes. First, the *comunidades agrarias* or agrarian communities were established to recognise the existence of human groups that had historically lived in a given region and whose members could prove that their ancestral lands had expropriated in the past, or that they were living there de facto (Durand-Alcántara 2009). The state recognised household heads as *comuneros* (i.e. individuals, mostly men, with *de jure* use rights), and granted them a collective title. The community generally governs itself by enforcing customary rules and developing new rules as appropriate. Despite internal arrangements for common land distribution among *comuneros*, selling land to outside parties is legally prohibited. None of the selected communities in this research is a *comunidad agraria*. The second regime, the *ejido* (as *Once*), was established for settlements that could not prove their historical presence in a given place (Durand-Alcántara 2009). The state granted such settlements a collective title and household heads were recognised as *ejidatarios/as*. These communities are governed by an assembly to manage natural resources and social life. The third regime, *pequeñas propiedades* or small properties (as *Sacrificio*), gives rights to smallholders to use and usufruct their granted land as well as to sell it, totally or partially (Appendini 2008). Thus, they do not necessarily develop collective governance structures to regulate access to and use of natural resources as in *comunidades agrarias* and *ejidos*. For further details about the governance system in *Once* and *Sacrificio* see section 4.1.

These three land tenure regimes are the legal frame that establishes the rights and duties of those who have land rights, as well as those inhabitants who have not. The typology of land tenure regimes in Calakmul respond to the different historical phases of colonisation of the area during the nineteenth century, further explained in the following subsection. The absence of *comunidades agrarias* in Calakmul reflects that despite being a territory of ethnically diverse richness at present, the current inhabitants are not historical users of the tropical forest of Calakmul.

3.1.2 The Municipality of Calakmul and its Biosphere Reserve

The municipality of Calakmul is a vast region of tropical forest of high biocultural richness located in the southeast Yucatan Peninsula (INE 1999; Turner II et al. 2001). Until 1996, this territory belonged to the municipalities of Hopelchén and Champotón in the state of Campeche[2] (INE 1999). In 1996, the municipality of Calakmul was officially constituted and the territory of Calakmul became part of this new municipality. The harsh climatic and environmental conditions of this region left this territory almost uninhabited for centuries (García-Gil and Pat-Fernández 2000). Calakmul presents a tropical wet and dried climate (Aw) characterised by low rainfall patterns[3] (García 1998), with an average annual precipitation of 986 mm and an average annual temperature of 25 degrees Celsius (Zoh Laguna[4] station). There are two well-differentiated seasons (Figure 3.2): a wet season in summer (from May to October) which is characterised by a dry middle period, known as *canígula*, and a dry season in winter (from November to April), which encompasses between 5 to 10.2% of annual precipitation. Both communities are affected by tropical storms during the wet season, particularly in September.

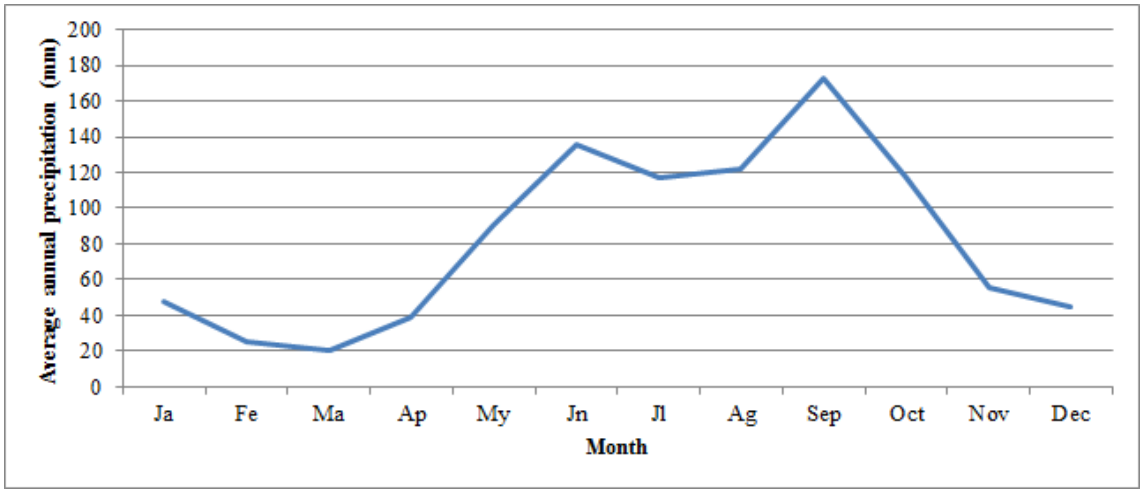

Figure 3.2: Average annual precipitation from 1949 to 2013

[2] The state of Quintana Roo is claiming for the eastern border of the Calakmul municipality as a consequence of a historical conflict about the precise location of the border marker (Ericson et al. 2001, Romero-Mayo and Rioja-Peregrina 2012).

[3] García (1998) establishes a meteorological classification to Mexico adapting the traditional Kóppen meteorological classification.

[4] The meteorological station of Zoh Laguna belongs to Water National Commission (CONAGUA in Spanish) and is the nearest meteorological station with historical records (58 and 76 km far away from *Once* and *Sacrificio*, respectively). It records meteorological data from 1949 to the present day.

Note: Source from CONAGUA, December/2014

This vast tropical forest is mostly located over *karstic* soils, which provide thin and poor soils with high permeability. The Calakmul region is thus characterised by having low yield soils with stationary river basins and lagoons (Galindo-Leal 1999; INE 1999), a relevant constraint for the development of local livelihoods. Land reforms policies undertaken during the twentieth century promoted the colonisation of *terrenos baldíos* (Durand-Alcántara 2009). In this territory, such reforms meant in practice the appropriation of forested areas by three remarkable waves of migrants from several Mexican states to Calakmul (Ericson et al. 2001).

The first immigration wave ran between 1900s-1940s, where seasonal migrant workers arrived to Calakmul to extract *chicozapote* resin (rubber) (*Manilkara zapota*), called *chicle* in Spanish, fuelled by a growing international rubber demand. This activity had a marginal impact on the local economy since only few *chicleros* (i.e. men who extracted *chicle*) permanently settled in the area. In the late 1940s, Mexican rubber's commercialisation collapsed due to the decrease in international demand and the increase in the commercialisation of similar functional resources with more competitive prices (Acopa and Boege 1999).

The rubber trade collapse coincided with the increase in timber[5] extraction promoted by state-driven protectionist policies, which granted forest concessions to a private logging company *Cooperativa de los Chenes* (Acopa and Boege 1999). Logging brought the second wave of migrants, from 1940 to 1980, and infrastructure development to the region, including paths, roads and a train line. A few settlements were established along the federal road between the cities of *Escárcega* to *Chetumal* (Ericson et al. 2001). However, despite the company's economic prosperity, the region remained highly isolated, and both socially and politically marginalised. According to some inhabitants in

[5] The main commercial species were mahogany (*Swietenia macrophylla*) and Spanish cedar (*Cedrela odorata*) (Ericson et al. 1999)

Calakmul[6], timber-logging extraction was an activity developed legally until mid-1980s, and clandestinely until now.

The third and last wave of migrants started in the 1970s and continued until the late 1990s. Families from other states lacking land tenure rights and social-economic stability were encouraged to migrate to Calakmul encouraged by the colonisation policies of presidents Echeverría, Portillo y Pacheco and De la Madrid (García-Gil and Pat-Fernández 2000; Navarro-Olmedo et al. 2015). As soon as families arrived to Calakmul, they cleared the forest and started to cultivate *milpa* (i.e. swidden agriculture of maize, beans and *chihua*, a local type of squash) for subsistence purposes, and when possible, to cultivate *jalapeño* chilli (*Capsicum annum L.*) for commercial purposes. The latter has been the main cash crop supporting households' economy in the region until now (Keys 2005).

This colonisation process explains the current socio-cultural mosaic that characterises the Calakmul territory (INE 1999), and explains the high deforestation rates experienced during the 1980s-2000s period (Klepeis and Turner II 2001; Keys and Chowdhury 2006). The tropical forest of Calakmul was perceived by those migrant families as a frontier to be opened up to agricultural activities (Klepeis and Turner II 2001). To reduce such deforestation rates, and following international conservation policy, the federal government established the CBR in 1989.

The CBR was established as the largest protected area of tropical forest in Mexico and a valuable place for biodiversity conservation (Ericson et al. 2001; INE 1999). This type of protected areas followed a more 'inclusive' human-nature management model and adhered to the Man and Biosphere Programme led by UNESCO, which supported the development of biosphere reserves worldwide. Thereby, the CBR aims include the promotion of long-term biophysical conservation of species and ecosystems making this overarching objective compatible with the development of those inhabitants living within and around to the biosphere reserve (INE 1999).

The CBR covers 723,185 hectares of forest divided into two areas: the strictly protected ecosystem (248,260 hectares) subdivided in two core areas, and the surrounding buffer

[6] More detailed information about the informants of these evidence is not here provider due to the high sensitivity regarding this issue in relation to potential conflicts intra- and inter-communities, as well as with the CBR's direction.

zone (474,924 hectares). In the two core areas, access and use of forest resources and gathering wild plants are banned, as well as the development of infrastructure (INE 1999). Conversely, in the buffer zone, human settlements and productive activities compatible with conservation management and rules, such as agriculture, hunting or gathering, are allowed (Ericson et al. 2001; INE 1999; Ruiz-Mallén et al. 2015a). Activities promoting land cover change or damaging protected species are however forbidden.

The conservation of natural resources is a transversal issue studied through this dissertation in relation to vulnerability and adaptation issues. Thus, further information about the influence of the CBR and other conservation initiatives in the governance system and the development of rural livelihoods is analysed in Chapter 4. The influence of conservation regulations as a sources of damage is analysed in detail in Chapter 5 to understand household vulnerability patterns. Finally, Chapter 6 investigates the role of the CBR and other conservation initiatives in enabling and constraining individual and collective agency for undertaking adaptive responses.

3.2 Fieldwork research

I spent nine months in Mexico over two periods: a first exploratory visit from September 2012 to November 2012, following an inductive research strategy, and then, a second period of fieldwork from September 2013 to April 2014 with a deductive research strategy (Figure 3.3). The first short exploratory fieldwork period enabled me to get an impression of the Calakmul region, CBR management, and local livelihoods in *Once* and *Sacrificio*. This fieldwork was crucial to develop, design and adapt the research methods to be used during the second fieldwork period. I spent approximately 90 days in each community, divided into periods of four to ten days, when possible. Long cohabitation periods are critical to exchange experiences and knowledge with community members. Talking to them regularly and eating with them were important daily task to gain trust with household members (see section 3.5).

The first fieldwork period started two months after I was enrolled in the doctorate programme in order to adapt to the development of the COMBIOSERVE project in both communities. During this period, I carried out a total of 27 semi-structured interviews (Interview guide 1) and five focus groups with 25 participants to explore the environmental histories of both communities and to identify locally perceived stresses

over their livelihoods (Focus group guide 1). This period allowed me to identify drivers of change and vulnerability trends within each community, while observing the social, economic and political context of those recently settled, migrant and multi-culturally diverse communities coexisting in the southern part of the CBR.

During the second period of fieldwork, I conducted a survey with a representative sample of households in each community (93 in total) to gather information on households' assets and livelihoods, in addition to collecting information about household heads' perceptions of the effects that the stresses that had been previously identified caused on such assets and livelihoods. I also interviewed 44 household heads about their adaptive responses, perceived opportunities, constraints, and the motivations fuelling their livelihood activities and decisions (Interview guide 2). During this long stay in Calakmul, I also carried out 25 semi-structured interviews with 19 local actors, including community, municipal, and regional authorities, CBR managers, NGO representatives and local associations on conservation and development promotion in Calakmul (Interview guide 3). At the end of this period, I conducted a participatory scenario building process with stakeholders (Focus group guide 3) to generate four narratives of plausible future social-ecological changes in Calakmul. These were further discussed with inhabitants in *Once* and *Sacrificio* through a total of six focus groups to explore vulnerability and adaptation pathways. With this last method, I covered the past, present and future of local vulnerability and adaptation patterns. Results from this latter method are not analysed in this dissertation, but have been used for a comparative study of environmental scenarios in Bolivia and Mexico within the framework of the COMBIOSERVE research project (Ruiz-Mallén et al. 2015b). However, I have decided to develop this participatory research method in this chapter (section 3.3) because it complemented the data gathered through other research methods, and is part of my learning processes throughout fieldwork.

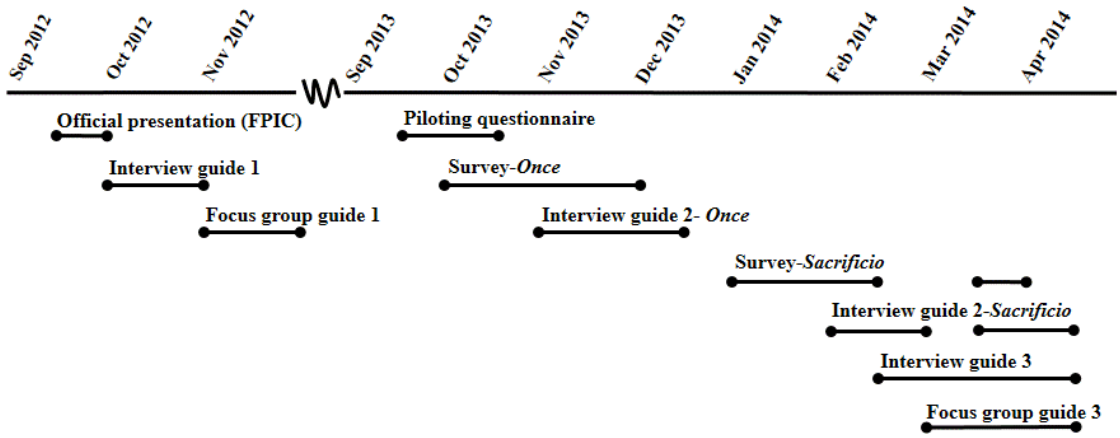

Figure 3.3: Fieldwork schedule

3.3 Research methods

This research used a mixed-methods approach, combining qualitative and quantitative data collection and analysis, to complement and contrast the results obtained (Bryman 2006; Newing et al. 2011). Participatory observation, semi-structured interviews, and focus groups were developed to collect data on individual and collective views about drivers of change, vulnerability perceptions, and implemented and envisioned adaptive responses, while gaining an understanding of the social-ecological context. This information was crucial to validate, understand, and contextualise the quantitative information gathered subsequently through surveys. I designed and conducted a survey with household heads to collect detailed information on household living conditions and livelihood activities that influence household vulnerability patterns and adaptation options. The main unit of analysis was thus the household, understood as a family-based social group that occupies and maintains its physical domains, and organises and operates labour productivity (Netting 1993).

Before implementing these methods, a Previous Free and Informed Consent (PFIC) was obtained from each participant through the COMBIOSERVE consent protocol. This protocol included information about the method to be used, the procedure (i.e. use of tape-recorder), type of information to be collected, the purpose of collecting this information, and emphasising the anonymity of each participant in the research.

I adapted each method to the local vocabulary, and social conventions and codes. This was previously reviewed by local members belonging to the COMBIOSERVE project

and piloted before its implementation in the field. By piloting each method, I ensured the accuracy and the validity of questions developed to gather the information desired (Newing et al. 2011).

3.3.1 Participant observation

Participant observation is an unstructured research method based on watching, listening and interacting in daily routines and activities of individuals, households and communities. This method aims to get a picture of "*the way things are done*" (Newing et al. 2011: 85) by documenting what people said or did, but also accounting feelings and personal experiences of the researcher during fieldwork. I took notes during the time I was living within both communities, having informal conversations with them, attending local meetings, assemblies, and other events to which I was personally invited (e.g. family parties, meals or religious ceremonies). I noted information related to experiential, emotional and theoretical thought based on household and collective daily domestic and productive tasks.

3.3.2 Semi-structured interviews

Semi-structured interviews are one of the central research methods employed in this dissertation. The basic difference between a semi-structured interview and other forms of interviews is that the former is "*based on an interview guide that is prepared in advance*" (Newing et al. 2011:101). This is a useful tool when there is not enough information to develop a questionnaire, or the nature of the explored topics regarding perceptions, opinions, behaviours, motivations, and even conflict-related issues are difficult to document by using a rigid method such as a questionnaire (Gillham 2000).

During the research, I designed and implemented three different interview guides (see Appendix I) to explore: 1) the environmental history and local governance system in *Once* and *Sacrificio*, 2) household's adaptive responses and agency to multiple stresses, and 3) local and regional stakeholders' opinions regarding conservation, development and vulnerability patterns in Calakmul.

The interview guide 1, called "The environmental history and local governance system", was applied during the first fieldwork period. The information collected was a starting point to contextualise the rural context. Five research themes were explored: 1) personal data to characterise the social-economic profile of interviewees, 2) households' adaptive

responses ever since their arrival to the community, 3) local governance aspects regarding land, forest, and water resources management, 4) households' assets and livelihood activities, and 5) locally perceived social-environmental changes affecting local livelihoods.

I completed 11 interviews in *Once* and 16 interviews in *Sacrificio* using this guide (Table 3.1), all in Spanish, ranging between three-quarters and one hour and a half in length, approximately. Interviewees were purposively selected to gather information from different social groups regarding land tenure, gender and ethnicity criteria. I stopped interviews when each social group was represented and no new information was being collected (Newing et al. 2011).

Table 3.1: Interview sampling across communities using interview guide 1

	N	**Land tenure rights**		**Gender**		**Ethnicity**	
		Yes	**No**	**Women**	**Men**	**Indigenous**	***Mestizo***
Once	12	8	4	5	7	5	7
Sacrificio	16	12	4	7	9	11	5

The interview guide 2, named "Household's adaptive responses and agency to multiple stresses", was conducted during the second fieldwork period. The interview guide explored households' adaptive responses, their motivations to initiate or give up a particular productive activity, and individual and collective interests to improve their livelihoods. I asked about the seven topics: 1) household's experiences facing the selected stresses (based on a pebble distribution exercise, see section 3.3), 2) household's perceived adaptive capacity to face the selected stresses, 3) household's knowledge and expectations on productive activities, 4) local environmental governance and social accountability issues, 5) social-political and economic causes of marginalisation, 6) information flow and transmission and social networks, and 7) individual expectations on how these stresses influence future livelihoods.

I completed 19 interviews in *Once* and 25 in *Sacrificio* using this interview guide (Table 3.3), ranging between half and one hour and a half in length. Interviewees were purposely selected based on three criteria: 1) previously surveyed households, 2) land tenure rights condition (i.e. with or without rights), and 3) a balanced gender representation. I did not

consider ethnicity as a criterion because, during the first round of interviews, I realised that households' conditions and opportunities were not significantly different between *mestizos* and indigenous people.

Table 3.2: Interview sampling across communities using interview guide 2

	N	Land tenure rights		Gender	
		Yes	No	Women	Men
Once	19	10	9	9	10
Sacrificio	25	14	11	9	16

The interview guide 3, named "Opinions regarding conservation, development and vulnerability patterns in Calakmul", was conducted at the end of the second fieldwork period. This guide explored local and regional opinions regarding the relationship between conservation and development policies in Calakmul, and the roots of marginalisation and vulnerability in the region. This guide covered six topics, which varied slightly depending on the type of organisation being interviewed: 1) economic development and conservation policies followed, 2) priority themes and actions, 3) enablers and barriers for rural development in Calakmul, 4) local mechanisms for communication of offered programmes and services, 5) challenges faced to reach objectives, and 6) past and recent relationships with the studied communities.

I conducted 25 interviews with representatives of 19 governmental and non-governmental organisations using this interview guide (Appendix III), ranging between half an hour and two hours in length, approximately. Interviewees were selected according to their potential knowledge and availability. Interviews were arranged by telephone, e-mail, or personally in a public event, when possible.

3.3.3 Focus groups

Focus groups are "*pre-arranged group interviews*" (Newing et al. 2011: 104) structured by a guide of topics to explore with involved participants. This collective discussion should bring out contrasting views and reflections, being a space where people can argue their perspectives (Newing et al. 2011). A focus group guide should cover no more than four topics, structuring a conversation of two or three hours. Focus groups should involve a small group of participants, who should be informed about objectives, procedures, and

confidential matters following the FPIC. The facilitator should be proactive, guiding the conversation and maintaining the equilibrium between participants who talk more and less, and giving everyone the opportunity to participate in the on-going discussion. It is also important to have a note-taker who understands the objectives of this method and the research framework in which it is embedded.

In order to adapt procedures to local conditions and cultural context, I arranged date and time with potential participants to minimise interferences with other activities in the community (e.g. day of harvest, assembly, or collective labours). During the research, I designed and implemented two different focus group guides (Appendix II) to explore: 1) the environmental history of the community through timelines, and 2) potential scenarios of global change in Calakmul for 2030.

The focus group guide 1, called "The environmental history of the community - Timelines", was applied at the end of the first fieldwork period. It aimed to identify and characterise historical, social and ecological drivers of change for local livelihoods, individual and collective adaptive responses undertaken in both communities, and relevant local governance mechanisms and rules enhancing or undermining adaptation options.

Participation was open to everyone who was willing to join, in order to promote local inhabitant's involvement in the umbrella research project. The number of participants did not exceed 13 people in any case. The facilitation of the focus group was led by CRIPX because I could not simultaneously facilitate both groups (men and women). I supported both facilitators and orientated the process. I further tried to organise complementary focus groups with social groups under-represented in the former focus groups, such as male household heads without land rights and indigenous female household heads. However, due to time limitations and unwillingness to participate among male landless household heads, I only conducted an extra focus group with female indigenous household heads in *Once*. Finally, I implemented three focus groups in *Once* and two focus groups in *Sacrificio* (Table 3.3).

Table 3.3: Participants involved in timelines focus groups across communities

	Focus group # participants (# focus groups)		
	Overall	**Women**	**Men**
Once	13 (3)	9 (2)	4 (1)
Sacrificio	12 (2)	5 (1)	8 (1)

The use of a local translator in *Chol* was necessary only in the women's group in *Sacrificio*. Data were compiled in a table to synthesise participants' comments. The group of indigenous women in *Once,* and men in *Sacrificio,* preferred to discuss the environmental evolution of their communities rather than to generate a timeline.

The focus group guide 2, on "Potential scenarios of global change in Calakmul for 2030", was applied at the end of the second fieldwork period. It was used to explore household and collective adaptive responses, in a context of four different plausible scenarios of social-environmental change, by using a participatory approach. Subsequently, and by using other focus groups, I generated a local discussion about opportunities and barriers associated with face these scenarios at the local level. I then applied Participatory Scenarios Building and Discussion Exercises (Figure 3.4) developed in five steps (Ruiz-Mallén et al. 2015b): 1) key regional and local stakeholders identification, 2) scenario-building workshop execution, 3) generation of scenario narratives by the local research team, 4) deliberative focus groups at community level execution to discuss adaptive responses to each of the previously defined scenario narratives, and 5) compilation of locally suggested policy options to overcome vulnerability enhancing adaptation.

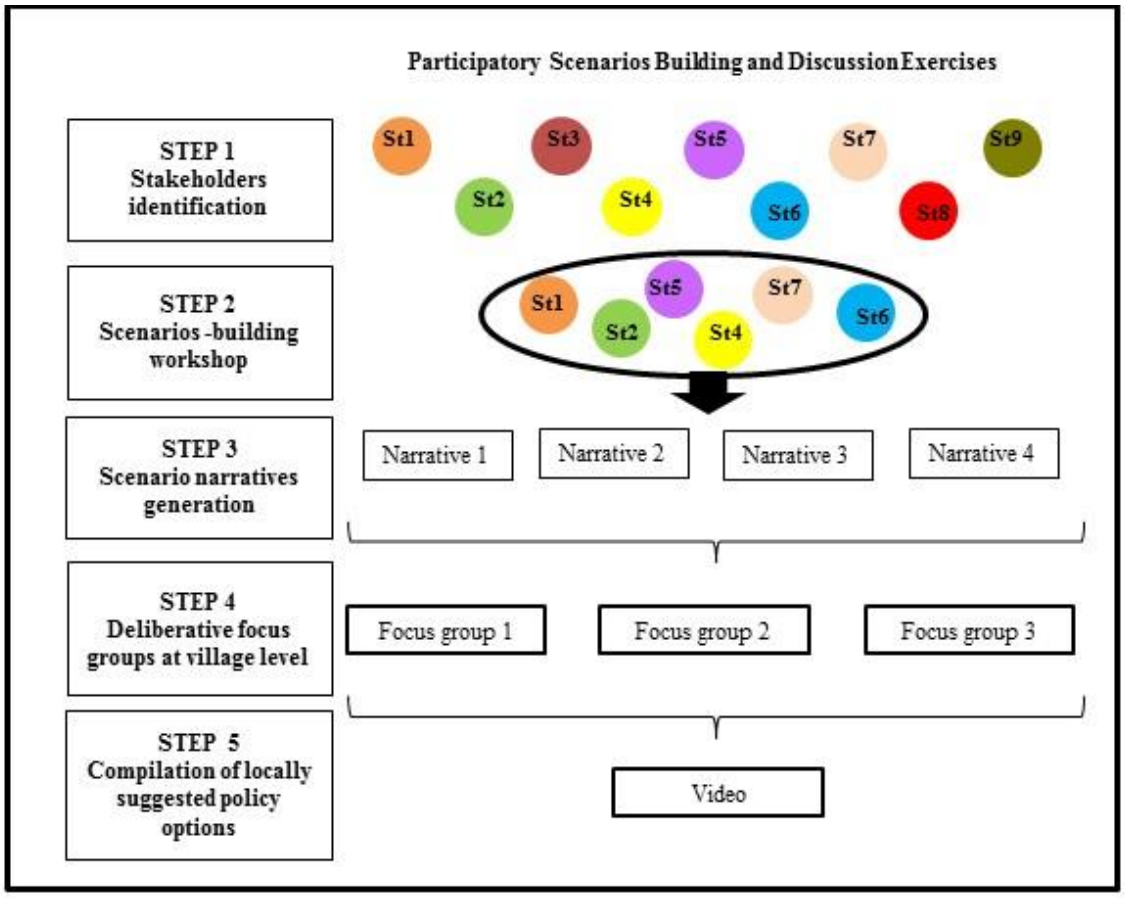

Figure 3.4: Participatory Scenarios Building Discussion Exercise scheme

Note: St_n refers to the local and regional stakeholders identified and invited (STEP1) and to those who finally attended to the Scenario-building workshop (STEP2).

Following step 1, I invited 17 local and regional stakeholders, selected based on their work in government, an NGO, or local committees, to participate in the scenarios-building workshop (Step 2). As facilitator, I conducted this designing scenarios workshop in a morning working session with eight participants. Participants ranked the four previously identified drivers of change (i.e. rainfall variability, uncertainty about cash crop prices, conservation rules, and infrastructure development) by their influence on future local livelihoods. I then selected the two higher ranked stresses - i.e. rainfall variability and conservation regulations - to generate four plausible scenarios through a two-axes approach varying the degree of impact (Appendix II) (Ruiz-Mallén et al. 2015b). The discussion to generate each scenario was motivated by two questions: 1) how will Calakmul be in 2030 under this scenario, and 2) why do participants believe that? It was also structured around local livelihoods: subsistence agriculture, commercial agriculture, livestock, beekeeping, firewood and timber extraction, hunting, harvesting

wild forest plants, other employments (education, wage labour, etc.). I then employed the information gathered to generate a local narrative about potential social-ecological changes and visual support for each scenario (Step 3). Scenario narratives were sent to all participant stakeholders to validate them, although feedback was not received.

Between March and April 2014, I conducted three different focus groups in both communities to discuss local adaptation options and likely vulnerable groups regarding each scenario's narrative (step 4). Participants were selected from a set of households previously surveyed taking into account land tenure rights and gender, which generated a group with male landholders, another group with male landless inhabitants, and a group with women. Participants were thus selected trying to maximise the representation of these households. I then, first, randomly selected participants from the two focus groups of men. Afterwards, women were invited if the male head of same household had not participated before. I personally invited 10-12 participants to each focus group to generate a fluid and easier-to-manage conversation group. On the arranged day, I also arrived in advance to ask them for their willingness to participate in the group, and to take the opportunity to invite new participants. A total of 33 household heads, 15 and 18 in *Once* and *Sacrificio* respectively, participated in the focus groups (Table 3.4).

Table 3.4: Description of participants involved in discussion of future scenarios by community

	N	**Focus group**		
		Men with land rights	**Men without land rights**	**Women**
Once	15	5	5	5
Sacrificio	18	6	6	6

3.3.4 Household survey

A household survey is a research method that aims to gather specific information about a household. I designed this household survey drawing on previous rural vulnerability and livelihood studies (Bebbington 1999; Eakin 2005; Eakin and Bojórquez-Tapia 2007; Scoones 2009; Tucker et al. 2010; Alayón-Gamboa and Ku-Vera 2011). Specifically, the household survey was composed of two instruments: 1) a household questionnaire, and 2) a pebble distribution exercise.

A questionnaire is a question-answer session where questions and possible answers are mostly pre-defined (Newing et al. 2011). This instrument has the advantage of gathering data in a format that is easy to compare and analyse statistically. However, its closed and standardised structure simplifies potential answers, which consequently over-simplifies the reality of respondents (Newing et al. 2011). To avoid this, information gathered through interviews and focus groups was key to contextualise the survey database. I designed the household questionnaire to gather data about household livelihoods, assets, adaptive responses, and perceptions to compare vulnerability patterns across households and communities.

The pebble distribution exercise, in turn, assessed household heads' perceived vulnerability to the three identified stresses (i.e. conservation rules, rainfall variability, and uncertainty about chilli prices). Respondents distributed 20 maize seeds between three pictures symbolising each locally perceived stress (Appendix III). If a respondent put more seeds in one of these pictures, this meant that his/her perceived vulnerability to this stress was higher than the other two stresses. Respondents could not keep any seed in his/her hands unless they considered that none of these stresses affect their livelihoods.

Surveyed households were selected based on two criteria: 1) to be formed at least two years ago because the time of reference for the questionnaire was a year before the current time, and 2) to be an independent household unit (i.e. its input and output of cash and material were controlled by the household, so they live and eat independently from other relatives), even if other households were using or were located in the same urban plot. Following these considerations, 27 couples were excluded in *Sacrificio*, while none was excluded in *Once*.

I applied a household survey to 50% of the identified households in both communities. This is a significant large sample to represent households' diversity across communities, but acknowledging the possible simplification of the communities' realities. The sampling method in both communities differed because of the unequal proportion of households holding land rights and those without. This proportion was not relevant in *Once*, and the sample was then randomly selected. In *Sacrificio*, the proportion of households claiming land rights is considerably larger that the proportion of landless households. Subsequently, I stratified the sample differentiating on the basis of land

tenure rights, and then I randomly selected the surveyed households within these two groups.

The survey was conducted with male household heads, when possible, because men develop and control most decisions regarding household livelihoods. I thus surveyed 39 households in *Once* and 54 households in *Sacrificio* (Table 3.6). In the cases where male household heads were not available or willing to participate, I conducted the whole household survey with female household heads. Additionally, I conducted a shorter version of the same questionnaire and the pebble distribution exercise to female household heads, when possible, to complement the information about each surveyed household. I then conducted 27 partial households to female household heads in *Once*, and 37 in *Sacrificio*.

Table 3.5: Description of household surveys completed by community and land tenure rights

	N	Households with land right	Households without land right
Once	39	23	16
Sacrificio	54	34	20

3.4 Data analysis

This section explains the procedure undertaken to analyse the quantitative and qualitative data in order to inform the three empirical chapters of this thesis, from Chapter 4 to 6 (Figure 3.7). First, recorded audios from interview guides were transcribed using Express Scribe software and transcriptions were manually coded by using content analysis. Focus group information was synthesised in tables and recording were listened to, so as to complement or contextualise information in tables, when necessary. Second, I generated a database with information collected through household surveys, which I then cleaned by using the Stata 11.1 statistical software. In doing so, I looked for possible mistakes when introducing data by contrasting information from related questions and observing missing or irregular values. Moreover, every step in designing and analysing this database was developed using the Stata 11.1 statistical software.

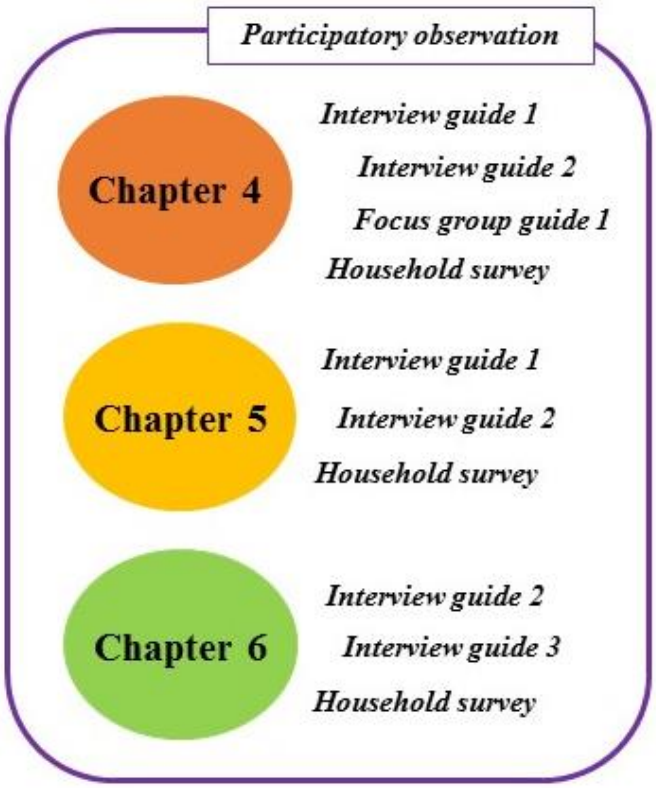

Figure 3.5: Schedule of the main research methods contributing to the analysis represented in the three developed empirical chapter of this dissertation

3.4.1 Field notes, interviews and focus groups

Field notes written from participant observation were useful to contextualise every empirical chapter of this dissertation. I read and included information relevant to the defined issues of interest in each chapter. Thus, field notes were a substantial source of information in Chapter 4 contextualising local governance procedures, livelihood patterns, and locally perceived stresses. In Chapter 5, I used field notes to add information required in the design of the HVI, principally regarding farm gate prices, but also, contrasting the quantitative analysis to enrich its accuracy. Finally, field notes complemented and contrasted the overall information described in Chapter 6, which deals with adaptive responses and local agency factors, as well as providing rich information to understand conflicting issues regarding local conservation initiatives.

Data from interview guide 1 were analysed to provide information for Chapter 4. I categorised the historical information into thee predefined codes: 1) past social-ecological events, 2) current local livelihoods, 3) perceived stresses. In doing so, data specifically contributed to: first, describe the social-environmental evolution of both communities

ever since their settlement (see section 4.1); second, to inform current local livelihood patterns (see section 4.2); and third, to identify and select the most influential stresses over local livelihoods (see section 4.3).

Data from interview guide 2 were analysed for in-depth understanding of issues previously addressed through interview guide 1, and new questions that arose after the first fieldwork period. These data were categorised into two predefined codes: 1) household's perceived vulnerability, 2) categories of adaptation processes and responses[7] based on Thornton and Manasfi's framework (2010), and 3) agency factors[8] based on Brown and Westaway's (2011) framework. Therefore, this method informed: first, the description of households' perceived vulnerability to the selected stresses (see section 4.3); second, the identification and classification of adaptive responses (see section 6.1); and third, the identification of external and internal enablers and constraints for adaptation (see section 6.2), including those related to the implemented conservation initiatives (see section 6.3).

Data from interview guide 3 were analysed to explore the role of external organisations in local vulnerability and adaptation. The information collected was categorised in five predefined codes: 1) conservation and development relationship, 2) causes of vulnerability in Calakmul; 3) enablers of adaptation in Calakmul; 4) constrains of adaptation in Calakmul, and 5) CBR relationship with *Once* or *Sacrificio*. Therefore, this method was principally informative as to the role of external organisations as enablers or constraints to local adaptation (see section 6.2). Data from some external organisations associated with the implementation of conservation initiatives, such as CBR, National Forestry Commission (CONAFOR in Spanish) or SEMARNAT, was useful to inform the specific influence of conservation rules and practices enhancing or undermining adaptation (see section 6.3).

The environmental histories and timelines from focus group guide 1 were analysed to describe the ecological, social-political, and economic context of both communities (see

[7] The categories of adaptation processes included in Thornton and Manasfi's framework (2010) are: polling, diversification, mobility, rationing, exchange, intensification, innovation and revitalization (see section 2.3 for further details).

[8] The agency factors based on Brown and Westaway (2011) are: recognition of the need to adapt, belief that adaptation is feasible and desirable, willingness to undertake adaptation, available resources to implement adaptation, ability to deploy resources in a proper way, and external constrains, barriers and enablers for adaptation (see section 2.3 for further details).

section 4.1). It also allowed the identification and characterisation of locally perceived stresses (see section 4.3).

Quantitative data gathered by using household surveys were useful to inform and complement qualitative data in every empirical chapter. Specifically, the generated quantitative database was analysed to characterise local livelihood patterns (see section 4.2). In particular, the pebble distribution exercise was informative about households' vulnerability perceptions regarding the previously identified stresses (see section 4.3). Moreover, this quantitative database was central to develop and calculate the HVI (see sections 5.1, 5.2 and 5.3). Steps undertaken to design and analyse the HVI were further explained below in this section. Finally, the household survey database was also useful to ensure the identification of adaptive responses (see section 6.1), as well as to inform some agency factors such as, the recognition of the need to adapt, the willingness to undertake action, and the availability of resources to undertake action (see section 6.2).

Additionally, I explored other channels of primary and secondary information. National and international statistical information was consulted regarding the chilli trade chain (FAO[9], SIAP[10]), as well as socio-demographic data and the published Marginalization Index (CONAPO[11]), and meteorological data (CONAGUA[12]). Local newspapers and official documents were consulted, principally, for information on the social-environmental history of both communities and the influence of conservation initiatives. In doing so, I read all federal laws related to land reform and management of natural resources (e.g. Mexico's Constitution of 1992, the Agrarian Law of 1992, the Sustainable Development Law of 2001, and the Sustainable Forest Development Law of 2003). In the case of CBR, I also read its Management Plan, as well as official procedures and regulations of the conservation initiatives implemented in both communities. To explore "win-win" conservation initiatives undertaken in *Once* (i.e. the Payments for Ecosystem Services programme and the Environmental Compensation programme), I consulted

[9] FAO database
[10] SIAP. Servicio de Información Agroalimentaria y Pesquera (SIAP). Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación, (SAGARPA).
[11] CONAPO database Available at http://www.conapo.gob.mx/es/CONAPO/Indices_de_Marginacion_Publicaciones, Last time consulted:
[12] CONAGUA database: Water National Commission (CONAGUA in Spanish) Available at: ****, Last time consulted: December 2014

official information available about the conditions to apply for these programmes, management principles, and surveillance procedures (CONAFOR).

3.4.2 Design and analysis of a Household-level Vulnerability Index

A vulnerability index is generated by using a set of indicators, measured in a quantitative format, which that can be aggregated statistically or theoretically, in dimensions and sub-indices, to a more manageable interpretation of those indicators (Tate 2012). A vulnerability index is thus useful for capturing a complex reality (Vincent 2004). It allows the evaluation of vulnerability patterns in a society across time and space. In fact, it is an instrument easily accepted among policy makers because it provides a concrete measure and it can be visually represented (Vincent 2004; Aegon and Bates 2015). For these reasons, I assessed vulnerability by designing and using the Household-level Vulnerability Index (HVI) in order to: 1) explore which factors determine the degrees of sensitivity across communities; 2) examine which factors determine adaptive capacity profiles across communities and identified clusters, and 3) identify the heterogeneity of vulnerability patterns across communities.

Mainly based on Tate (2012) I designed the HVI in seven steps. In Step 1, I established which components of vulnerability may be addressed in the HVI based on my theoretical framework and research aim. I then included the households' sensitivity to each identified stress (i.e. rainfall variability, uncertainty about chilli prices, and conservation rules), and the households' adaptive capacity, which is independently assessed from the stress effect as a potential condition in the present time, in the HVI. The households' exposure to the selected stresses was excluded from the HVI because of first, I did not have access to accurate meteorological data to differentiate slight variations in rainfall across households and communities; second, both communities share the same chilli production chain; and third, conservation rules influence similarly the local environmental governance. I then assumed households' exposure equally distributed among households and communities (e.g. Adger et al. 2004; Vincent 2004; Hahn et al. 2009; Notenbaert et al. 2013).

In Step 2, I designed the structure of the HVI as a hierarchical model of four levels (see Figure 3.8). Level 1 meant the highest level of aggregation in the HVI composition. It was followed by two sub-indices (Level 2): the Sensitivity Index (SI) and the Adaptive Capacity Index (ACI). The SI was then sub-divided into three dimensions (Level 3) corresponding to the SI to each specific stress: *S_market, S_climatic* and *S_conservation*.

The Adaptive Capacity Index (ACI) was also sub-divided into six dimensions: *AC_economic, AC_education, AC_material, AC_social, AC_workforce,* and *AC_natural*, according to a categorisation of households' capacities adjusted from Adger et al. (2004). Each of these SI and ACI dimensions were composed by a set of variables (Level 4), which further reflect a specific aspect of each corresponding dimension.

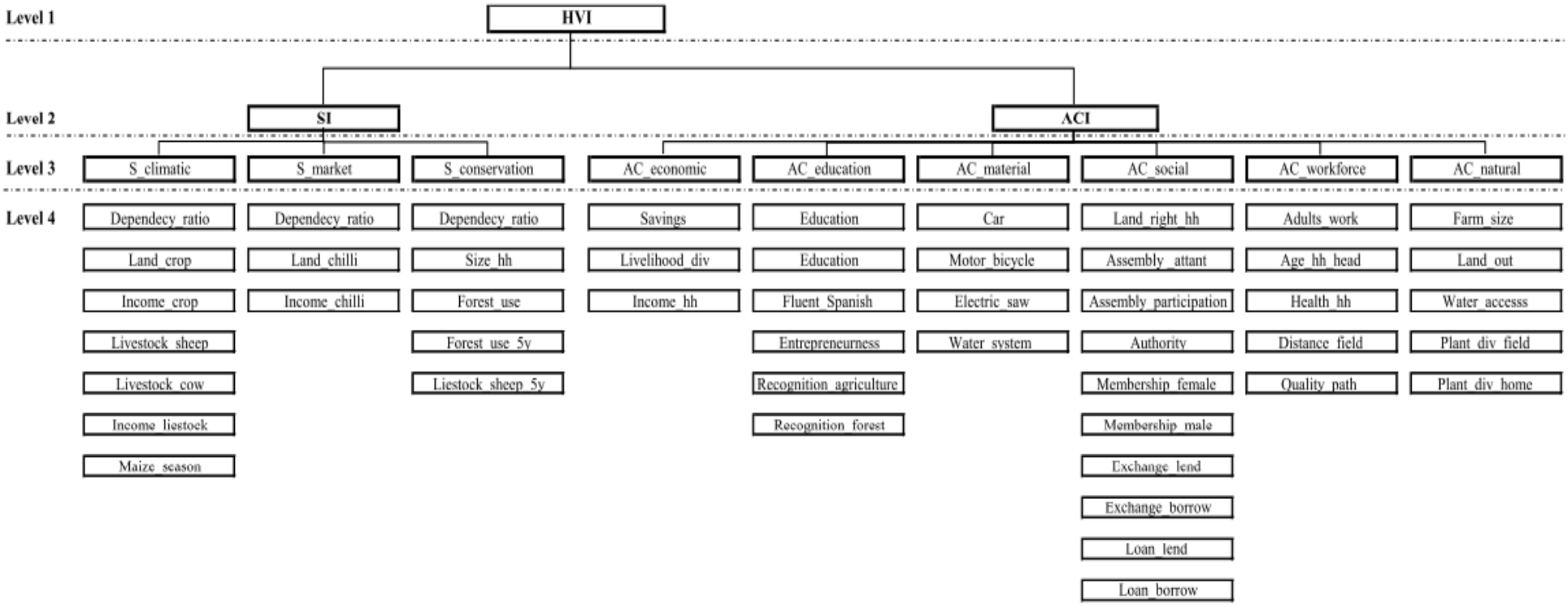

Figure 3.6: Hierarchical structure of Household-level Vulnerability Index (HVI)

In Step 3, I established the scale of analysis at household level. Vulnerability studies at household and community scale are often based on qualitative data to describe processes and conditions of such vulnerability (Pensuk and Shrestha 2007; Notenbaert et al. 2013), and only a few vulnerability studies assess multiple stresses though a vulnerability index (e.g. Eakin and Bojórquez-Tapia 2007).

In Step 4, I selected indicators for the HVI. This is a delicate step in the construction of any vulnerability index independent of its framework, model or selected scale. Indicators should be precise and accurate to reflect a particular idea or concept (Tate 2012). In this HVI, SI indicators were selected to reflect the close relationship between livelihood activities (Eakin and Bojórquez-Tapia 2008), and household composition (Notenbaert et al. 2013) to each of the identified stresses. In turn, to select ACI indicators, I referred to existing literature (Cutter et al. 2003; Adger et al. 2004; O'Brien et al. 2004; Vincent 2004; Eakin and Bojórquez-Tapia 2007; Hahn et al. 2009; Mountjoy et al. 2013; Notenbaert et al. 2013), adapting the identified indicators to the local context, when necessary. Appendix V, provides further details of indicators and correspondent variables included in HVI.

Subsequently, in Step 5, I normalised some variables when it was required to change the measurement unit or to develop an equation with two or more variables. Thus, I used Equation 1 in order to express them in a scale between 0 and 1.

Equation 1: normalisation of variables, when necessary

Normalised variable $(X_n) = (X_n - X_{min}) / (X_{max} - X_{min})$

In Step 6, I conducted a set of Pearson pairwise correlations to test for inter-correlations between variables in order to avoid double counting. This test showed low correlation between variables (values <0.6). That is why I determined that each variable was independent from the others and would independently contribute to the index.

In Step 7, I aggregated variables (Equation 2) and dimensions (Equation 3) to generate a value for each dimension and sub-index composing the HVI. Aggregations were simple arithmetic sums divided into the number of components in order to maintain a result on a scale between 0 and 1. The resulting sub-indices were then integrated using Equation 4.a. to generate the overall HVI scores, and Equation 4.b. to generate HVI scores for each

stress. The rationale to justify the format of these equations reflects that vulnerability has a direct relation to sensitivity and an inverse relation to adaptive capacity.

Equation 2: aggregation of variables (Level 4) to generate a dimension (Level 3)

$$Dimension\ (D) = (V_1 + V_2 + \ldots + V_n) / n$$

Equation 3: aggregation of dimensions (Level 3) to generate a sub-index (Level 2)

$$Sub\text{-}index\ (SI\ o\ ACI) = (D_1 + D_2 + \ldots + D_n) / n$$

Equation 4.a: function of sub-indices (Level 2) to generate HVI (Level 1)

$$HVI = SI / ACI$$

Equation 4.b: function of a specific Sensitivity Index (SI_stress) and the generic Adaptive Capacity Index (ACI) (Level 2) to generate a HVI_stress (Level 1)

$$HVI\_stress = SI\_stress / ACI$$

In addition to these seven steps, it is possible to assign, via expert-opinion or theoretically, a weight to each variable, dimension or sub-index. It is a critical decision in the index building process because weights reflect the importance of each variable, dimension or sub-index contributing to every index. Weights determine *de facto* the importance of variables or dimensions. However, I decided not to include weights in my analysis because it would have obstructed the identification of the hidden roots of households' vulnerability by giving an unequal priority to the studied variables. Subsequently, I examined which factors determined each sub-index (SI and ACI). The distribution of the SI, ACI, and their related dimensions were plotted using a box plot diagram (see Figures 5.1 and 5.2, in Chapter 5).

Later, I applied three non-parametric tests to independently identify SI and ACI variables that are significantly different across communities. Due to differences on available data, the SI analysis was carried out with 87 households, whereas the ACI analysis was carried out with 90 households. Nonetheless, this slight difference did not entail a problem due to the purpose and the independence of both analyses. Thus, I applied a Kruskal-Wallis test for continuous variables, and either a Chi-square test or Fisher's exact test for interval and dummy variables (Appendix VIII). Specifically, I ran a Fisher's exact test instead of a Chi-squared test when less than five individuals were represented in, at least, one of

four cells in a Chi-squared table generated, assuming a highly unequal distribution of data. The levels of significance accepted for these three non-parametric tests were 90% (*p<0.1), 95% (**p<0.05) and 99% (***p<0.01) of probabilities to reject the null hypothesis.

Additionally, I assessed the potential relationship between the SI of each selected stress (i.e. SI_conservation, SI_rainfall, and SI_chilli) by using a pairwise correlation (see Table 1, in Chapter 5). Also, I identified and grouped households with similar ACI patterns by using a Hierarchical Cluster Analysis (HCA), which allocated households into homogeneous groups according to their ACI (internal homogeneity). Before running the HCA, I had transformed five out of 32 variables included in the ACI (i.e. *Education, Assembly_participation, Quality_path, and Authority*) from interval to dummy variables. This transformation was required to balance their contribution in the computation of distance and to minimise error when measuring the variance of these variables. However, the analysis of these variables was undertaken with the more desegregated version of these variables.

I used the Ward method as an agglomerative technique and square Euclidean measure to determine the difference between households in relation to adaptive capacity variables. The Ward method is based on the analysis of variance instead of distances. The method compares the individual observations for each variable against the cluster mean for that variable (minimising the error from squares) and alternatively maximising the r^2 value (i.e. the proportion of variation explained by a particular clustering of the observations). The Ward method started out with *n* clusters of size 1 and continued until every observation was included into one cluster. The cluster analysis produced a dendrogram to illustrate the hierarchical agglomerative process and distances between clusters, and based on it I decided to divide the sample into four clusters (Figure 4 in Chapter 5). The four clusters generated were analysed to identify variables significantly different when applying the same non-parametric tests explained above (i.e. Kruskal-Wallis test, Chi-square test, and Fisher's exact test) (see Table 3, in Appendix III). Finally, radar graphs were used to illustrate different adaptive capacity profiles across communities and clusters (see Figures 5.3 and 5.5 in Chapter 5).

A correlation analysis undertaken was aimed at exploring the relationship between SI and ACI (N=86 households). I explored: 1) the existence of an overall pattern between SI and

ACI, 2) the association between SI and ACI in relation to the previously identified clusters, 3) the computation of overall HVI and each specific HVI (HVI_conservation, HVI_rainfall, and HVI_chilli), and 4) the classification of these latter measures according to three vulnerability ranks – low, medium and high vulnerability (see Appendix V). For further details on HVI data and analyses, see section 5.3, and Table 4 in Appendix VIII.

3.5 Dynamics, reflexivity and ethical considerations

This last section reflects on the initial reliance on the local organisation, CRIPX, to conduct my research, and my personal learning process during fieldwork, while reflecting on opportunities and challenges of my position as a female researcher. As mentioned earlier in this chapter, the COMBIOSERVE research project aimed to strengthen CRIPX research capabilities as a local grassroots organisation in Calakmul. Since my interaction with both communities was promoted and guided by CRIPX, my relationship with them was direct. However, I was unable to arrange regular meeting with them to exchange information and impressions of the communities, contrasting emergent findings and receiving feedback. The main role of CRIPX in relation to my research was then limited to support the execution of some research methods, being facilitators, workshop assistants, reviewing methods or providing logistical support.

During the first fieldwork period, I realised that the information that CRIPX had about *Sacrificio* and landless households in both communities was particularly limited. Moreover, I realised that the way we were communicating our activities in the communities facilitated the collaboration with the most empowered inhabitants only. In this case, landholders were mostly contacted and informed about the activities developed by COMBIOSERVE research team. Therefore, and though the initial COMBIOSERVE meeting was opened to everyone, internal social-political differentiation patterns limited the participation of landless, women, and young inhabitants (see section 4.1).

Following my personal research interest, I tried to include the voices of people socially and politically marginalised, principally landless households and women. Thus, the research strategy applied during the second period of fieldwork was designed and implemented to achieve the participation of the unpowered sectors of the population. I avoided organising more open-door workshops. Instead, I started to gain trust and build a close relationship with potential participants, giving them a personal invitation and

emphasising that other invited participants to this workshop were of similar status to them; e.g. if the workshop was orientated to landless inhabitants, only inhabitants without land rights were invited. This change was positively accepted by participants, achieving the participation of landless inhabitants and women.

In this learning process, living in both communities for long periods of time facilitated my access to some households more than others. In *Once,* I was living with two non-indigenous families. Since they spoke fluent Spanish it was easy for me to participate in the normal life of the family. By contrast, in *Sacrificio* I was living with a *Chol* family, where the female household head had a poor understanding of Spanish. Subsequently, everyday conversations were mainly conducted through children and the male household head. Moreover, in *Sacrificio,* it was more difficult to gain trust among household heads than in *Once* due to the low trust and social cohesion among inhabitants, and a general distrust of external organisations. People opened their door and spend a few minutes with me, but I felt these meetings were generally uncomfortable and tense. Hence, while in *Once* I gathered diverse information from a wide range of key informants, in *Sacrificio* information obtained from key informants was limited but highly relevant.

Finally, being a female researcher in this cultural context had both advantages and disadvantages. Being a young Spanish woman facilitated my access to local and regional organisation's representatives. Moreover, in the communities, being a woman allowed me to spend considerable time with female household heads and children, thus getting valuable information about domestic tasks, social networks, and silent conflicts regarding domestic and collective life. Although household heads opened their doors out of curiosity or personal interest, in general they associated my presence with CRIPX. To avoid this confusion, I explained to them the research objectives in accordance to the FPIC, but I also talked with them about my personal interests and circumstances. Moreover, and during the first fieldwork, being a female researcher made me feel somewhat vulnerable in *Sacrificio,* a community with a violent history resulting from several political and social circumstances - some of them unknown to me at that point. This influenced my research schedule during that period in this community, which was always adapted to CRIPX's availability for departure.

4 Land tenure, livelihood, and related stresses

This chapter discusses the land tenure regimes in *Once* and *Sacrificio*, household livelihoods and the locally perceived stresses. In doing so, it addresses research question one, "*How are land tenure regimes and livelihood patterns related to the locally perceived stresses in the two studied communities?"* Resulting knowledge of community livelihoods informs my understanding of local vulnerability patterns to multiple stresses (Chapter 5), and adaptive responses to those stresses in a conservation context (Chapter 6).

This chapter relies on quantitative and qualitative data collected by means of participatory observation, semi-structured interviews, focus groups, and household surveys (see section 3.4). The chapter is divided into four main sections. Section 4.1 discusses the influence of land tenure regimes and local conservation initiatives on local governance and social differentiation. Section 4.2 analyses livelihood patterns, identifying changes in the cultivation of marketable commodities across communities and socially differentiated household groups. Section 4.3 identifies the most relevant institutional, environmental and socio-economic stresses on local livelihoods. Finally, section 4.4 discusses the configuration of the local governance system and the livelihood patterns of both communities in a context of an open market economy and ongoing external efforts to conserve biodiversity.

4.1 Land tenure and governance in *Once* and *Sacrificio*

The two communities differ in terms of their underlying land tenure regime result of diverse environmental histories. *Once* is officially considered an *ejido*, while *Sacrificio* is a group of unofficial small properties. This distinction is not trivial, and has a remarkable impact on the local governance systems of both communities.

4.1.1 Environmental histories

The environmental histories of the communities located in the Calakmul region are influenced by their inhabitants' status as migrants (see section 3.1). Some communities are made up of migrants sharing an ethnic and geographical background, whereas other communities, such as *Once* and *Sacrificio,* are made up of migrants of various ethnicities

and from different locations in the country. In specific terms, *Once* was an abandoned rubber camp when the first permanent inhabitants arrived in 1981. They were part of the third migrant wave registered in Calakmul, and came predominantly from Veracruz, Michoacán, and Chiapas. *El Sacrificio*, by contrast, was founded in the early 1990s by a few families from Veracruz at the beginning of the fourth, and last, migrant wave in Calakmul.

These migrant families cleared forests to stake a property claim and to cultivate land. The official facilitation of land appropriation and tilling was foreclosed in 1989, with the establishment of the Calakmul Biosphere Reserve (CBR), but the inertia of colonisation policies nevertheless brought more migrants to this territory during the 1990s. Moreover, the fact that the CBR boundaries were based on pre-existing property title maps poorly contrasted with the new local situation since the colonisation process, resulted in various types of land tenure conflicts (García-Gil and Pat-Fernández 2000; Ruiz-Mallén et al. 2014a).

The communities, such as *Once*, that started their entitlement process before 1989, found that their territory was part of the less restrictive buffer zone. Conversely, several settlements formed during the 1990s were located inside the more restrictive CBR core areas, which put them at risk of relocation (Acopa and Boege 1999). Today, the inhabitants of *Once* and *Sacrificio* acknowledge the very limited information they received during those years as regards the CBR perimeter and its conservation regulations.

From 1988 onwards, the inhabitants of *Once* began their entitlement process, and obtained provisional recognition as an *ejido* in 1991. The community was officially recognised in 1994 and granted 4,177 hectares of forests, partially linked to the buffer zone. Fifty-five -mostly male - household heads were recognised as *ejidatarios*, i.e. individuals with full access and usufruct rights over a 50 hectare agricultural field, a household plot and the corresponding equal share of 2,012 hectares mapped as forest and pasture commons. Two collective areas were also specifically designated for the school plot and for an Environmental Management Unit for Women (UAIM in Spanish).

By the late 1980s, not far away from *Once*, a small number of families settled within the buffer zone creating the unofficial community of *El Sacrificio*. Moreover, new migrants arriving a few years later found that most of the accessible land had already been

appropriated and had thus to settle further away from the existing roads and move unknowingly into the CBR core areas.

By the end of the 1980s and early 1990s, the people from *Once* and *El Sacrificio* were living in conditions of acute poverty and social-political marginalisation, with limited access to roads and public services (CONAPO 1995). The state-driven protectionism policies that encouraged rural development in other states through peasants' productive associations and state concessions, had a limited impact on Calakmul's migrant settlers (see section 3.1.). Thus interviewees noted that, in those days, they focused on surviving by cultivating *milpa* and chilli as main cash crop. Public support was insufficient to develop efficient productive systems and to gain improved access to chilli market, which was - and still is - controlled by local intermediaries. The most intensive drought recorded since 1949 occurred in 1994, further exacerbating their adverse situation[13]. A local, community-based demonstration took place in 1995 in response to the insufficient support of the state's government, which did not guarantee water and food security. The government of the state of Campeche constituted the municipality of Calakmul in 1996 in order to bring public services closer to the communities and to better control future peasant uprisings.

This new political and institutional context also fuelled the operationalisation of the CBR, which covers more than half of the municipality. In 1997 the CBR administration recognised the existence of settlers living within both the CBR core areas and who were responsible of ongoing deforestation. The CBR and the SRA coerced the affected settlements to accept a resettlement (Ericson et al. 2001; CRIPX, Interview guide 3, #3).

Between 1997-1999, four of these settlements located inside core area I (i.e. *Las Delicias*, *22 de Abril*, *San Isidro–Aguas Amargas*, and *Aguas Turbias*) were requested to re-settle together with *El Sacrificio*. Since the re-settlement in 1999, this community has officially been known as *Santo Domingo-El Sacrificio* (referred to herein as *Sacrificio*). The CBR published its first Management Plan in the same year, which regulates the access and management of natural resources in both the core and buffer areas.

[13] Data from the meteorological station of Zoh Laguna belonging to the Water National Commission (CONAGUA in Spanish) (for further details see section 3.1)

The state of Campeche allowed the resettled families from *Sacrificio* to claim individual property rights, as collective land titling was forbidden by that time, following Mexico's 1992 counter-reforms[14] (see section 3.1). Ninety-nine individuals were then provisionally recognised as small property owners, and were granted approximately 20 hectares each for farming purposes and two household plots, i.e. a total of 1,980 hectares. Despite the fact that *Sacrificio* did not have any surplus land as "commons" due to the previous division in individual plots of all its provisionally granted land, its families decided to govern themselves through a collective assembly and hoped they would be soon recognised as an *ejido*.

Land distribution in *Sacrificio* was initially led by the leaders of each relocated settlement, which also led to some tensions over who controlled the mechanism for land acquisition and entitlement. This created low levels of trust and social cohesion between people from the various original settlements, and ultimately a weak system of governance characterised by low accountability. A wave of internal and external conflicts and violence occurred during the early years of *Sacrificio*. This situation forced local administrations to discontinue their support and, subsequently, *Sacrificio's* families were unable to effectively organise themselves to claim their official land rights. Finally, in 2006, they were informed that four agricultural fields again located inside the CBR core area I, due to an error in the resettlement process (SEDATU, Interview guide 3, #16). This again fuelled the conflict between local people and the state administration, leaving the land entitlement process in a standstill. During this dissertation I will therefore refer to individuals holding provisional small property titles as "landowners" because of this unresolved land entitlement.

The state's conservation agenda was later expanded through the promotion of the federal government's incentive-based tools for conservation, such as Payments for Ecosystem Services (PES), supported by CONAFOR since the 2003-2004. In 2008, *Once* included 1,436 hectares of agricultural and common lands under the programme, which caused some conflict with the *ejidatarios* who were working within the newly demarcated PES area. Each *ejidatario* received 10,000 Mexican pesos (MXN) annually for a period of five years for implementing this conservation initiative. This meant that PES payments became a significant source of the *ejidatarios'* income (see section 4.2). In 2012, this

[14] Mexico's 1992 Agrarian Law is the legal document that defines the land tenure regime associated with the *ejido* regulation in its third section (URL: http://www.diputados.gob.mx/LeyesBiblio/pdf/13.pdf)

community also enrolled 122 hectares in the federal government's programme for Environmental Compensation (EC), which was also promoted by CONAFOR. This three-year funded programme rewards *ejidatarios* for carrying out restoration tasks, such as cleaning the forests perimeter, reforesting, and monitoring activities. In 2013, *ejidatarios* once again enrolled on a PES programme located exclusively on communal forests and involving an additional 421 hectares.

In *Sacrificio*, similar conservation initiatives have not yet emerged given the lack of land titles and the resulting non-eligibility for funding from conservation programmes. Thus, the different land tenure status between *Once* and *Sacrificio* (i.e. official *ejido* tenure *versus* unofficial individual property rights) contributes significantly to establishing social-economic differences between these two communities. Nonetheless, most programmes and subsidies aimed at reducing the communities' Marginalisation Index[15] and other federal programmes to alleviate poverty have been granted regardless tenure rights (e.g. OPORTUNIDADES, or the country's Special Programme for Food Security, PESA in Spanish).

The environmental history of both communities has also been influenced by periodical environmental events. Interviewees identified hurricanes (1989, 1995, 1998, 2007 and 2007) more than extreme droughts (1994, 1999 and 2008), but the greatest impact on household food security and local economy was more associated with the latter (Ruiz-Mallén et al. 2015a). Indeed, the long and intensive drought of 1994 followed by Hurricane Roxana in 1995 was a critical period, remembered by every adult interviewed in *Once*. It is also a community susceptible to flooding due to its flat topography. However, most of the low-lying lands were assigned to common lands. By contrast, the sloping topography of *Sacrificio* reduces the impact of hurricanes and floods, and the surrounding large forest cover provides a buffer from drought damage.

Figure 4.1 below summarises the environmental histories of both *Once* and *Sacrificio*. Appendix VII and VIII present detailed information on each community's timeline.

[15] The Marginalisation Index assesses the scarcity of services to which Mexican communities are subject, and is published by the National Population Council (CONAPO in Spanish), which classifies both *Once* and *Sacrificio* as at a high level of marginalisation (CONAPO 2005, 2010)

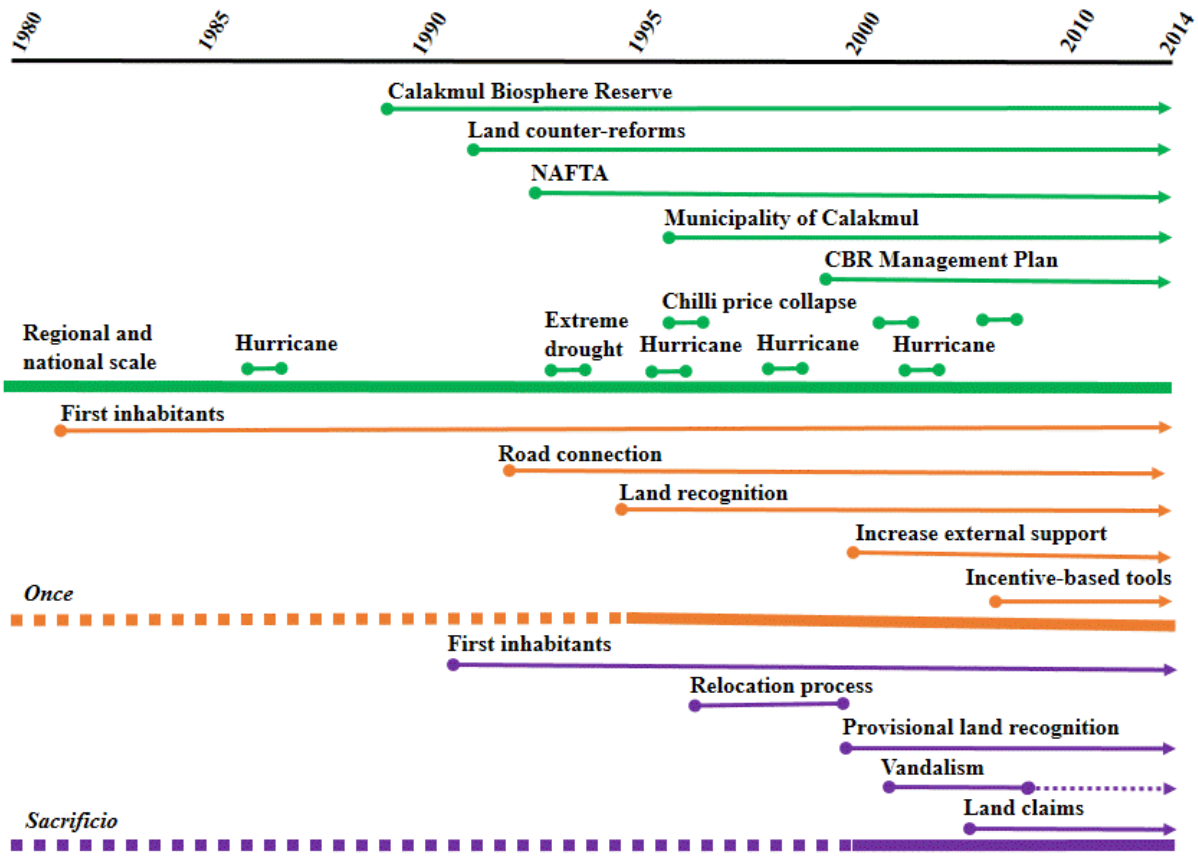

Figure 4.1: Timeline of Once and Sacrificio referencing to the main regional and national milestones

4.1.2 The local governance systems

Land regimes in Mexico are structured on several institutional levels, with the *ejido* (*Once*) or small properties (*Sacrificio*) being the lowest possible level. Mexico's 1992 counter-reforms cemented social differentiation across land tenure regimes and between community members. As I noted in the previous section, the status (i.e. official *versus* unofficial) and type (i.e. communal or individual) of land tenure rights is critical to understanding the history of the two case study communities and their resulting governance system. The co-existence of families with land tenure rights with those who do not have them is examined here in the light of how both *Once* and *Sacrificio* are governed politically and socially.

All *ejidos*, such as *Once*, share a governance structure defined by law. *Once* therefore has an *ejidal* assembly (*asamblea ejidal*), an *ejido* authority (*comisariado ejidal*), and a surveillance council (*consejo de vigilancia*). The *ejidal* assembly is composed of every

male and female *ejidatario*, and it meets once a month. This is the political forum where rules concerning access to and use of common resources are established, collective tasks within the *ejido's* lands are defined, and members and committee representatives are informed about social and productive policy programmes. Decisions are recorded in the assembly's minutes and regulations are written down in the *ejido's* internal "code of practice" (*Reglamento interno*). The *ejido* authority, which is made up of a president, a secretary, and a treasurer, leads the *ejidal* assembly. This authority is entitled to represent the *ejido* at formal meetings with representatives of the government and other organisations. Additionally, the surveillance council, composed by a president and two secretaries, oversees the authority's functioning. The *ejidal* assembly elects the representatives of these two governance authorities every three years.

In the case of small properties, such as *Sacrificio*, every "landowner" has the right to make decisions about his/her own titled or designated land, without prior consultation with any collective governance body. In *Sacrificio*, however, the original settlers established a governance system similar to an *ejido* to facilitate the management of the urban area, share costs (human and financial), and have access to external funding opportunities. They therefore follow the *ejido* model (i.e. a general assembly, main assembly authority, and a surveillance council), but the assembly does not debate issues related to the management of common lands – which do not exist – and its efforts today are still geared towards the property titling process. To date, *Sacrificio* has kept a poor record of assembly minutes and no formal 'code of practice' has been developed.

Each community has an additional representative authority, the municipal agent, who is paid by the municipality of Calakmul. This authority provides information about and manages programmes related to the urban area, mostly focused on improving housing conditions and collective infrastructure. He/she also manages internal social conflicts and claims regarding cohabitation within the urban area, and imposes sanctions according to the established municipal regulations. Theoretically, this authority should be elected in an open voting process regardless of land tenure rights.

The overall governance systems in the two communities have been significantly influenced by the co-existence of multi-cultural identities (see section 3.1). This social-cultural mosaic has limited the strength of social cohesion beyond kinship networks. As a result, both communities share a low level of social trust. In *Once*, and since the 2000s, several

organisations have engaged some inhabitants to work collectively, such as female household heads cultivating vegetables in community gardens. However, every collective experience has failed due to internal conflicts resulting from the lack of trust and poor functioning. These experiences have weakened the local governance system, which seems unable to strengthen its accountability among the members involved. In *Sacrificio,* the resettlement created more social conflicts over land appropriation and leadership. Households remained in a collective governance system but in fact they have been working individually on their granted lands since, and they only work together on those tasks agreed in the assembly. At present, and according my interviews, household members are not willing to work in groups, regardless of their location and gender.

The similarity in the governance system between the communities is mainly based on the assembly, despite their unequal land tenure regime. *Ejidatarios* and "landowners" control every decision-making process on issues affecting the communities, regardless of the weakness of the overall system. This situation is detrimental to the empowerment of the households who are landless but recognised by the assembly as residents, known as *pobladores*. In *Once*, 22 households (28%) do not hold formal land rights. But 29% of these landless households have a kinship relationship with at least one *ejidatario/a*, which makes access to land and forest resources easier for them. A higher percentage of households can be considered landless in *Sacrificio* (33.6%, 45 households). Here, kinship networks could be also spread, but the smaller size of the agricultural fields hinders land-sharing arrangements.

Pobladores in the two communities do not have voting rights in the internal assembly. In *Once*, it is a rule established in the above-mentioned "code of practice", which also gives them the opportunity to organise in a committee of landless inhabitants (*Junta de pobladores*) and to designate a representative to participate in the *ejidal* assembly. However, neither *ejidatarios* nor *pobladores* reported being aware of this possibility. In fact, *pobladores* are often unwilling to participate in –and even attend - the assembly because many *ejidatarios* do not welcome their participation. This situation seems to exacerbate the social differences between the empowered households and those that are not empowered. In *Sacrificio,* as noted earlier, no "code of practice" exists, landless and female household heads usually attend the assembly, but "landowners" retain control over decision-making processes due to holding exclusive voting rights.

There are some differences between the communities in terms of how the municipal agent is elected. In *Once*, the central power of the *ejidal* assembly has assumed the right to elect this representative, which means that this decision is also controlled by the *ejidatarios*, and excludes the *pobladores*. This practice contradicts the municipal regulation and its basic aim of caring of every community member's well-being without any distinction based on land ownership. Conversely, in *Sacrificio* the appointment has been more evenly shared between "landowners" and landless households.

Pobladores in the two communities have limited opportunities to become a member of the authorities, especially in *Once*. This is not a trivial matter, since the officials are crucial gatekeepers and knowledge brokers in the flow of information between the community and external agents. They are ultimately responsible for the transparent management of funds, and they play a critical role in ensuring that money is fairly spent according to assembly-based decisions. The community's authorities and representatives also benefit from the privilege of first-hand access to information, which gives them some knowledge-driven powers. In *Once*, *pobladores* have generally been excluded from political positions and marginalised in decision-making processes. By contrast, *pobladores* in *Sacricifio* have been active political agents widely recognised by "landowners". This situation explains the more limited feelings of disempowerment among *Sacrificio's* landless households in comparison to those in *Once*.

The overall distribution of benefits and costs between social groups also seems to be fundamentally determined by land tenure rights. Historically, every subsidy and programme offered by external organisations must first be presented to and discussed at the assembly. Information is then distributed and controlled by landholders, which is a focus of criticism from landless inhabitants, who say that they always receive benefits after the landholders. For instance, most of landless households in *Sacrificio* obtained no benefit from building domestic water tanks until 2012, when an NGO provided this infrastructure to every household without one. In *Once*, *pobladores* questioned the (un)fairness of agricultural subsidies, such as the Programme of Direct Support to Countryside (PROCAMPO in Spanish): even when they borrow *ejidatarios'* lands to cultivate maize, the subsidy flows into the hands of landholders.

When it comes to the PES and EC programmes implemented in *Once*, benefits and costs are also unequally distributed. Communal pasture and forest lands legally belong to the

ejidatarios as part of their communal rights but landless households had traditionally enjoyed access to firewood and wildlife hunting with few restrictions. However, *ejidatarios'* fear of losing the PES and ES programmes rewards triggered restrictions on access to and use of common lands by every member of the community, which has impacted most negatively the livelihoods of the landless. This issue is further explored focusing on the household sensitivity to conservation rules and enforcement (Chapter 5), and analysing the overall role of conservation initiatives in household agency and adaptation (Chapter 6).

Throughout this dissertation, I highlight the influence of social differentiation on households' vulnerability patterns based on land tenure rights (see section 5.2). In doing so, I pay specific attention to the mechanisms of control and distribution of assets, and the opportunities arising from the co-existence of households with and without land tenure rights, in which the two communities have some similarities and differences (see sections 6.2 and 6.3).

4.2 Livelihood activities in *Once* and *Sacrificio*

Households in the two communities engage in several on-farm and off-farm livelihoods (Table 4.1). Agriculture (for subsistence and/or commercial purposes), backyard animal rearing and wage labour are the most regular combination of livelihoods. In *Once*, livestock rearing is practiced by 48.7% of households, while in *Sacrificio* this is still a marginal activity (14.8% of households). In overall terms, off-farm activities are increasingly important, with more than 92.6% of households in *Sacrificio* involved in wage labour, and 64.1% of households in *Once*.

Taking into account on-farm and off-farm sales, plus the subsidies flowing into household income (Table 4.2), it is apparent that first, the average household income (from productive activities, subsidies and remittances) in *Sacrificio* is half of one in *Once*. Second, agriculture is the most valuable livelihood in terms of financial contribution in the two communities, followed by backyard animal rearing, and livestock rearing in *Once* and off-farm activities in *Sacrificio*. Third, subsidies are the second most important source of income in both communities, and the contribution of conservation rewards in *Once* is especially important.

Table 4.1: Summary of households engagement to each livelihood activity in Once and Sacrificio and its ranking position

		On-farm								Off-farm			
		Agriculture		Backyard animal		Livestock		Beekeeping		Wage		Small trade	
	N	%hh	Rank	%hh	Rank	%hh	Rank	%hh	Rank	%hh	Rank	%hh	Rank
Once	39	94.9	1	89.7	2	48.7	4	12.8	6	64.1	3	17.9	5
Sacrificio	54	94.4	1	92.6	2	14.8	5	5.6	6	92.6	3	24.1	4

Note: Activities are ranked from 1 to 6, being 1 the most frequently practiced by households and 6 the least practiced.

Table 4.2: Summary of annual average household income across livelihood activities reported by interviewees in Once and Sacrificio and their ranking position

		On-farm sales								Off-farm income				Subsidies[3]		Average household income
		Agriculture		Backyard animal		Livestock		Beekeeping		Wage labour[1]		Small trade[2]				
	N	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	MXN
Once	39	33.7	1	15.1	3	13.2	4	0.8	7	8.6	5	1.2	6	27.6	2	59,035
Sacrificio	54	37.0	1	5.1	5	2.5	6	0.7	7	17.9	3	5.9	4	30.9	2	27,807

[1] The category of Wage labour includes wages from public services within the community, such as educational and health assistance, as well as economic remittances from household members.

[2] The category of Small trade includes income from small small sale at community level communities, sales of handcraft, meal and vegetables.

[3] The category of Subsidies includes income provided by PROCAMPO (to cultivate maize), Procampito (to spend on specific agrochemical and farming material stores), OPORTUNIDADES (to female household heads to enhance child literacy), Brecha Cortafuegos (to clear the CBR perimeter), 70 y Más (economic and food subsidy to elderly), PROGAN (livestock production), and PES rewards.

4.2.1 On-farm livelihood activities

Agriculture in both communities is characterised by the cultivation of four main crops – maize, beans, *chihua* (a local squash) and chilli (Table 4.3). The traditional Maya swidden agricultural system is the *milpa* (i.e. a positive association between maize, *chihua* and beans), which provides the main source of food income in the region (Schmook et al. 2013). In *Once*, 48.7% of households practice *milpa* combining only maize and squash. In *Sacrificio*, 87.0% of households practice it, but only half of them combine the three traditional crops. Overall, six households (four in *Once* and two in *Sacrifcio*) reported to have given up *milpa* and to have started buying maize.

Table 4.3: Summary of agriculture practices in Once and Sacrificio

		Maize (*temporal*)		**Maize (*tornamil*)**		**Bean**		**Squash**		**Chilli**		**Total**
	N	**%hh**	**%MXN**	**%hh**	**%MXN**	**%hh**	**%MXN**	**%hh**	**%MXN**	**%hh**	**%MXN**	**MXN**
Once	39	82.1	8.5	84.6	12.4	46.2	^	59.0	28.9	64.1	50.1	775,250
Sacrificio	54	96.3	5.5	40.7	0.2	61.1	^	87.0	48.7	57.4	44.7	555,069

^ means marginal contribution to household income

No household has an irrigation system in place, but 71.8% of households in *Once* use tractors for preparing land, whereas only 5.6% of households in *Sacrificio* do this. This drastic difference is due to the households' limited investment capacity and the sloping topography in *Sacrificio*. Conversely, in the two communities, 85% of households reported using agrochemicals for chilli cultivation, and more recently for maize. Moreover, agricultural activities are eligible for federal and state subsidies, including the above mentioned PROCAMPO (i.e. a cash reward for cultivating maize) and the commonly known as Procampito (i.e. an economic voucher to purchase agricultural supplies). Interestingly, while PROCAMPO is tied to land rights, Procampito is not.

Between 2008-2013, *ejidatarios* in *Once* have increased the planting area of *tornamil* (i.e. maize cultivated in dry season) (43.5% of households) and *chihua* (30.4% of households), while they have reduced the planting area of *temporal* (i.e. maize cultivated in wet season) (39.1% of households). Similarly, "landowners" in *Sacrificio* have increased the planting area of *chihua* (26.5% of households) but only a few have

increased the planting area of *tornamil* due to the adverse topography and seasonal migration (29.4% of households). Furthermore, landless households in *Once* have increased the planting area of *chihua*, which is indicative of the progressive transition from chilli to *chihua* regardless of tenure rights. However, unlike *ejidatarios* and "landowners", landless households in both communities have increased the planting area of *temporal* instead of *tornamil* because their informal contracts to borrow land expire at the end of the year, which restricts their ability to grow *tornamil*. Moreover, crops cultivated during the dry season need to be planted in low-lying lands, while crops cultivated in the wet season should be located in high lands. To date, landless households have to borrow a small portion of land (between 0.5 to 2 hectares in most cases), preferring high lands in order to cultivate *temporal* and cash crops.

In both communities, agriculture is complemented by small-scale husbandry activities (Table 4.4). This is an important source of food and immediate cash in times of contingency. The high demand for maize and recurrent diseases impacting on turkey rearing significantly decreased this activity in both communities. Pig rearing is also a marginal activity in *Sacrificio* due to the high demand for feed involved. In *Once*, by contrast, pig rearing is a regular activity undertaken on a small scale, principally for subsistence purposes.

Table 4.4: Summary of backyard animal practices in Once and Sacrificio

		Chicken		Turkey		Pig		Total
	N	**%hh**	**% MXN**	**%hh**	**% MXN**	**%hh**	**%MXN**	**MXN**
Once	**39**	92.3	41.4	30.8	40.0	76.9	18.6	44,050
Sacrificio	**54**	92.6	70.2	35.2	25.5	13.0	4.3	38,800

Between 2008-2013, more than 25% of the *ejidatarios* in *Once* and "landowners" in *Sacrificio* have reduced the amount of reared chickens and turkeys, and they reported an overall decrease in sales. Conversely, landless households in both communities have increased the number of average chickens raised and reported higher sales due to the lack of alternatives to increase their household's income. In *Once* alone, pig rearing has increased by 22% among *ejidatarios* and 19% among landless households - a very

different trend to *Sacrificio*, where it has remained stable, and where only seven households reported rearing pigs during this period.

Livestock raising includes rearing sheep and cows (Table 4.5). Households in both communities have benefited from federal and municipal government programmes providing financial support for livestock rearing. Households therefore uses the cash revenue granted to begin sheep rearing, which is much cheaper than rearing cows.

Table 4.5: Summary of livestock practices in Once and Sacrificio

		Sheep rearing		Cow rearing		Total
	N	**%hh**	**%MXN**	**%hh**	**%MXN**	**MXN**
Once	39	30.8	24.0	41.0	76.0	303,000
Sacrificio	54	14.8	100.0	0.0	0.0	38,000

Between 2008-2013, 35.9% and 46.2% of households in *Once* have engaged in sheep and cow rearing, respectively. Conversely, in *Sacrificio*, only 16.7% of households have reared sheep, and nobody have engaged in cow rearing. Of these households, only one landless household in each community have reared sheep, and three landless households in *Once* have engaged in cow rearing.

Livestock rearing is limited in both communities by the small size and low carrying capacity of the grass pastures, combined with the high economic investment required for fencing and watering, the household's need to guarantee access to forest resources, and the family-based land sharing practices. These limitations are more acute in *Sacrificio* than in *Once* due to the smaller proportion of land available for grass pasture, the small size of the agricultural fields and the sloping topography. Moreover, *Sacrificio's* households have a limited household income, hindering investments in the infrastructures necessary for livestock rearing. Landless households are also faced with the lack of lands available for long-term borrowing, which makes them highly dependent on kinship networks. Nevertheless, livestock rearing are enabled by local commercial structures, and local producers are likely to join the local livestock association located in *Xpujil*. However, only five producers from *Once* currently belong to it, and the rest prefer to sell their production to intermediaries who go to the community and pay on the spot.

Beekeeping, a widespread activity in Calakmul where there were 51,000 producers in 2015 (SMMAS 2015), is nevertheless marginal in both communities. In *Once*, there are five beekeepers selling honey as a complementary income source. Four of them are *ejidatarios* and only one is a landless farmer. In *Sacrificio*, almost no "landowner" or landless farmer had tried beekeeping activities until 2012. At present, a group of ten female household heads in *Sacrificio* has started a three-year beekeeping project that was co-funded by CDI and the municipality government. However, internal conflicts and small harvests have ended in the leave of a half of the members.

Beekeeping is an activity unknown to most households, who do not have the proper knowledge, or the equipment for this activity. Moreover, most chilli producers acknowledged the incompatibility of beekeeping and chilli cultivation, due to the use of agrochemicals for the latter. This partially explains the small number of beekeepers in both communities, which are traditionally chilli producers. Also, the lack of land rights constrains the opportunities for landless households to engage in beekeeping. Two local associations of beekeepers provide a better access to markets than the intermediaries. However, only three beekeepers holding land rights producing high honey harvest in *Once* belong to them.

4.2.2 Off-farm livelihood activities

Wage labour is the most important off-farm activity in the two communities (Table 4.6). In this category, I included every activity with an associated payment, such as working on local farm activities (approx.100 MXN/day), on larger commercial farms (approx. 100-200 MXN/day), in non-farm jobs in nearby cities or abroad, including remittances from household members who had migrated to the USA. I also included other means of income, such as health and teaching assistance services, earned within the communities and paid monthly by the municipality.

Table 4.6: Summary of wage labour practices in Once and Sacrificio

		Within the community	Surrounding communities	Nearby cities	USA	Total
	N	**%hh**	**%hh**	**%hh**	**%hh**	**MXN**
Once	39	66.7	12.8	7.7	5.1	39,600
Sacrificio	54	75.9	70.4	64.8	5.6	40,500

Landless households from both communities rely on wage labour to complement their scarce farm income. There is an internal demand for workers at harvest times and for livestock management. In *Once*, landless inhabitants do most of the wage work offered by *ejidatarios*. By contrast, the internal labour demand in *Sacrificio* is limited because the "landowners" cultivate smaller plots compared to those in *Once,* livelihood rearing activities can be carried out by the household members, and household incomes are too limited to pay for additional workers. Hence, in *Sacrificio* more than 60% of "landowners" and 70% of landless households reported regularly working for landowners in other communities and seasonally for regional sugarcane farm enterprises located in the neighbouring state of Quintana Roo, from late November to late April. Currently, only two *ejidatarios* in *Once* and three "landowners" in *Sacrificio* reported having a member of the household working in the USA. The interviewees generally reported that only a small proportion of landless households intend to migrate abroad, given the large amount of money required (approx. 50 thousand MXN, according to interviewees in 2014).

Small trade as a source of income is insignificant in the studied communities. Some female household heads report handcrafting (6.5%), while others prepare meals and vegetables for sale (11.8%), and some others have a small shop in the community (9.7%). Over the last five years, the number of households engaged in these activities has remained steady. Only handicraft making appears to have increased in three households out of seven in *Once*. In overall terms, the differences are more acute between landowners and landless households than across communities, and households with land rights are more widely engaged in small trade than landless households. These activities partially satisfy households' needs, but they are not very widespread due to limited commercial entrepreneurship, particularly among indigenous women, and the limited transport to neighbouring communities that could facilitate the trade in handicrafts and agricultural products.

In short, households in both communities are developing a mosaic of livelihoods for subsistence and commercial purposes (Table 4.7). Approximately 50% of households – regardless of their tenure rights - are involved in at least three activities to earn a living. Nonetheless, *ejidatarios* in *Once* and "landowners" in *Sacrificio* have a larger percentage of households involved in four or more activities. This higher degree of diversification reflects the low profitability of local livelihoods, which forces farmers to engage in as many activities as possible to access more sources of income, subsidies, and market

opportunities. By contrast, landless households are less diversified since they have limited access to land and to subsidies, and thus ultimately constraints their opportunities for developing long-term and high investment livelihoods.

Table 4.7: Summary of wage labour practices in Once and Sacrificio

# Livelihood activities	*Once*						*Sacrificio*						Overall (N=93)	
	Ejidatarios (N=23)		Landless (N=16)		Total (N=39)		"Landowners" (N=34)		Landless (N=20)		Total (N=54)			
	%	#	%	#	%	#	%	#	%	#	%	#	%	#
<3	9	2	19	3	13	5	3	1	30	6	13	7	13	12
3	52	12	56	9	54	21	47	16	55	11	50	27	49	46
>3	39	9	25	4	33	13	50	15	15	3	33	18	36	26

In overall terms, these results show that most households are keener on diversifying their livelihood portfolio rather than intensifying one activity. For example, most households raising livestock in *Sacrificio* have not given up wage labour activities. In *Once,* this proportion of households is smaller, but nine of 19 households still combine livestock rearing and wage labour. The diversification is even more evident among beekeepers, who are engaged in more than three activities, combining beekeeping with at least one of either livestock rearing, wage labour, or small trade activities. Similarly, 18 of 20 households involved in petty trade are engaged in at least four activities. Each of these activities can therefore be considered a complementary market-based livelihood.

4.3 Locally perceived stresses

Characterising rural livelihoods is an entry point for exploring the relationship between livelihoods and households' exposure and sensitivity to global change stresses (Adger 1999, Luers et al. 2003). In both communities, the most harmful perceived stress was the uncertainty about chilli prices, followed by rainfall variability and conservation regulations (i.e. through this thesis also referred as market, climatic and conservation stresses) (Table 4.8). In *Once,* interviewees perceived the uncertainty about chilli price and the rainfall variability as equally harmful, followed by the conservation regulations.

In *Sacrificio,* interviewees felt highly vulnerable to changing chilli prices, followed by conservation regulations and then rainfall variability. The following subsections describe the diversity of the interviewees' perceptions and the impacts of each stress on households' livelihoods.

Table 4.8: Pebble distribution to evaluate the perceived vulnerability to multiple stresses

	# Pebbles	Stress		
		Market (%)	Climatic (%)	Conservation (%)
Once	1320	38.9	38.9	22.2
Sacrificio	1258	44.6	22.6	32.8
Total	2578	41.7	30.9	27.4

4.3.1 Market stress: uncertainty about chilli prices

According to the federal government database SIAP[16] (2014), Mexico is the world's leading exporter of green chilli, with the USA being the main importer. Mexican production[17] is dominated by the countries' northern states, including Chihuahua, Sinaloa and Zacatecas, which were responsible for 62% of the total national volume of green chilli production in 2012. Chilli production in these states is irrigated and highly technified, generating yields of over 40 tonnes per hectare (t/ha). In the state of Campeche, and in the studied communities, chilli production is far from the marketing centres and it is neither irrigated nor technified. Consequently, local chilli producers of Campeche reported average yields of 4.8 t/ha. Moreover, the resulting chilli production does not meet international market standards, and local production is classified as a second-rate quality product, which lowers the farm gate price (SEDICO, Interview guide 3, #20).

[16] Agricultural and Fisheries Informational Services (SIAP in Spanish) belonging to SAGARPA

[17] Data refer to green chilli, because national and international databases do not distinguish between the species of chilli.

The average farm gate price in Campeche is 2.7 MXN/Kg from 1993 to 2012 (Figure 4.2) (SIAP 2014). The figures show that the price of chilli was highly volatile between 1996 and 2006, while the price has remained more stable but low over the last ten years.

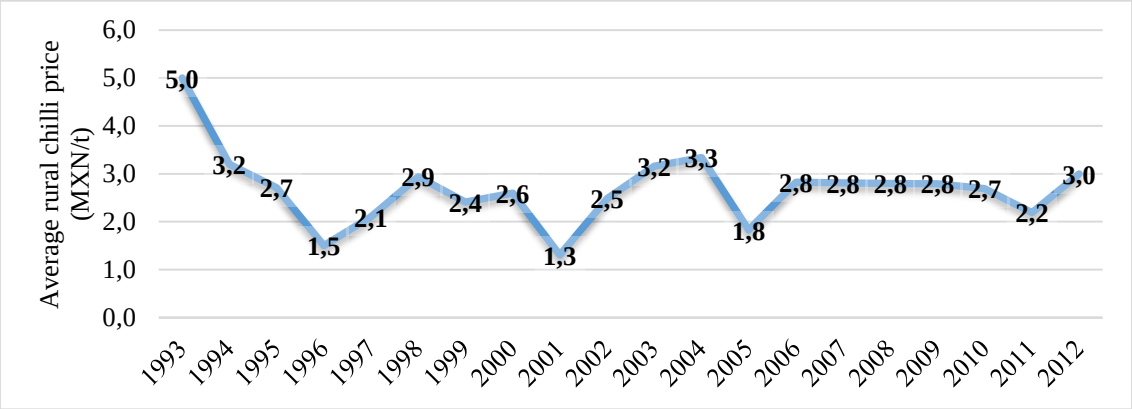

Figure 4.2: Average rural price for chilli producers in Campeche

Note: Source from SIAP, December/2014.

These records of annual prices, however, hide the weekly price adjustment by intermediaries who purchase the harvest directly from the farmers. As interviewees noted, it is very common to find at least two *coyotes* negotiating purchases with them – in terms of quantity and price - before the harvest, which leads to internal disputes about when it is best to sell and to whom. The price during the negotiation with intermediaries can rise or fall by a minimum of 0.10 and a maximum of 0.5 MXN/Kg in the space of a week. Intermediaries establish the price of chilli before the harvest and once the harvest is collected in *arpias* (i.e. bags where chilli is collected), farmers are obliged to sell at the previously agreed price. Intermediaries are thus identified by interviewees as the parties responsible for disadvantageous trading conditions.

In the words of one farmer, "*the price ruins the people, it is not profitable, coyotes take everything*" (Pebble method, *Once*, 11071). Another farmer highlighted the critical importance of this crop for his household income, "*if it (the chilli harvest) is sold, clothes, shoes or whatever (we) need is bought"* (Pebble method, *Once*, 11270). A minimal change in the balance between costs and profits in the chilli harvest alters the local economy to the extent that many farmers said that they sought wage labour outside the community only when this balance is negative.

The uncertainty regarding the farm gate price of chilli influences farmers' decisions about the planting area of chilli, and it has cost implications (Table 4.9). While the price of chilli, and therefore the profit from it, is tied to intermediaries and international market prices, farmers can only make decisions about their production costs. Bearing in mind that the average yield in both communities is around 3.6 t/ha (i.e. an equivalent to 144 *arpias* of 25Kg), the average economic income of chilli producers is estimated at 11,880 MXN (the estimated price of chilli was 3.3 MXN/Kg in 2012/13). Hence, the marginal economic surplus from the cost-benefit balance is a third or a half of the income generated, and only the costs of hiring the workforce is subtracted. Overall, this explains why the farm gate price of chilli is crucial to the crop's profitability, and why some households in both communities have recently abandoned chilli cultivation.

Table 4.9: Summary of costs borne by chilli producers in the studied communities

Costs	**MXN/ha**	**Observations**
Land rent	500 – 1000	
Tractor	700 – 1200	
Seeds	150 – 400	A kilogram for hectare
Agrochemicals	80 – 400	A bottle for hectare
Hiring workforce for:	Transportation: 450 – 600	150 MXN/trip, 40-60 *arpias*/trip
	Closing *arpias*: 1440	10 MXN/*arpia*
	Harvesting chilli: 2.300 – 3600	16 – 25 MXN/*arpia*

The interviewees in both communities argued that the increasing presence of pests affecting chilli plants, mostly unknown to them, was discouraging some from continuing to cultivate the crop. Similarly, they were also concerned about the potential impact of recurring hurricanes and floods on the chilli harvest running from September to November, an increasing rainfall variability that I analyse below.

4.3.2 Climatic stress: rainfall variability

Agriculture is the primary source of both food and cash income in the studied communities (see section 4.2). Lack of access to water for irrigation and the people's inability to invest significantly in their production systems constrains further agricultural development. "*Next year, who knows*" (Pebble method, *Once*, 11310) is a common saying

among local farmers, who always stress their dependence on rainfall in order to obtain a sufficient harvest and be food secure. Figure 4.3 shows how mean precipitation levels have changed in recent decades, suggesting an overall decrease in the mean accumulated precipitation, which is especially significant during the wet season. Moreover, data suggest that the rainy season is arriving earlier (in April rather than May), while there is a slight rise in precipitations in December, which *de facto* contributes to extending the wet season.

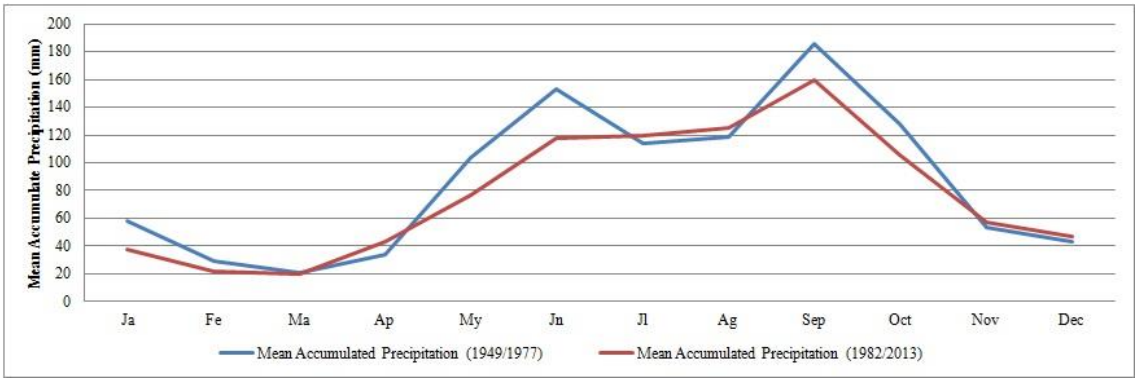

Figure 4.3: Mean annual accumulated rainfall in Calakmul

Note: Source from CONAGUA, Zoh Laguna meteorological station

Most migrant families located in these communities, and especially in *Once*, moved around before arriving at their final community settlement. They learnt how and when they should cultivate from inhabitants in surrounding communities. This direct learning process among local farmers was critical in achieving food security for these households, who did not previously cultivate *milpa* in this tropical climate (see section 3.1). Thus, changes in rainfall patterns have influenced the agricultural calendar in both communities.

As in other communities in Calakmul, local people carry out two agricultural cycles of preparing, cultivating and harvesting maize (Table 4.10). The first and main cultivation cycle starts in March-April, when land is ploughed to lay *temporal*, beans, *chihua* and chilli plant seeds. The reported slight shift forward of the wet season from May to April has undermined farmers' decisions about when *chihua* seeds should be planted. The second cultivation cycle starts with the dry season in November, when farmers lay the fields for cultivating *tornamil*, with a different maize seed with a shorter cycle than the seeds normally used for *temporal*. In this cycle, rainfall episodes have gradually become more prolonged, which interferes with the preparation of land and cultivation of *tornamil*. The situation has become particularly critical in *Once*, where cultivation of maize during

this season is widespread. In 2013, for example, when precipitations ended by mid-December, interviewees from *Once* reported losses of planted maize seeds due to very high soil humidity conditions.

The interviewees' main concern as regards rainfall variability is therefore the potential damage to the maize harvest. One farmer, for example, noted that "*last year was not rainy, so we had a very poor maize harvest. The changing weather is altering cultivation patterns. Sometimes maize is profitable, other times not, but it still provides enough to cover subsistence needs*" (Pebble method, *Sacrificio*, 12211). As mentioned before, interviewees are also worried about the loss of the chilli harvest due to droughts and hurricanes, as well as the resultant loss of their economic investment in chilli cultivation. The early onset of the wet season when chilli needs to be planted is converging with the end of people's late seasonal migration in *Sacrificio*. Male household heads must therefore decide between ending their wage labour season earlier, or paying someone to prepare their land for *milpa* or for chilli cultivation.

Table 4.10: Agricultural calendar

Farm tasks	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Land preparation												
***Temporal* (maize)**					**C**	**C**				**H**	**H**	**H**
***Tornamil* (maize)**		**H**	**H**	**H**							**C**	
Beans	**H**	**H**	**H**			**C**				**H C**	**H C**	**H**
Chihua				**C**	**C**			**H**	**H**			
Chilli						**C**			**H**	**H**	**H**	
Beekeeping (harvest)												

Note: C = cultivation; H = harvest (source: Interviews guide 2, complementary material)

However, many inhabitants in the two communities have assumed and accept the impacts of rainfall variability on their agricultural activities. Many interviewees suggested that meteorological variability is a natural and chronic phenomenon, since rain "*happens a little every year"* (Pebble methods, *Once*, 11280) or it is part of a grand religious plan.

Illustratively, one farmer said: "*what can we say? Ultimately God sends the rain; we cannot complain to anyone"* (Pebble method, *Sacrificio*, 12020). This kind of belief also explains why some farmers do not find it necessary to anticipate the risks associated with changing weather conditions.

4.3.3 Conservation stress: conservation regulations

Forest resources are a key source of domestic goods and services in *Once* and *Sacrificio*. Households use firewood for everyday meal preparation, and timber for fencing land plots where cattle roam or for building houses. Forest resources also contribute to food security when farmers engage in hunting and gathering, and to healthcare when they collect wild plants for medicines. *Once* and *Sacrificio* are not different in this regard, and access to these resources is critically mediated by the existence of the CBR. As noted earlier in section 4.1, *Once* is partially located in the CBR buffer zone, which establishes some slight restrictions on the use of natural resources. This community also enrolled in two other conservation initiatives – PES and EC programmes – that also impact their forest management since the late 2000s. Conversely, *Sacrificio* is mainly part of the CBR buffer zone, and a few agricultural fields are located inside the CBR core area I, where access to and use of resources is heavily restricted. In both *Once* and *Sacrificio*, conservation regulations (i.e. the set of rules restricting the access to and use of natural resources and its enforcement) are perceived as a concern to livelihoods on the basis of five main arguments. The first three are shared by the two communities, while the other two are held distinctively by interviewees in *Once* and *Sacrificio*, respectively.

First, people see their access to and use of natural resources as being limited by these conservation initiatives, without distinguish between the CBR and the incentive-based conservation tools in place. A commonly heard argument by the farmers is: *"They do not allow us to collect firewood, and they don't want us to hunt either"* (Pebble methods, *Once*, 11051). Household heads believe that conservation regulations undermine food security and interfere in domestic activities (e.g. storage of firewood for cooking). Since the CBR core area I is far from the urban area of both communities, households do not actually extract timber or firewood there, but several interviewees acknowledge that hunting and gathering of *chicozapote* resin (rubber) (*Manilkara zapota*) and *palo santo* timber (*Bursera graveolens*) take place inside this.

Second, interviewees in both communities stressed that the CBR regulations also impact upon farming practices. The CBR aims to reduce logging and resource extraction in old forests, exerting pressure on households to avoid expanding their agricultural practices by limiting permits for slash-and-burn procedures to open new agricultural fields. According to the interviewees, the only alternative to increasing agricultural productivity while conserving the forests would be to intensify agricultural management, e.g. by through mechanisation and increased fertilization, which increases the on-farm costs.

Third, interviewees also complained that the existence of the CBR has led to an increase in the population of jaguars (*Panthera onca*) and other wild animals, which often damage local crops, particularly maize and *chihua*, as well as livestock. *"We cannot hunt a dear or a wild pig. If we kill a tiger, we go to prison"* (Pebble methods, *Sacrificio*, 12381), argued an interviewed farmer with some resentment. The interviewees are aware that these wild species are protected, and that they can be severely punished for killing them.

Fourth, in *Once*, the landless members interviewed also considered PES and EC programmes as a key source of damage. They emphasise the loss of the customary access to communal forest for subsistence practices, while they are not gaining any benefit from these incentive-based conservation mechanisms. These conservation payments are made exclusively to *ejidatarios*. *"Nothing for pobladores"* is a regular complaint among landless households.

Fifth, and last, in *Sacrificio* the ongoing conflict with the CBR resulting from overlapping tenure claims prevents households from applying to several federal programmes (see section 4.1). Additionally, many interviewees bitterly remembered how the CBR had broken the re-settlement agreement by failing to grant them with formal property titles. According to one farmer, "*the CBR did not keep its word. They know how peasants work, (…), here they say that we cannot work. They do not pay us. They do not help us. The CBR said that it will support us with a house"* (Pebble methods, *Sacrificio*, 12161).

4.4 Discussion

This discussion turns now to address the first research question, "*How are land tenure regimes and livelihood patterns related to the locally perceived stresses in the two studied communities?*" This chapter has identified local stresses as deeply subjective processes and ideas rooted in people's perceptions (O'Brien and Wolf 2010), which are framed and

re-framed by social-ecological changes. Thus, my findings show, first, the influence of Mexico's land counter-reforms and the support for conservation initiatives modifying the local environmental governance system, which have impacted on livelihood patterns and exacerbated social differentiation. Second, my findings also suggest that poor rural households feel more vulnerable to market stress due to their high economic dependence for subsistence, undermining their vulnerability to rainfall variability or conservation regulations. This chapter specifically contributes social vulnerability and adaptation studied by understanding conservation initiatives as drivers of damage (i.e. stresses) impacting on people's vulnerability (see Chapter 5), and to which households and collectives develop adaptive responses (see Chapter 6).

4.4.1 Land counter-reforms and the social hierarchies

Mexico's 1992 land counter-reforms have had significant effects on rural governance systems because they implied the end of both the government-driven colonisation policies (Ericson et al. 2001), and the distribution of land (Appendini 2008). The counter-reforms aimed at titling of intra-community family-managed plots allowed land title markets – which already existed informally - to expand, which in turn put landless communities and households in an even more disadvantaged position (e.g. Navarro-Olmedo et al. 2015). Thus, *Sacrificio* could no longer aspire to receive a collective land title, and landless people in both communities were forced to purchase land at market prices within or outside their communities - a costly option given farmers' limited economic investment capacity (see section 5.2).

The research findings also suggest that the counter-reforms have contributed to deepening existing hierarchies in access to land tenure rights (e.g. Navarro-Olmedo et al. 2015), which ultimately have exacerbated the vulnerability of the most marginalised households. In *ejidos* such as *Once*, the system of common land tenure rights guaranteed that *ejidatarios* would have control of the internal governance system because granting land to landless members has yet to be approved by the assembly. Today, strict limitations on acquiring land tenure rights enable *ejidatarios* to further control the internal governance system by excluding landless inhabitants from decision-making at the assembly level. This means that the commons have in fact become an exclusive "property" domain of a specific group within the community (Ellis 1999). *Ejidatarios* use their land tenure rights to maintain power and distribute benefits in the community (Ribot and Peluso 2003).

However, increasing demographic pressure from landless households and potential long-term conflicts challenges this empowered position. In *Sacrificio*, hierarchies in access to land tenure rights seem to be less prominent due to the similar levels of vulnerability among households, since land titles have not yet been formally recognised by the state.

In this regard, most related research in Mexico has focused on the influence of land counter-reforms on the transformation of the agrarian commons into private property regimes (Haenn 2004), on the social-cultural changes that counter-reforms might induce among rights holders (Renteria and Delgado-Serrano 2012), or on the potential alienation of land by third parties, including by conservation initiatives (Fairhead et al. 2012). However, the effects of these counter-reforms on procedural and distributive mechanisms of the local governance system, highlighted in my case study, have been often overlooked. An exception is Navarro-Olmedo et al. (2015), who examined the transition from social to market concepts of membership in *ejidos* affected by the counter-reforms, and found similar results to this research as regards the reinforcement of internal hierarchies.

4.4.2 The interplay of conservation initiatives in the local governance system

In parallel to this socio-economic and political transformation in Mexico and other developing countries, international and national agendas have increased their support for biodiversity conservation initiatives (Borras et al. 2012; Fairhead et al. 2012). Conservation regulations thus have contributed to limit local people's access to natural resources, which has constrained livelihood opportunities (Himley et al. 2009; Borras et al. 2012; Fairhead et al. 2012). My findings in this regard suggest that conservation regulations from the CBR are identified as an important stress for household livelihoods. Interviewees complained that they were not consulted about conservation regulations, and they mentioned their limited power to make CBR regulations more flexible and well-suited to local needs. This suggests that local people feel vulnerable to conservation regulations because there is no institutional body able and willing to promote a participatory process which is sufficiently inclusive and flexible to guarantee the legitimacy of existing conservation regulations in both communities (e.g. Merino-Perez 2013). Although previous research has documented a positive endorsement of CBR's regulations and processes by some Calakmul communities (Haenn 1999), this is clearly not the case in *Once* and *Sacrificio*. Historical processes such as increased access to technology, which allows agricultural and livestock practices to be intensified, and the

lack of cohesion to successfully address collective natural resources management plans may be factors constraining the endorsement of the CBR's regulations in the studied communities. Thus, CBR seems to develop a limited influence promoting the development of sustainable livelihoods in an "inclusive" participatory model, despite its founding principles (INE 1999) – this issue is further explored in relation to local adaptive responses and human agency in Chapter 6.

My study also provides evidence for the socio-economic and political implications derived from incentive-based conservation initiatives (i.e. PES and EC programmes in this research). The research findings from *Once* illustrate the enhancement of *ejidatarios'* economic capacity as a result of conservation payments. However, since participation in such initiatives and the distribution of their ensuing payments are tied to land tenure rights, landless households have yet to benefit from them (e.g. Corbera et al. 2007; Fairhead et al. 2012). Consequently, the unequal distribution of conservation benefits has fuelled internal tensions between rights holders and landless inhabitants. Thus incentive-based initiatives need of social and political mechanisms based on distributional and procedural justice to deal with the disparities between households and to increase the legitimacy of conservation policies (Lemos and Agrawal 2006).

4.4.3 Market and climatic pressures over rural livelihoods

Together with the land counter-reforms and the conservation promotion, market pressures have proliferated in Mexico and worldwide since the mid-1980s, impacting rural livelihoods (McMichael 1997; O'Brien and Leichenko 2000; Borras et al. 2012) together with climate change processes. Reported evidence show how individuals and societies deal with the market and climatic stresses through livelihood diversification (Ellis 1999; Agrawal 2010), market specialisation (Eakin 2005), and even migration (López-Carr et al. 2012; Warner and Afifi 2014). My case study is an example of how rural communities' lack of power in terms of negotiating market costs and benefits triggers the diversification of livelihoods (e.g. livestock, beekeeping and even conservation initiatives), and is very often promoted and facilitated by external agents. Interviewees reported moving in-between a subsistence *and* market-oriented livelihood portfolio as a strategy, which has also been documented elsewhere in Calakmul (Schmook et al. 2013), in other Mexican states (Eakin 2005) and around the world (Meyfroit et al. 2014).

Additionally, the fact that local communities are completely unable to negotiate or control farm gate prices is a key factor for identifying the uncertainty about chilli prices as a key stress to their livelihoods. The limited external support for improving production and commercial of chilli in Calakmul is closely related to increase of deforestation rates since the late 1970s, when chilli cultivation was quickly expanded (Klepeis and Turner II 2001; Keys and Chowdhury 2006; Schmook et al. 2013).

My research also demonstrates the importance of the *milpa* system to farmers' food security and cultural identity, which has been shown to increase the social resilience of farm systems (e.g. Dwiartma and Rosin 2014). Thus the persistence of subsistence agriculture in the *milpa* system is nonetheless suggestive of a lack of confidence in chilli and other cash crop markets (e.g. Schmook et al. 2013). This is why farmers vigorously assert their unwillingness to completely substitute this swidden agricultural system with intensive cash crop cultivation (Ruiz-Mallén et al. 2015b). However, my findings reveal a decline in the amount of land dedicated to *milpa* at the expense of more intense maize cultivation, in the more market-oriented community of *Once.*

The analysis of local governance, livelihoods and locally perceived stresses sheds new lights on two questions further addressed in this dissertation. First, there is a need to refine our understanding about how and why social differentiation patterns influence households' sensitivity and their adaptive capacity to the three locally-identified stresses (see Chapter 5). Second, it is critical to understand the role of biodiversity conservation initiatives on vulnerability patterns and adaptive processes across communities and socially differentiated households (see Chapter 6).

4.5 Summary

This chapter has outlined the influence of Mexican land counter-reforms and the promotion of conservation initiatives impacting on rural environmental governance and livelihood systems, which ultimately determines which are the locally perceived stresses to the local livelihoods. The analysis of the environmental histories has revealed that, from a community standpoint, the main socio-economic and political differences come from both the creation of the CBR in 1989 and the end of both the land distribution and the abolishment of *ejido* tenure rights in 1992. While *Once* is an officially recognised *ejido*, *Sacrificio* is still not legally recognised as a small private properties after an

unsuccessful resettlement process that aimed at relocating them outside of the CBR core area I. This differences in the land tenure regime and status between the studied communities explain the overall advantage situation of households living in *Once* in comparison to those in *Sacrificio*, who are excluded from most of the federal programmes, e.g. PROCAMPO and PES programme.

From a household standpoint, the land counter-reforms have triggered the cementation of the social hierarchies between those members who have tenure rights, and those who have not within communities. At present, landless members can gain access to tenure rights through the local market of land titles, or borrowing and renting a small piece of land. Specifically in *Once*, internal hierarchies have further exacerbated by the implementation of incentive-based conservation tools (i.e. PES and EC programmes), which tied their participation to land tenure rights. Thus, conservation payments are controlled by *ejidatarios*, and *pobladores* claim for the unequal distribution of costs and benefits.

The chapter has also showed the influence of the social-ecological context in the portfolio of rural livelihood activities, and the differences between communities. My findings reveals that despite of being agriculture practices the first source of income among households, subsidies are the second one, highlighting the relevant influence of external support for these rural households. Moreover, the current low profitability of chilli production seems to be related to the persistence of the *milpa* system that guarantee the subsistence production. My research findings further suggest that, at present, the limited support for improving access to market and commercialisation of marketable commodities (e.g. timber, chilli, handcraft, etc.) have triggered the diversification of household livelihoods as a way to complement the limited household income.

This chapter has finally argued that in this socio-economic, political and ecological context households perceived a variety of market, climatic and institutional stresses over their livelihoods. Thus, they recognised the uncertainty about chilli prices as the most harmful stress to their well-being due to their still high economic dependence from this local cash crop. Rainfall variability is also recognised as a stress for agriculture and livestock activities because no irrigation systems or water capitation system are not widely spread, thus ultimately implies that households are high dependent of weather conditions. Finally, conservation regulations, understood as the set of rules restricting the access and use to natural resources and its enforcement, are also identified across

households as a source of damage to their subsistence and commercial practices. Moreover, the overall low involvement of the studied communities in the decision-making process around CBR and incentive-based conservation tools has triggered the low legitimacy of these conservation regulation, which has limited the compliance of conservation rules.

The following chapter aims at understanding the household vulnerability patterns to the three locally-identified stresses (i.e. uncertainty about chilli prices, rainfall variability, and conservation regulations). In doing so, I will analyse households' sensitivity and their potential adaptive capacity to reveal the hidden factors of vulnerability across communities and households, highlighting on socially differentiated patterns.

5 Measuring household vulnerability to multiple locally perceived stresses

This chapter assesses local vulnerability patterns to multiple stresses in *Once* and *Sacrificio* using a Household Vulnerability Index (HVI). The chapter addresses research question two, "*How vulnerable are households and communities to locally perceived stresses?"* In doing so, the chapter identifies the key factors influencing household sensitivity against the most relevant stresses identified in Chapter 4, and their potential adaptive capacity to deal with such stresses. Insights from this chapter informs about household and collective adaptive strategies analysing factors of human agency and social structures in Chapter 6.

Results of this chapter rely on a database of 90 household surveys. Participatory observation and semi-structured interviews were also useful for contextualising quantitative findings. The quantitative data were selected and transformed to develop a hierarchical HVI, which is composed of 45 variables distributed between two sub-indices: a Sensitivity Index (SI), and an Adaptive Capacity Index (ACI). Three statistical tests were used to identify which variables contribute significantly to SI and ACI in each community, and to identify the main differences in adaptive capacity variables across clusters (see section 3.4).

The chapter is divided into four main sections. Section 5.1 identifies the key factors determining household sensitivity to the previously identified market, climatic and conservation stresses, and their inter-relations. Section 5.2 identifies the key factors influencing household adaptive capacity across communities, and highlights similar clusters of households regarding their adaptive capacities using a Hierarchical Cluster Analysis (HCA). Section 5.3 assesses household vulnerability patterns by ranking the resulting HVI as low, medium and high vulnerability, in terms of the overall stresses and across them. Finally, section 5.4 discusses the main findings of this chapter in the light of other similar studies and vulnerability analysis approaches.

5.1 Assessing sensitivity to multiple stresses

5.1.1 Sensitivity Index (SI) to multiple stresses

The distribution of each sensitivity measure (*S_market*, *S_climatic*, *S_conservation*, and *SI*) is concentrated between 0.1 and 0.5, in a range between 0 and 1 (Figure 5.1). This means that household sensitivity to these stresses is relatively low across communities. Both communities present low-medium levels of *S_climatic* and *S_market* (<0.59 and <0.64, respectively), although households nevertheless heavily depend on farming activities. Most farmers maintain subsistence agricultural practices, but diversify through market-oriented activities (see section 4.2), which contribute to reducing the influence of market and climate instability, as illustrated by these low sensitivity scores. The outlier households in *S_market* include farmers who are still highly dependent on chilli income. By contrast, the results show a larger distribution of *S_conservation*, suggesting that restrictions on the access to forests and hunting have a wider degree of impact across households.

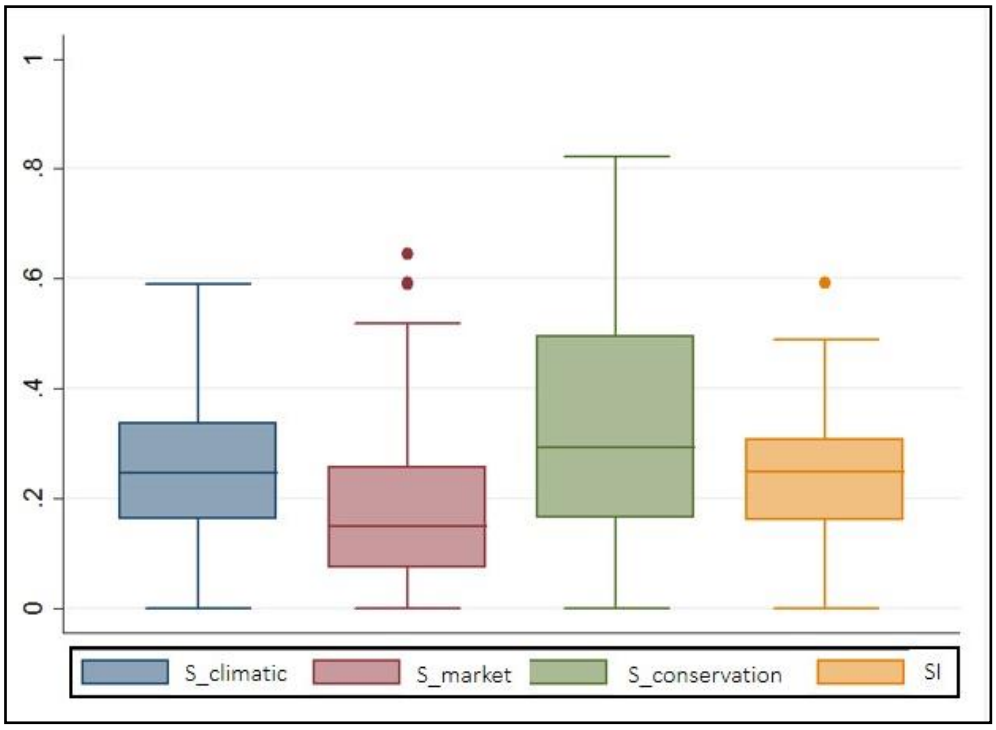

Figure 5.1: Overall distribution of each specific sensitivity (S_market, S_climatic, S_conservation) and Sensitivity Index (SI)

5.1.2 Comparing sensitivity profiles across communities

The results of the comparative analysis show differences in the degree to which variables belonging to *SI* influence overall household sensitivity across communities. I identify three main factors shaping this difference in sensitivity: 1) households' livelihood profiles, 2) households' demographic patterns, and 3) the community's resource management institutions.

First, the two communities differ in variables related to livelihood activities (see section 4.2), and particularly livestock rearing and maize cultivation, which shape their different sensitivity to conservation and climatic stresses (*S_conservation* and *S_climatic*, respectively). These results show that livestock-related variables are significantly higher in *Once* than in *Sacrificio*, including the number of cows reared *(Livestock_cow; mean Once=0.138, mean Sacrificio=0.000, p<0.01)*, and the income provided by livestock *(Income_livestock; mean Once=0.158, mean Sacrificio=0.046, p<0.1)*. These variables are associated with a higher *S_climatic* in *Once* due to a higher water demand for livestock rearing. There are as yet no households in *Sacrificio* involved in cattle rearing due to constraints on both economic and natural assets.

Additionally, planting maize in both wet and dry seasons *(Maize_season; mean Once=0.743; mean Sacrificio=0.404, p<0.01)* is another factor differentiating sensitivity towards rainfall variability (*S_climatic*) across communities. Although the main maize harvest is cultivated during the wet season (i.e. *temporal*), the rise in the maize price encourages households to cultivate large areas of maize during the dry season (i.e. *tornamil*) as a complementary source of food and income. Both *temporal* and *tornamil* cultivation are sensitive to climatic stress, since farmers do not have access to any irrigation system or greenhouses to protect maize from droughts or floods. In *Once*, households have land and human resources available to plant maize in the dry season, which increases their *S_climatic*. By contrast in *Sacrificio*, the cultivation of *tornamil* is a marginal practice due to the lack of appropriate lands for cultivation resulting from the adverse topography, as well as due to the fact that this agricultural task takes place in the middle of the seasonal migration of male household heads abroad (see section 4.2).

Second, the results suggest that demographic-related variables contribute to explain divergences in household sensitivity across communities and across the three perceived stresses, and more acutely in *Sacrificio* than in *Once*. Households in *Sacrificio* have a

higher household dependency ratio *(Dependency_ratio; mean Once=0.184, mean Sacrificio=0.302, p<0.05)*. Adults in *Sacrificio* are therefore more challenged by the adverse conditions when satisfying the daily needs of household members than those in *Once*. This detrimental demographic condition in *Sacrificio* is exacerbated by the larger number of household members *(Size_hh; mean Once=0.286, mean Sacrificio=0.400, p<0.01)*, which is illustrated by the households' demand for firewood. Households in *Sacrificio* may therefore be using their forests more intensively than in *Once*, and they probably use forests within the CBR core area I for domestic activities, which also contributes to increasing their sensitivity to conservation regulations.

Third, differences in sensitivity across communities are also related to their regulations governing natural resource management and its enforcement. Households reported changing their firewood and timber collection and hunting habits more often over the last five years in *Once* than in *Sacrificio (Forest_use_5y; mean Once=0.688, mean Sacrificio=0.346, p<0.01)*, resulting in a higher sensitivity to conservation rules in *Once*. In *Sacrificio*, there is a low conservation enforcement associated with the surrounding CBR core area I. As a result, some households reported using this conserved area despite the existence of restrictive regulations on the use of natural resources. A different situation characterises *Once*, where conservation rules and enforcement come from both the CBR and the voluntarily adopted PES and EC programmes (see sections 4.1). These federal government incentive-based tools have successfully engaged most *ejidatarios* in conservation activities. However, the low levels of accountability among some inhabitants, who continue to use conserved target areas, have encouraged *ejidatarios* to completely restrict access to communal forests – even those not included in these programmes. To date, the extraction of forest resources and hunting is only allowed in agricultural fields belonging to *ejidatarios*. By doing so, external and internal conservation rules and enforcement have forced households to change their forest resource and hunting habits (further detailed in section 6.3). Nevertheless, some of them still free-ride and they are thus liable to be sanctioned by the internal assembly, as well as by the Federal Attorney for Environmental Protection (PROFEPA in Spanish). Free-rider households include landless households, but also *ejidatarios* who are unable or unwilling to collect the required forest resources from their own lands.

These three factors - households' livelihood profiles, households' demographic patterns, and community's resource management institutions – that explain the divergences in

sensitivity profiles in *Once* and *Sacrificio* are also crucial for understanding the relationships between each specific sensitivity. Pair-wise correlations across sensitivity measures (*S_market*, *S_climatic*, and *S_conservation*) were conducted to identify interactions between stresses (Table 5.1). This analysis shows a positive relationship between the two agricultural-related stresses (*S_market* and *S_climatic*) in *Sacrificio*, which can be explained by the community's significant dependence on chilli production. By contrast, households in *Once* are less sensitive to these two stresses, because households' income sources are less dependent from chilli production, particularly among *ejidatarios*, who gain benefit for example of livestock rearing and conservation rewards (see section 4.2).

The results indicate other slightly significant and positive associations between *S_conservation* and *S_climatic* in each community, and between *S_conservation* and *S_market* in *Sacrificio* alone. In *Once*, households with land rights are mostly focused on intensive agricultural management and livestock rearing, which as noted above, are both constrained by climatic and conservation stresses. Moreover, a small proportion of *ejidatarios* who have completely cleared their lands are more sensitive to restrictions on communal forests, as are landless households. In *Sacrificio*, the high demographic pressure and the limited land available may explain these two significant associations. Conservation regulations further restrict available land for clearing and cultivation, constraining livelihood opportunities. This, ultimately, increases household dependence on agricultural practices for subsistence and on chilli production to generate households' economic income.

Table 5.1: Relationship between each specific sensitivity across communities

	Once			***Sacrificio***		
	N	**Mean**	***p-value***	**N**	**Mean**	***p-value***
S_climatic – S_market	35	0.2671	*0.1208*	52	0.550***	*0.0000*
S_climatic – S_conservation	35	0.296*	*0.0844*	52	0.233*	*0.0960*
S_market – S_conservation	35	0.085	*0.6269*	52	0.263*	*0.0598*

*Note: * indicates significance in the relationship between the two indicated variables in a pair-wise correlation (*p<0.1; **p<0.05; ***p<0.01)*

5.2 Adaptive capacity profiles

5.2.1 Adaptive Capacity Index (ACI)

The results show that the overall distribution of 0-1 *ACI* is concentrated between scores of 0.3 and 0.5 (Figure 5.2), suggesting that households' capacity for dealing with the identified stresses is relatively low. As regards adaptive capacity, *AC_economic* stands out due to its large distribution (0.036 to 0.801) and low mean (0.344), illustrating the diversity of wealth across households. *AC_education* presents the largest distribution of these capacities (0 to 0.833) with a relatively high mean (0.389), highlighting the wide diversity of learning and expertise capacities across households.

AC_material, which is derived from four interval variables, reflects the fact that around 50% of the sample has *AC_material* below 0.25 (equivalent to one material out four materials surveyed). The concentration of *AC_social*, for which 50% of households have scores ranging from approximately 0.25 to 0.45, illustrates that social capacities are less diversified than other capacities. *AC_workforce* presents the highest mean (0.650), showing the healthy status of adults working in the fields and the relatively good accessibility to agricultural fields. Finally, *AC_natural* presents the lowest mean (0.225) but its extensive distribution (0.026 to 0.607) reflects the differences between households in available land and water resources.

The analysis of outliers suggests the existence of higher levels of social differentiation in the adaptive capacity of households in *Once* compared to *Sacrificio*, where households seem to have more homogeneous adaptive capacity profiles. In *Once* the variable *AC_material* of six households is equal to 1, the highest possible score. One of these households is noteworthy because of its high *AC_social* (0.75) due to its active participation in the *ejidal* assembly, membership in productive associations, and high level of material exchange. The households with the lowest *AC_workforce* value are also located in *Once*, which is distributed from 0 to 0.55 in six households (15.4%) with elderly, sick or disabled household heads who are less able to do key livelihood tasks. The same outlier patterns are then reflected in *ACI* distribution of three households located in *Once*.

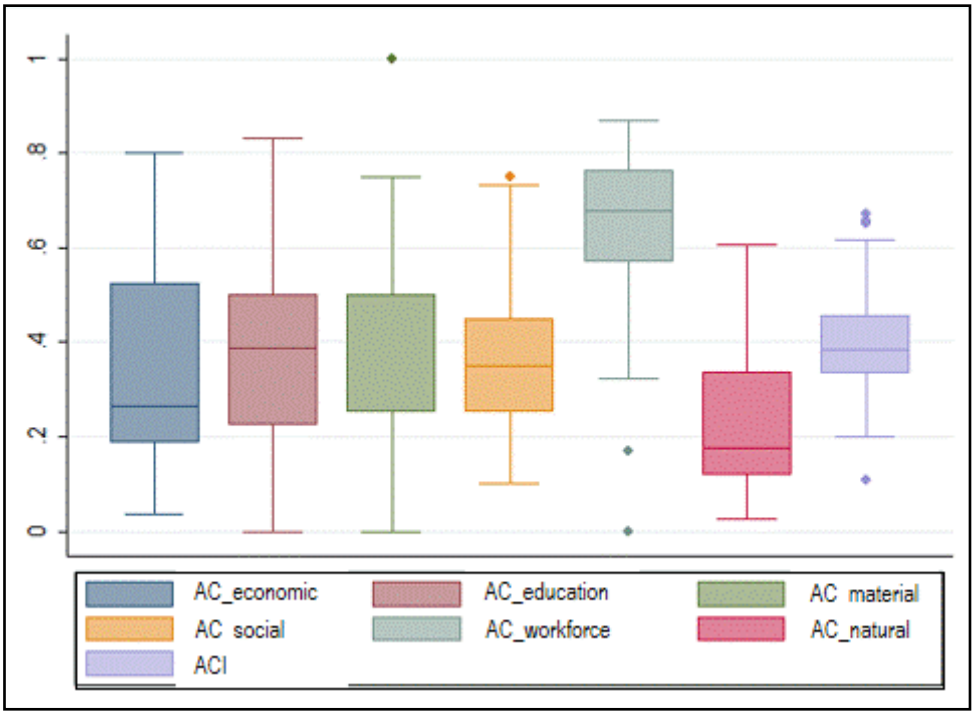

Figure 5.2: Overall distribution of each adaptive capacity dimension and Adaptive Capacity Index (ACI)

5.2.2 Comparing adaptive capacity profiles across communities

Figure 5.3 illustrates a more constrained adaptive capacity condition in *Sacrificio* than in *Once*, where *ACI* means are 0.364 and 0.447, respectively. Two adaptive capacity dimensions (*AC_material* and *AC_natural*) and 13 of 33 analysed variables are identified as contributing significantly to the differences in the *ACI* between communities (Table 5.2 in Appendix IX). The analysis of environmental histories and land tenure regimes (see section 4.1) sheds light on these differences according to the different evolution of the social-political and economic context of the two communities.

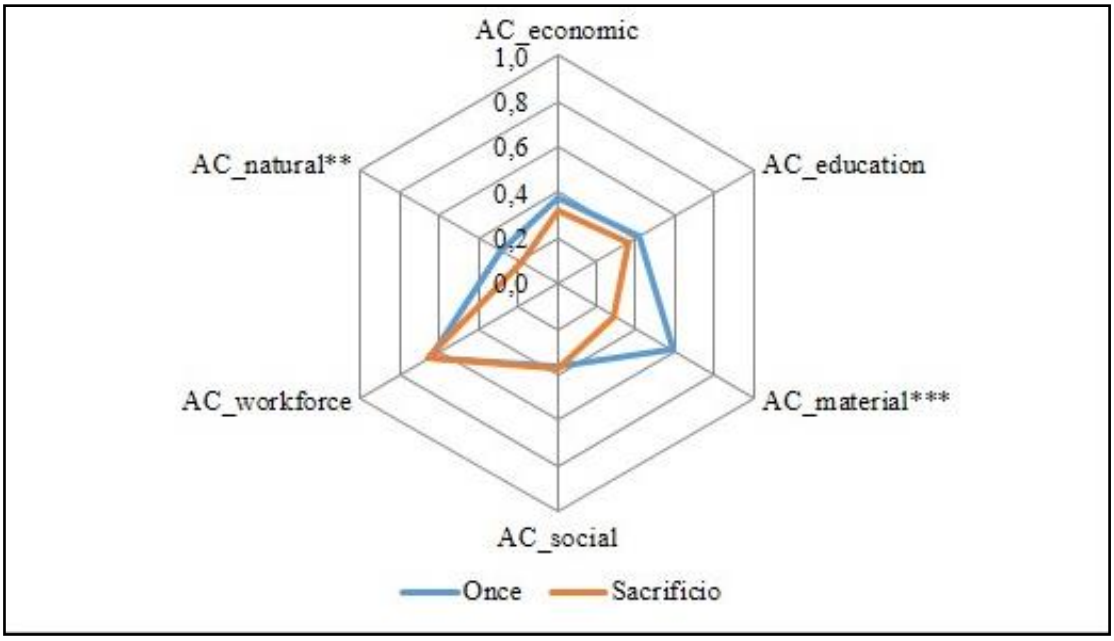

Figure 5.3: Comparison between adaptive capacity dimensions across communities
*Note: * indicates significance of variables in distinguishing adaptive capacity profiles in non-parametric tests (see section 3.4) (*p<0.1; **p<0.05; ***p<0.01)*

The results show significant differences in the material and infrastructure capacity between the two communities (*AC_material, mean Once=0.586, mean Sacrificio=0.288, p<0.01),* which are higher in *Once* than in *Sacrificio*. This difference can be explained by the spending of local remittances on material goods and infrastructure for cattle rearing. Today, local migration to the USA has decreased but households reported investing conservation rewards in material assets. In *Sacrificio*, migration to the USA has remained marginal and they do not receive conservation payments, which has limited households' investment in enhancing their material and infrastructure capacity.

The differences between the two communities in the natural resources capacity of households are also significant (*AC_natural; mean Once=0.283; mean Sacrificio=0.183; p<0.05).* Household adaptive capacity based on available natural resources is higher in *Once* than in *Sacrificio*. For instance, the size of households' farming land in *Once* is significantly larger than in *Sacrificio (Farm_size; mean Once=0.279; mean Sacrificio=0.102; p<0.01),* because *ejidatarios* were granted with 50 hectares, whereas "landowners" were provisionally granted with 20 hectares (see section 4.1). Additionally, in *Once*, households have bought land rights in the community and in other surrounding communities to expand their land for agriculture and livestock activities. Six households in *Once* (15.4%) are therefore in possession of two or three land titles. Households in

Once also have greater access to water in agricultural fields than those in *Sacrificio (Water_access; mean Once=0.526; mean Sacrificio=0.077; p<0.01)*, which partially explains the livestock expansion in this community - which does not occur in *Sacrificio*. Conversely, the diversity of plants in agricultural fields providing food or economic income is significantly higher in *Sacrificio* than in *Once (Plant_div_field; mean Once=0.240; mean Sacrificio=0.365; p<0.01)*. This reflects the persistence of subsistence agriculture in *Sacrificio*, where female household heads have a crucial role cultivating these secondary crops.

Although the overall economic well-being capacity is also higher in *Once* than in *Sacrificio (AC_economic; mean Once=0.378; mean Sacrificio=0.319; p>0.1)*, the results show no significant differences between them. However, data analysis reveals a significantly higher household economic income in *Once* than in *Sacrificio (Income_hh; mean Once=0.225, mean Sacrificio=0.105, p<0.01)*, which is linked to the development of market-oriented activities and the implementation of conservation initiatives generating economic rewards in *Once*, while this is not the case in *Sacrificio* (see section 4.2).

Neither the overall workforce capacity *(AC_workforce; mean Once=0.646; mean Sacrificio=0.653; p>0.1)* nor the related variables are significantly different between communities. Households present similar workforce levels, with an average of 2.6 adults per household, involving 69.6% of household heads between 20 and 49 years old, and 10.8% of these are sick or physically disabled. The accessibility of agricultural fields is also similar, since the municipal government has recently invested in improving access to these areas.

The overall education and knowledge capacity reflects no differences between the two communities *(AC_education; mean Once=0.421; mean Sacrificio=0.365; p>0.1)*, with the exception of household heads attending training courses (*Training; mean Once=0.579, Sacrificio=0.327, p>0.05)* where *Once* has a higher score than *Sacrificio*. This difference is probably explained by the long-standing conflict in *Sacrificio* that to date has limited external intervention and support, and has resulted in fewer projects and related training.

Although the overall institutional, local governance and social network capacity is not dramatically different in both communities *(AC_social; mean Once=0.367; mean*

Sacrificio=0.370; p>0.1), the results show that a significantly higher proportion of household heads in *Sacrificio* attend the assembly than those in *Once (Assembly_attendant; mean Once=0.789; mean Sacrificio=0.981; p<0.01)*, regardless of their tenure status. Another significant difference is the higher membership of male household heads in productive associations and organisations in *Once* than in *Sacrificio (Membership_male; mean Once=0.395, Sacrificio=0.173; p<0.05)*. Indeed, reluctance to work in groups partially explains the low mean reported in both communities.

Overall, these findings suggest that household adaptive capacity is higher in *Once* than in *Sacrificio*. Moreover, higher educational and social capacities in *Once* suggest a higher potential capacity for livelihood diversification. Nevertheless, the reality is that the communities' livelihood diversification pattern does not differ significantly between *Once* and *Sacrificio (Livelihood_div;* mean *Once*=0.553, mean *Sacrificio*=0.545; *p>0.1)* (see section 4.2 for further details about livelihood patterns across communities).

The analysis of adaptive capacity dimensions between communities does not reflect the internal differences based on land tenure rights noted through participatory observation and documented in the literature (Navarro-Olmedo et al. 2015). This is because households holding land rights (officially or unofficially) live together in both communities. This means that household hierarchies regarding land tenure rights exist in both communities. There is therefore a need to analyse adaptive capacities across households rather than comparing communities, in order to highlight groups of households sharing similar adaptive capacities regardless of their location.

5.2.3 Comparing adaptive capacity profiles across households

The Hierarchical Cluster Analysis (HCA) indicates the existence of four different clusters in the settings studied, which differ in their adaptive capacity (Figure 5.4). The four identified clusters are described below, in terms of the composition of each cluster (Table 5.2) and the significant variables and dimensions that make clusters different from each other based on non-parametric tests (Table 5.2 in Appendix III). Figure 5.5 illustrates the distribution of adaptive capacity dimensions across clusters. Variables and then dimensions are arranged to symbolise that a higher score means a higher adaptive capacity.

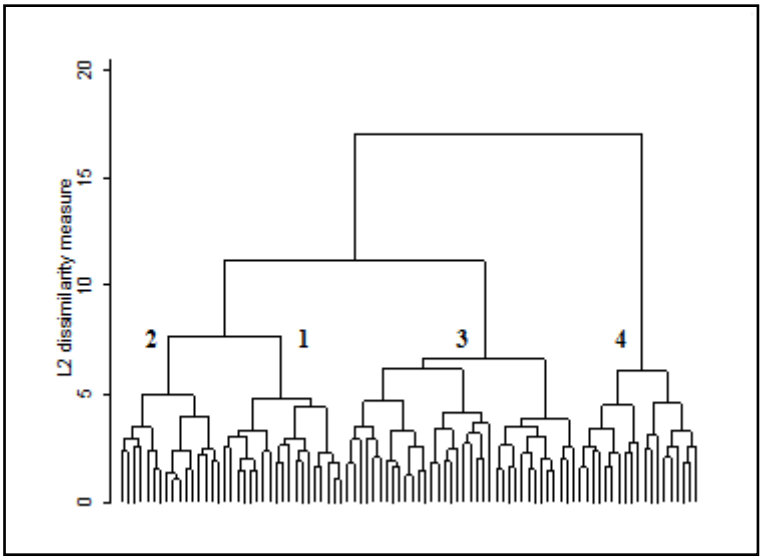

Figure 5.4: Dendrogram resulting from using adaptive capacity variables in a hierarchical cluster analysis

Table 5.2: Composition of each cluster for location and land tenure rights

Cluster	***Once***		***Sacrificio***		**N**
	Ejidatarios	Landless	"Landowners"	Landless	
1	1	2	6	10	19
2	1	5	4	6	16
3	5	8	19	4	36
4	16	0	3	0	19
Total	23	15	32	20	90

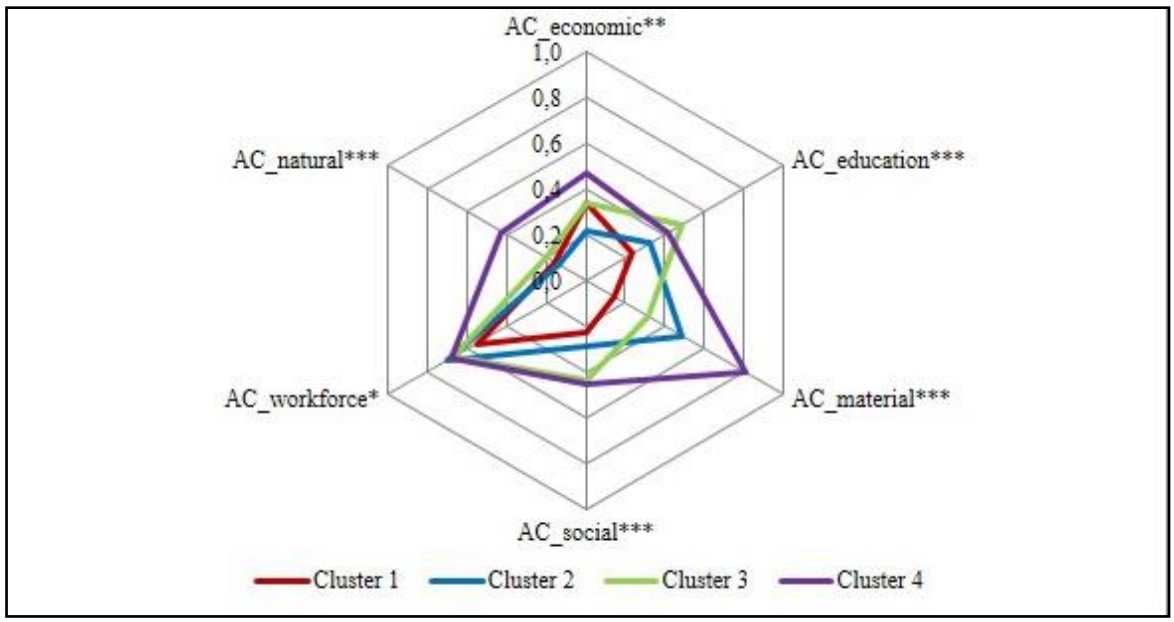

Figure 5.5: Adaptive capacity profiles across clusters

*Note: * indicates significance of variables in distinguishing adaptive capacity profiles across clusters in non-parametric tests (*p<0.1; **p<0.05; ***p<0.01)*

Cluster 1: the "marginalised households". This is a cluster mostly made up of households belonging to *Sacrificio* (16 of 19 households, 84.2%), all landless except six "landowners" from *Sacrificio* and one *ejidatario* from *Once*. This composition explains the lower average land size of this cluster (10.4 hectares), where households, and especially landless households, borrow or rent lands to cultivate *milpa,* and chilli in some cases. The cluster has limited household income and few material assets. They are also characterised by negligible entrepreneurship and training capacities. These households are not involved in decision-making processes or production networks, as reflected in their limited assembly attendance rates and memberships. A few have been in charge of a communal service, but never as authorities. Despite the marginal situation of this group, they do not borrow money. This cluster also includes sick and disabled household heads, which reinforces their marginal status.

An illustrative example of Cluster 1 is a household located in *Once* formed by a young couple (he is 23 and she is 19), who have a daughter under 5 years old. He is an indigenous Chol, and arrived from Chiapas four years ago, after being invited by his uncle who is an *ejidatario* in *Once*. She is an indigenous Tzeltal who was born in the community, and belongs to one of the largest families in the *ejido*. They live in a small woodhouse with

one room and a *huano* roof[18]. The house is located in a flooding prone area, which severely restricts their capacity to use this land for activities such as vegetable cultivation. Moreover, this area is heavily exposed to wild animal attacks, limiting husbandry because it is next to the boundary with communal forests. This household cultivates maize in both the wet and dry seasons, and occasionally works for a wage in the community. They are borrowing a small plot of land (1 hectare) from his uncle, which is approximately six kilometers away from their urban plot. He also has limited work opportunities due to a physical disability in his left hand.

Cluster 2: the "young households". This is a cluster of households composed of 11 landless households and five households holding land rights, with four out of the latter five belonging to *Sacrificio*. This composition also explains the low average land size of this cluster (15.3 hectares), and their regular practice of borrowing or renting lands to cultivate *milpa* and chilli. The cluster includes the youngest and healthiest household heads. These households have a poor economic situation, with marginal income returns and savings. Their social networks are structured around family members because they are usually descendants of other households in the community. Subsequently, they often have access to family land, equipment and economic loans. This group has some schooling but limited training and entrepreneurship. They are disconnected from productive networks and decision-making circles because they neither belong to a productive association nor attend assemblies. Only a few of them have been in charge of a communal service, but never as an authority. The cluster also has the smallest plant diversity in home gardens because many are located on the worst urban lands or share their urban plot with another family member, which reduces the available land.

An illustrative example of Cluster 2 is a household from *Sacrificio*, formed by a young couple (he is 30 and she is 21) with two children. He is a *mestizo* and she is an indigenous Tzotil. They live in a small woodhouse with a cardboard roof, located within the urban plot of his family. Their social network is closely related to their direct family members. It is a landless household that cultivates *milpa* on a small piece of a borrowed land (2 hectares), and work for a wage in the community and abroad. He currently earns extra-income by repairing different machinery in the community - knowledge that he acquired working in the nearby town of *Chetumal* some years ago. He would like to open a

[18] *Huano* roof: it is a roof of a house build with a local type of palm that is mostly recollected in the agricultural fields.

carpentry shop in the future. However, the household investment capacity is limited and highly dependent on agricultural sales.

Cluster 3: the "households on the edge". This is a large group composed of 36 households, 13 located in *Once* and 23 in *Sacrificio*. This cluster has a similar economic situation to clusters 1 and 2 but slightly higher incomes, which is a product of their higher training, skills and entrepreneurial attitude. The cluster includes households belonging to a local productive association or cooperative, and in charge of a communal service at present or in the recent past, including six authorities and some community leaders. Household heads in this cluster are healthy adults still able to handle demanding labour tasks. However, the average farm size in the cluster is not very high (19.9 hectares) because 33.3% are landless households and those with land rights are mostly located in *Sacrificio* (19 households), with small agricultural fields (20 hectares). This cluster has very diverse home gardens (mean of 8.4 species), and some have access to natural water springs in their agricultural fields.

An illustrative example of Cluster 3 is a household in *Sacrificio*, formed by a mature indigenous Chol couple (he is 56 and she is 47). They have a large family of six children, three of whom still live with them. They came from Chiapas in the early 1990s and first settled in *22 de Abril*. In the resettlement process, this male household head played a leading role in the negotiations with the correspondent governmental institutions. This household has two provisional small private property titles and owns one of the best urban plots, where they maintain a high diversity of garden plants and trees. They have two houses, one of which is made of concrete. Their livelihood is based on agriculture, principally cultivating maize and chilli, and working for a wage abroad during the dry season. Their future expectations are oriented towards gaining official recognition of their land tenure rights. He recognises that chilli cultivation is not a profitable activity. However, the household has limited investment capacity and the difficult and competitive access to markets constrains the improvement of their lives.

Cluster 4: the "empowered households". This cluster involves 19 households that have land rights and mostly live in *Once* (16 households, 84.2%). They have the highest household income and material assets. Some households have *jagüeyes* (i.e. an artificial lagoon) and almost all have access to water in their agricultural field. Their average farm size (64.5 hectares) is much larger than in the previous clusters (with two households

holding 150 hectares[19]). Some are members of local productive associations or cooperatives, and have generally participated in several training initiatives, showing a strong entrepreneurial attitude. They are actively involved in community assemblies, where some male household heads are identified as leaders. Moreover, they are in charge of some communal services, and five are authorities. This cluster includes the oldest but still healthy household heads.

An illustrative example of Cluster 4 is a household from *Once*, formed by a mature couple of *mestizos* (he is 62 and she is 57), who arrived in *Once* from Veracruz in the late 1980s. They have two sons alive, and one of them lives separately in the *ejido* but works closely with them. Both household heads are *ejidatarios*, and their son also has land tenure rights. Their livelihood involves the cultivation of large areas of maize in the wet and dry season (5 hectares), *chihua* (3 hectares) and even chilli (1 hectare). Additionally, they have 10 heads of cattle, 22 heads of sheep, 13 pigs, as well as a large number of turkeys and chickens. This household has a good supply of water in both the urban plot and the agricultural fields to meet the livestock's water demand. Farming sales provides a high economic income, which together with conservation revenues means a high investment capacity. Future expectations are related to maintaining or increasing the cattle herd and engaging in lucrative reforestation or conservation activities.

The description of each cluster shows the relevance of personal skills and land tenure rights in determining adaptive capacity across households. Factors such as age and health status, formal and informal knowledge, and motivation and entrepreneurial attitudes illustrate personal skills for appropriate deployment of household resources differentiating these clusters. Land tenure rights are not only essential in providing the means to put knowledge and motivations into practice, but also a major factor in differentiating household's participation in decision-making processes. However, the HCA suggests that despite these crucial differences, tenure status does not in itself explain the composition of each cluster. In fact, there are *ejidatarios* and "landowners" present in each cluster and mixed with landless households, except for Cluster 4 – the "empowered households". The Chapter 6 of this dissertation explores in detail the relevance of these uncover factors differentiating households' adaptive capacities in relation to their agency

[19] These two households were not treated as outliers or as discarded households because the mean farm size removing them is 10 hectares down (54.5 hectares), but leave the cluster still neatly differentiated from the other three clusters

for undertaking adaptive responses within the power relationship farming social structures in both communities.

5.3 Assessing household vulnerability

Generally speaking, a vulnerable household has a high sensitivity to a harmful situation and a low capacity to deal with this damage (Adger 2006; Eakin and Luers 2006; Smit and Wandel 2006) (see Equation 4.a.b, Chapter 3). This section then explores the relationship between SI and ACI across household clusters and communities, as well as that ranks the HVI measures to each locally perceived stresses. Appendix X presents detailed information about HVI measures at household level.

5.3.1 Linking Sensitivity and Adaptive Capacity Indices

The pair-wise correlation analyses between *SI* and *ACI* scores (Table 5.3) show that there is a significant positive relationship between both components of vulnerability. It implies that at higher levels of *SI*, households also are likely to present high levels of *ACI*. Nonetheless, this relationship does not hold in *Sacrificio* and among households in Cluster 2, the "young households".

Table 5.3: Overall pair-wise correlation analysis between Sensitivity Index (SI) and Adaptive Capacity Index (ACI), and across communities and household clusters

SI - ACI	N	Mean	*p-value*
Overall**	86	0.294	*0.006*
Once**	34	0.402	*0.018*
Sacrificio	52	0.156	*0.269*
Cluster 1**	19	0.651	*0.003*
Cluster 2	16	-0.148	*0.585*
Cluster 3**	36	0.421	*0.011*
Cluster 4*	16	0.448	*0.094*

*Note: pair-wise correlation analysis (*p<0.1; **p<0.05; ***p<0.01)*

Figure 5.6 illustrates the relationship between *SI* and *ACI* in each cluster, where in order to compare their vulnerability patterns, I have established the point of intersection between axes (0,0) at the mean of sensitivity (*mean SI: 0.246*) and adaptive capacity (*mean ACI: 0.392*). Therefore, the upper left hand quadrant includes the most vulnerable

households, the upper right hand quadrant the households that are most sensitive but potentially able to face the stresses studied, the lower left hand quadrant the less adaptive also least sensitive households, and the lower right hand quadrant the most adaptive and least vulnerable households.

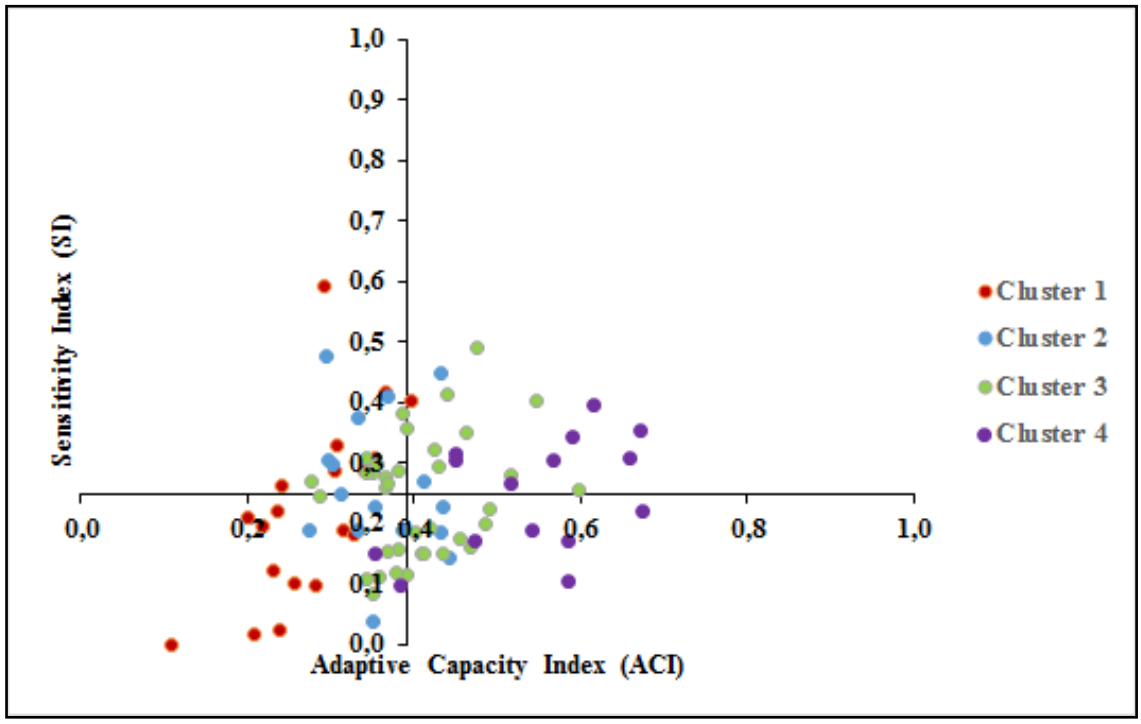

Figure 5.6: Distribution of household vulnerability according to both Adaptive Capacity Index (ACI) and Sensitivity Index (SI) scores

The analysis of correlation between *SI* and *ACI* (Table 5.3) and its distribution (Figure 5.6) evidence the difference vulnerability patterns among household clusters. Thus, Cluster 1, the "marginalised households" is distributed in positions of adaptive capacity under the overall mean. In this cluster, households with high levels of adaptive capacity households also present higher levels of sensitivity. This is not the case of Cluster 2, the "young households", where households are concentrated in similar levels of adaptive capacity despite their sensitivity. Cluster 3, the "households on the edge" are distributed among the four quadrants of Figure 5.6, evidence the diversity of vulnerability levels within this cluster of households. It implies that despite of being households with similar adaptive capacities, they differ in terms of their livelihood activities, demographic conditions, and/or in the management of natural resources. Finally, Cluster 4, the "empowered households" is mostly in the totality distributed over the overall adaptive

capacity mean. However, these households also present high sensitivity to the multi-stress situation.

Overall, these findings suggest that households with higher adaptive capacities tend to present also high levels of sensitivity to this multi-facet stressful situation. It reveal that households more potentially able to face the locally perceived stresses may engage in adaptive responses that increase their sensitivity to one or more of these stresses, and subsequently, to increase their overall vulnerability condition. This insight is further explored in Chapter 6 in the analysis of household and collective reported adaptive processes and responses to the three identified stresses.

5.3.2 Ranking of Household-level Vulnerability Index (HVI)

This section ranks HVI scores in three categories: low, medium, and high vulnerability (Table 5.4). The resulting categorisation of the overall HVI shows that 54.7% of households in both communities have a low HVI, whereas 43.0% present a medium HVI, and only 2.3% of households have a high HVI. In overall terms, the mean HVI is 0.642, which means that households are slightly vulnerable to multiple stresses. This is an expected result, since the HVI equation aggregates each HVI score to each specific stress. This is not a trivial question since this compensation undermines the estimated effect of multiple stresses on household well-being.

Table 5.4; Distribution of each specific and overall HVI according to low, medium and high rank (N=86)

	Mean	**Low (%)**	**Medium (%)**	**High (%)**
HVI_overall	*0.642*	54.7	43.0	2.3
HVI_market	*0.488*	72.1	22.1	5.8
HVI_climatic	*0.672*	45.4	40.7	13.9
HVI_conservation	*0.794*	55.8	36.1	8.1

Examining the HVI for each specific stress, Table 5.4 above shows that the conservation stress influences household vulnerability conditions more than the other two stresses (*mean HVI_conservation: 0.794*). This is explained by the high dependence on forest resources regardless of location or tenure rights. Every household needs to collect natural resources in forest areas, and high household dependency ratios exacerbate difficulties in satisfying household members' needs. Despite this noted high dependency to forest

resources, 55.8% of households are ranked as low vulnerable to conservation stress in the comparison across households, whereas 8.1% of them are highly vulnerable to this stress. Six out of seven of households classified in the high rank belong to *Sacrificio,* and none of these households belong to Cluster 4, the "empowered households". Moreover, these high vulnerable households are notable for their ongoing use of forest-conserved areas over the last five years. This means that they are identified as community free-riders who undermine internal accountability and exacerbate the weak governance system.

The *HVI_climatic* measure follows a different distribution to *HVI_conservation*. In this case, the distribution is concentrated around a lower score (*mean HVI_climatic: 0.672*), but it still reflects a considerable degree of vulnerability across households. This is indeed the stress with the highest proportion of households ranked as highly vulnerable (12 households, 13.9%). Among these highly vulnerable households to rainfall variability, there are households from both communities but 11 are landless. Most are heavily dependent on agricultural income and belong to Cluster 1, the "marginalised households", except for three households.

Contrary to expectations from interviewees' reported concerns analysed in Chapter 4 (see section 4.3), the measured *HVI_market* has the lowest mean in comparison to the other two stresses (*mean HVI_market: 0.488*). Moreover, Table 5.4 shows that a very large share of households (72.1%) are low vulnerable to this stress. The small proportion of highly vulnerable households to this stress (5.8%) are landless who borrow or rent land, with half of their land devoted to chilli cultivation, except for one household. Moreover, their household income depend heavily (over 50%) on chilli sales, except for one household, which dramatically influences their overall vulnerability.

5.4 Discussion

This section now turns to discuss the research question that guides this chapter, "*How vulnerable are households and communities to locally perceived stresses?"* Thus my findings show that, first, land tenure rights together with personal skills are key factors in understanding socially differentiated patterns of households' adaptive capacities. Second, may findings also evidence that households present an overall higher HVI mean to conservation rules and enforcement in comparison to market and rainfall stresses. Third, and finally, my findings show the need for a mixed-methods approach in vulnerability

studies to explore the influence of historical processes on how vulnerability is measured and perceived.

5.4.1 Socially differentiated patterns of households' adaptive capacities

My study reveals two uncover factors that explain divergences in household adaptive capacity, i.e. land tenure rights and personal skills. Land tenure rights are highlighted here by their multidimensional character being land as a natural and its rights political asset in this social-political context (Eakin and Bojórquez-Tapia 2008). Land ownership is the means of production for communities like *Once* or *Sacrificio*, whose economy is based on on-farm livelihoods (see section 4.2) (Chambers and Conway 19992; Ellis 1993, 2000). In this rural Mexican context, being in possession of land tenure rights also provides social-political benefits, since landholders are key decision-makers in these communities (see section 4.1). Nonetheless, the cluster analysis carried out demonstrates that land tenure rights are key, but not determinant, in understanding households' adaptive capacity in the studied area. Personal skills, and particularly age, health, knowledge or motivation and entrepreneurship are additional explanatory factors in adaptive capacity differentiation.

Apart from economic, material and educational capacities, the research findings also shows the importance of motivation and entrepreneurship as two socio-cognitive factors shaping household adaptive capacity (Grothmman and Patt 2003). The identification of these patterns of differentiation is fundamental in understanding the intra-community dynamics improving and undermining household adaptive capacity. Chapter 6, section 6.2, in this dissertation will provide further insights in how motivation and entrepreneurship play a key role in how each cluster of households perceived their willingness for undertaking adaptive responses to the recognised harmful situations.

In this regard, the research findings advocate by the need to consider communities as heterogeneous and highly context-specific entities for analysing social vulnerability, and orienting policy interventions. Moreover, the identification of socially differentiated patterns across households and communities is a further step in the understanding of the local distributional and procedural (in)justices (Adger et al. 2005), which may explain the power relations generating and framing at present the disparity between the adaptive capacity across clusters. Nonetheless, the analysis of these distributional and procedural

mechanism are very often overlooked in quantitative vulnerability assessments (Eakin and Luers 2006).

5.4.2 Household sensitivity to conservation regulations

Despite such social heterogeneity and diverse household adaptive capacity, my findings reveal that households in the two studied communities are more vulnerable to conservation rules and enforcement than to market and climatic stresses. Overall, the conservation rules have constrained the appropriation of tenure rights and limited access to and use of forest resources and hunting within and beyond community boundaries (see section 4.3). This has impacted on the diary use of firewood, wood for building housing and hunting for subsistence, or even commercial purposes, which has contributed to reframe the relationship that these individuals, households and communities have with their surrounding environment (Merino-Pérez 2013; Wunder et al. 2014). Thus, the overall high vulnerability mean to conservation regulation is explained because the households' dependency on conserved areas and resources for living increases their sensitivity to this stress, and because such restrictions undermine the households' adaptive capacity, especially among the less powerful households.

Interestingly, the analysis of sensitivity to conservation stress shows the presence of free-riders, by using forest and non-forest resources in the CBR core area I in both communities, as well as in PES and EC target areas in *Once*. These free-riders try to mitigate their vulnerability despite the increase of their sensitivity by the possibility of being pursued for it, and the damage to the already weak local governance systems and the lack of internal accountability (see section 4.1). Moreover, in line with previous studies the overall low legitimacy of CBR regulations by the lack of local involvement in decision-making processes argued in the previous chapter has implied that the use of resources within the CBR core zone I is not internally pursued in both communities. The local notion of "criminalisation" is a matter of context, and the use of these conserved natural resources is highly context-specific of the social and political structures in which local people access to those resources (Ribot and Peluso 2003).

Precisely, in *Once,* where the fear of losing the PES and EC payments as a result of ineffective enforcement has triggered the "criminalisation" of free-riders' actions and the development of highly restrictive regulations on the use of communal forests. Despite that both *ejidatarios* and landless households are equally sensitive to these high restrictive

rules over the access to and use of natural resources, the reality is therefore that *ejidatarios* are likely to cope with such constraints by using the forest resources of their own agricultural fields. This alternative is not available to landless households. As a result, in *Once* this high level of conservation restriction on communal forests fuels internal tension and exacerbates the dependence of the landless and less able households on *ejidatarios'* parcelled forests. This finding provides insights about institutional misfits into downscaling international conservation policies. It reinforces the view of those who argue that behind "win-win" and "inclusive" conservation programmes there are always critical impacts on the poor that remain almost invisible (Fairhead et al. 2012).

5.4.3 The challenge of measuring social vulnerability

Another relevant finding from this chapter is the large percentage of households that are not very vulnerable to the uncertainty of chilli prices (72.1%), which contrasts with findings in section 4.3 that suggested otherwise. This is not an inconsistency but a reflection of a methodological issue. Each variable included in the HVI reflects the immediate current situation, resulting from past adaptive processes (Adger et al. 2004). Therefore, the measured *HVI_market* does not consider that despite households at present have diversified their sources of income (e.g. livestock or PES rewards) to confront the impact of this stress over the last year, still they perceive a high dependency from the chilli production as the main agricultural cash crop over the last three decades. The use of quantitative and qualitative data as complementary perspectives thus provides an understanding of the gap between the current degree of damage that households are facing (measured vulnerability) and the degree of damage that households believe themselves to be experiencing based on their past and recent experiences (perceived vulnerability).

This result draws on Grothmann and Patt (2005), who argue that human cognition is a key factor to be taken into account when assessing vulnerability. People potentially evaluate stressful situations based on the probability of being affected and their ability to undertake actions to prevent or reduce this impact. Nevertheless, most vulnerability assessments have neglected the fact that vulnerability is also a perceived condition (O'Brien and Wolf 2010). The normative and the incommensurability of this concept make its inclusion in vulnerability indices difficult. To fill this gap, some scholars have engaged in risk perception assessment in relation to the likely adaptations undertaken on a small scale (Tucker et al. 2010; Frank et al. 2011; Kuruppu and Liverman 2011). This

insight reinforces the value of exploring the perceived dimension of vulnerability as a means of illustrating the temporal dynamics and sensitive issues influencing local vulnerability conditions (O'Brien et al. 2004; Adger 2006; O'Brien and Wolf 2010).

After more in-depth consideration of the theoretical and methodological challenges of measuring social vulnerability, my findings also question the widely accepted premise that there is a direct link between adaptive capacity and adaptation (Notenbaert et al. 2013). This understanding is related to the idea that humans undertake actions to reduce their sensitivity and/or their exposure to harmful situations (Eakin and Bojórquez-Tapia 2008). Nonetheless, the analysis of the HVI together with the environmental histories reveal that some households, as soon as increase their adaptive capacity, particularly through economic and material assets, they also engage in livelihood activities that are potentially more sensitive to the identified stresses. For instance, investment in livestock rearing to reduce household dependency on cash crop sales lead to an increase in household sensitivity to climatic stress, due to the high water demand in this activity. This shows that the improvement in people's adaptive capacity is not necessarily associated with a reduction in their sensitivity to perceived stresses, and also demonstrates the presence of unsuccessful adaptive responses, which is addressed in Chapter 6.

5.5 Summary

This chapter has revealed the main factors of sensitivity and adaptive capacity that explain the differentiated patterns of social vulnerability to market, climatic and conservation stresses across households. Comparing sensitivity to the three identified stresses across communities, my analysis has shown the influence of households' livelihood and demographic patterns, and natural resource management restrictions as three key factors differentiating the sensitivity across communities. In this regard, my findings have highlighted that, the intensification of agricultural practices and the investment in livestock rearing significantly increase the sensitivity to rainfall variability in *Once* in comparison to *Sacrificio*. This analysis has also reflected that the community's enrolment in "win-win" conservation initiatives has fuelled the generation of free-riding households, which increase their sensitivity to conservation rules and enforcement. In *Sacrificio*, however, households' sensitivity patterns are remarkably influenced by the high size and dependency ratio of households, which implies a significant demand for natural resources and substantial efforts by household heads to satisfy household needs. Moreover, this

chapter has also shown the strong relationship that exists between sensitivity to climatic stress and to market stress in *Sacrificio*. This double exposure illustrates the high dependency on chilli as the main source of income in *Sacrificio,* whereas in *Once* households reduce this dependency by diversifying their sources of income.

The analysis presented here includes a Hierarchical Cluster Analysis (HCA) to identify groups of households with similar adaptive capacities, which has allowed me to identify four different clusters of households. In this regard, my findings have pointed out that land tenure rights is a remarkable factor influencing household vulnerability, but it ownership is no guarantee of a better adaptive capacity. This has been illustrated by the classification of households holding land rights (officially and unofficially) in clusters with limited adaptive capacities (e.g. Clusters 1 and 2). In fact, the statistical analysis has performed out also reveals that personal skills, including socio-cognitive factors (i.e. age, health, formal and informal knowledge, motivation and entrepreneurship) also substantially contribute to differentiating household adaptive capacity across clusters of households. My findings therefore aims at contributing to the discussion about the influence of social structures and agency for exploring context-specific vulnerability patterns.

Finally, this chapter has argued that contrary to what is commonly reflected in the literature, a high household adaptive capacity does not necessarily entail reduced sensitivity. In fact, some clusters of households with higher adaptive capacity tend to increase their sensitivity to these multi-stressful condition by looking for new and diverse sources of income. Moreover, my findings have highlighted that households are more vulnerable to conservation rules and enforcement that to the other two stresses. This result is further discussed comparing the measured and the perceived vulnerability, where conservation and market are respectively identified as the main concern. This comparison shows that measuring vulnerability means focusing on current conditions, and relevant historical and subjective information play a key role in explaining differences between perceived and measured household vulnerability. Thus there is a need for implementing mixed-methods approach for social vulnerability assessments where the subjectivity of vulnerability could be addressed.

The following chapter aims at exploring the adaptive processes and responses undertaken at household and collective level to confront with the multi-stressful

context. In doing so, I will analyse households' agency for undertaking adaptation based on the revealed factors of social differentiation of adaptive capacity across clusters.

6 Adaptation, agency, and conservation

This chapter examines the households and collective adaptive processes undertaken to face multiple stresses in the two studied communities and it discusses the role of human agency in these processes. The chapter also explores the influence of conservation initiatives on constraining or enabling adaptation, focusing on the case of the CBR in the two communities and on the PES and EC programmes in *Once*. In doing that, this chapter addresses research question three, "*How are local adaptation and household agency influenced by conservation initiatives in a context of multiple stresses?"*, and it provides answers to related issues concerning local adaptive responses and agency of previously identified household clusters. This final empirical chapter contributes to a better understanding of the linkages between vulnerability, adaptation and conservation governance, considering that access to benefits from natural and social resources is shaped by the cultural, economic and social-political context, where conservation initiatives play a pivotal role.

The chapter relies on qualitative and quantitative data collected through participatory observation, semi-structured interviews, and household surveys (see section 3.4). It is divided into four main sections. Section 6.1 describes household and collective adaptive processes and responses undertaken to face the three previously identified stresses. Section 6.2 analyses the adaptive capacity experienced by clusters of households identified in the previous chapter, focusing on their agency for undertaking adaptive responses. Section 6.3 explores the influence of conservation initiatives in shaping household and collective agency and the implications for adaptive processes. Section 6.4 discusses the success of the reported adaptive responses in terms of reducing household and collective vulnerability, as well as the role of conservation in enabling or constraining local agency and adaptation.

6.1 Household and collective responses to multiple stresses

Communities reported a wide variety of adaptive responses to confront market, climatic and conservation perceived stresses. Across household clusters, those belonging to Cluster 3, the "households on the edge" identified the highest number of adaptive responses to these multiple stresses (#36). Cluster 4, the "empowered households",

identified almost the same number (#34); Cluster 2, the "young households" highlighted 28 responses and Cluster 1, the "marginalised households" identified the lowest amount of responses for adaptation (#19).

Households are engaged in adaptive processes of diversification, exchange, rationing, pooling, intensification, mobilisation, innovation, and revitalisation of their assets and livelihoods to deal with the locally relevant stresses. Seven of the 40 different responses reported are collective responses (i.e. conducted by households together), mostly related to or derived from the implementation of conservation initiatives. Households undertake more planned responses (adapt to) than reactive responses (cope with), regardless of their cluster and location. Every collective response and some responses at household level are promoted, supported and/or implemented by external organisations. A summary of the adaptive processes and responses to multiple stresses identified across clusters and communities is presented in Table 6.1, and the information is further analysed in the following three sub-sections.

Table 6.1: Self-reported adaptive processes and responses to multiple stresses across clusters and communities

Process	Sub-process	Responses	Type of strategy[1]	Commu-nity[2]	Cluster				Stress			Scale[3]	Supported by:
					1	2	3	4	Climatic	Market	Conservation		
Diversification	**Planting choice**	Reducing planting area of chilli	A	B	x		x	x		1		HH	None
		Reducing planting area of maize	A	B	x	x	x		1			HH	None
		Planting maize in different fields	A	B		x	x	x	1			HH	None
		Planting in high fields	A	B			x	x	1			HH	None
		Coming earlier the crop plantation	A	B	x	x	x	x	1			HH	None
	Cropping choice	Changing maize seed varieties	A	B	x	x	x	x	1			HH	None
		Introducing new pasture grass varieties	A	O			x	x	1			HH	None
	Managing choice	Moving cattle across fields	A/C	O			x	x	1			HH	None
		Changing places for collecting firewood	A	O	x	x	x	x			1	HH	None
		Changing places for hunting	A	B		x	x				1	HH	None
	Occupational diversification	Wage working in/outside the community	A/C	B	x	x	x	x	1	1		HH	None
		Working in fire prevention	A	O			x	x			1	HH	CBR
		Investing in a small trade shop	A	B		x	x	x		1		HH	None
		Investing in beekeeping	A	B			x	x		1		HH	None
		Investing in livestock (cows)	A	O			x	x		1		HH	None
		Investing in livestock (sheep)	A	B	x	x	x	x		1		HH	CDI, Municipality

Exchange	**Trade**	Selling vegetables and/or animals	A/C	B	x	x	x	x	1	1			HH	None
		Selling maize	A	B	x	x	x	x		1			HH	None
		Reforesting with woody timbers for selling	A	B		x	x	x		1			HH	CONAFOR
		PES programme	S	O	x	x	x	x		1		1	CO	CONAFOR
		EC programme	S	O	x	x	x	x		1		1	CO	CONAFOR
	Improving access market	Selling dry chilli	C	S	x	x	x			1			HH	None
		Commercial agreement to sell chilli	A	O				x		1			CO	CRIPX
	Non-market exchange	Gathering firewood for *ejidatario's* and own household needs in *ejidatario's* plot	C	O	x		x	x				1	HH	None
Rationing	**Storage**	Buying maize	C	B	x	x	x		1				HH	None
		Buying land out of the community	A	O			x	x		1		1	HH	None
		Building infrastructure to protect cattle from wild animals attacks	A	O				x				1	HH	None
		Building infrastructures to accumulate water in agricultural fields	A	B		x	x	x	1				HH	SAGARPA, Municipality
	Preservation	Saving firewood by reducing consumption	A	B	x	x	x	x				1	HH	None
		Preserving forest cover in the field	A	B		x	x	x				1	HH	None

Pooling	**Institutional pooling**	Claiming for land rights collectively	S	S	x	x	x	x			1	CO	CRIPX
		Increasing restrictions in the use of forest resources	T	O	x	x	x	x			1	CO	None
	Communal pooling	Beekeeping project	T	S		x	x			1		CO	CDI Municipality
Intensification	**Agricultural intensification**	Increasing planting area of chihua	A	B	x	x	x	x		1		HH	None
		Increasing planting area of maize	A/C	B	x	x	x	x	1	1		HH	PROCAMPO, CBR
		Using agrochemicals and/or mechanised agriculture	A	B	x	x	x	x	1		1	HH	SAGARPA, Municipality
Mobility	**Migrating**	Long-term migration	A	B		x	x	x		1		HH	None
		Migration to *Aguas Amargas*	A	S		x					1	HH	None
Innovation	**Experimental agriculture**	Experimental project for agriculture innovation	S	O				x	1	1		CO	CRIPX, Municipality
Revitalisation	**Weather forecast**	Annual weather prediction	A	O			x	x	1			HH	None

[1] Classification of types of strategies based on Brown and Westaway (2011): coping (C), adaptation (A), self-help (S), and transformational (T)

[2] Community: *Once* (O), *Sacrificio* (S), and both (B)

[3] Scale (i.e. level of involvement): household (HH), and collective (CO)

6.1.1 Classifying local adaptive processes and responses

Overall, households in *Once* develop more adaptive responses in comparison to those in *Sacrificio* (#36 and #26 respectively). More than half (#22) are undertaken in both communities, which can be explained by their similar livelihood strategies (see section 4.2), while the specific social-political and economic context explain different adaptive processes.

Diversification (#16) is the most widespread adaptive process at household level. Diversification includes responses aimed at managing climatic and market stresses, such as planting maize in different fields or introducing new pasture grass varieties. Households also turn to management choices to diversify their source of forest and non-forest resources in response to conservation regulations. Seven responses in *Once* and five in *Sacrificio* concern occupational diversification, with Clusters 3 and 4 households diversifying their livelihoods most widely to deal with climatic and market stresses.

Adaptive processes based on exchange rationality are referred to in eight responses, four of which are specific to *Once* and one to *Sacrificio*. Both communities face uncertainty about chilli prices and they are therefore looking for new trading options or gearing towards a better access to markets. Additionally, some of these responses aim to counter-balance the conservation stress through the conversion of communal natural resources in "win-win" conservation initiatives, such as PES and EC programmes. The latter response is limited to those with land tenure rights, thus excluding from conservation benefit streams *Sacrificio's* inhabitants as well as landless members of *Once* (see section 4.1). Cluster 4 households have a strong commercial orientation towards chilli production and commercialisation, arising from a pilot project bringing together some *ejidatarios* and a chilli enterprise in 2013. Other activities, such as selling dry chilli to obtain a better farm-gate price, or supplying firewood in exchange for labour, are other responses developed across clusters.

Rationing encompasses six adaptive responses, two of which are specific to *Once*. Storing resources through the market (buying resources), or building infrastructures for livestock rearing, as well as preserving domestic sources of forest resources to guarantee the household's firewood supply, are the core drivers of such responses. Four out of six reported responses deal with the indirect pressure on resource access generated by conservation regulations. These responses therefore aim at reducing households' risk by

guaranteeing their access to land and forest resources, and preventing sheep rearing from jaguar attacks. Other storage responses endeavour to guarantee food supplies by buying maize in the face of climatic stress, as well as ensuring access to water in agricultural fields by building water tanks or artificial lagoons, which are critical for livestock rearing. Despite these reported responses, there is a significant lack of responses focused on accumulating harvested crops, which are particularly beneficial for livestock rearing. Once again, Cluster 1 households reported fewer storage responses, while Cluster 4 households are notable for their investment in livestock infrastructure to reduce damage from jaguar attacks in *Once*. Households in Clusters 2 and 3 have a wider variety of storage responses.

Most collective adaptive responses in *Once* and *Sacrificio* involve pooling processes (#3), based on institutional and common pooling responses. The two institutional pooling responses reported are highly specific of the social-political context in which conservation initiatives have been implemented. In *Sacrificio*, a collective demand for land titling started after the community's resettlement in 1999, which has been reinvigorated by CRIPX support since 2013. In *Once*, the institutional pooling response aims to internally regulate access to and use of forest resources. These internal regulations have resulted in a strict prohibition on the use of forest resources and hunting in the communal forest, in order to reduce the risk of losing the economic reward obtained from PES and EC programmes (see section 4.1). In *Sacrificio*, ten female household heads belonging to Clusters 2 and 3 have begun a communal pooling response, joining in a beekeeping project co-funded by the municipal government and CDI to deal with the market stress.

The process of intensification relates to agricultural practices, which involves three responses undertaken across communities and across all clusters to deal with the market stress. Some households reduce their dependence on chilli, while increasing their dependence on other cash crops such as maize and *chihua*. Others increase their cash crop yield by using agrochemicals and/or mechanised agriculture.

Mobilisation processes are illustrated by two well-differentiated reported adaptive responses. First, the medium and long-term migration of at least one household member abroad (mostly to the USA) or elsewhere in the country is reported across communities and clusters, except for households in Cluster 1. Although migration to the USA has

decreased in recent years (see section 4.2), some household members have recently migrated, or remain abroad. Second, the reported migration of one landless household in *Sacrificio* to *Aguas Amargas* was aimed at obtaining tenure rights in a new settlement. However, this response should be considered exceptional because this settlement is located inside the CBR core area I and thus prone to relocation in the near future (CRIPX in pers. comm.). Nonetheless, both responses pursuit to overcome limited access to land and income-earning alternatives to confront both conservation and market stresses.

A collective monitoring process of agricultural practices to cope with climatic and market stresses illustrates an innovative process for adaptation in *Once*. CRIPX and the municipal government have supported the creation of some experimental fields involving the participation of a few *ejidatarios* (all belonging to Cluster 4 households). However, since these experimental fields are located inside some *ejidatarios'* agricultural fields, there are no collective tasks and knowledge transmission is limited.

Finally, revitalisation adaptive processes are almost irrelevant in both communities. Only a few non-indigenous *ejidatarios* in *Once* noted that weather forecasting, based on a long tradition in Mayan communities on the Yucatan Peninsula, is being used to predict annual weather patterns from the meteorological events occurring in January. The respondents argued that this is an attempt to keep alive a long tradition to confront climatic stress.

6.1.2 From coping to transformational adaptive responses

The historical impact of these stresses in the territory of *Once* and *Sacrificio* is reflected in the large number of adaptive responses reported (#31), in comparison to 7 coping responses, 4 self-help responses, and 2 transformational responses.

In particular, the management of natural resources requires strategic thinking from households when facing the conservation stress. Changing areas for collecting firewood or hunting, preserving their forest cover as a future forest reservoir, or building infrastructure to counteract wild animal attacks are some examples of farmers' long-term adaptive responses. Only one of these nine reported responses at household level is aimed at coping with conservation regulations (i.e. gathering firewood for the landowner's and own household needs on the landowner's plot). At a collective level, some households reported three self-helping responses to face conservation stress by a particular social group to apply for a benefit mainly by *ejidatarios* in *Once* or claim tenure rights by

"landowners" in *Sacrificio*. The weak governance system characterising the two communities seems to limit further collective responses to management of land and forest resources. Only one transformational response to this stress was reported in *Once*, where *ejidatarios* increase resource access restrictions in communal forests, in response to low levels of self-enforcement of external and internal conservation regulations (see section 4.1).

Adaptive responses to rainfall variability are diverse. There is a predominance of long-term adaptive responses (#14) *versus* few short-term coping responses (#5). Most adaptive responses reported are related to agriculture, because farmers plan what they will cultivate and how much of it in March-April (see section 4.3). Conversely, the cultivation of *tornamil* follows a different planning rationale. Farmers have an idea of how much to cultivate early in the year, but when *tornamil* is planted in November, damage to the previous maize harvest or low profits on chilli commercialisation encourage farmers to increase *tornamil* planting. The experimental project for agriculture innovation is classified as a self-help practice, since there is a deficient communication flow among the group of *ejidatarios* involved. This ruins the knowledge-sharing and transformational nature of this action in response to both climatic and market stresses.

Finally, the wide variety of adaptation responses (#15) to uncertainty over chilli prices indicate that this is a recurrent stress which households have tried to compensate for by seeking alternative income-generating activities. Investing in livestock rearing or in beekeeping are two examples of these strategic responses at household level. These households also reported coping with urgent cash requirements by reactive responses (#5). Looking for temporary wage labour opportunity in/outside the community is often an option for obtaining cash to solve household contingencies. Two of the three reported self-help responses pursuit new sources of income by preserving their natural resources in exchange for economic rewards. The other self-help response (i.e. experimental project for agriculture innovation) involves improving agricultural management to increase chilli harvests, while reducing the crop's sensitivity to environmental stresses. The group of women in *Sacrificio* working collectively and sharing costs and benefits from a beekeeping project is the only transformational response to the market stress reported.

The range of reported responses suggests that households in the two communities often remain in a vicious cyclic process of short-term (coping) responses because they plan

their agricultural tasks every year. Planned decisions (adaptation), such as reducing the area dedicated to chilli cultivation are then evaluated annually based on the human and economic resources available and the information on tentative chilli prices for the next harvest season. Moreover, most collective responses could be considered collective platforms to obtain external support (self-help), and particularly to access expert-based farming knowledge and better trading conditions, rather than platforms for changing their surrounding natural and/or social systems (transformation). This is why only two of the collective responses in pooling adaptive processes can be categorised as transformational - one in *Once* (i.e. increasing restrictions in the use of forest resources) and the other in *Sacrificio* (i.e. the beekeeping project).

6.1.3 Adaptive responses to multiple stresses

The locally perceived market, climatic and conservation stresses have been impacting local livelihoods and households' living conditions for at least two decades (see section 4.3). As a result of the synergic damage from chilli's reduced profitability, bad harvests, and constraints imposed on land titling by conservation regulations, households have engaged in various adaptive processes with responses such as long-term migration, the exploration of new cash crops, and occupational off-farm diversification in and outside the community.

Interestingly, double response relationships are often reported across households facing multiple stresses. For example, households in every cluster reported using agrochemicals and/or mechanised agriculture to deal with agricultural management problems arising from both climatic and conservation stresses. Enrolment in diverse conservation initiatives (i.e. PES and EC programmes) in *Once* aims at confronting the uncertainty about chilli prices and the restrictions from the CBR to benefit from conserved target areas. Mobilisation responses also deal with market and conservation stresses, because both the high level of households' dependence on chilli and the constrained land appropriation encourage out-migration, while remittances are invested in buying land titles or diversifying household livelihoods. The last double response relationship relates climatic and market stresses, where damages over subsistence and cash crop harvests influence cropping choices (e.g. how much temporal maize or *tornamil* to cultivate), cause occupational diversification (e.g. how long to engage in waged work), or reaching new markets (e.g. vegetable sales).

Finally, a particular response to confront one type of stress may lead to more responses to face the same stress, or other stresses, in a cascade of adaptive responses. For example, the low profitability of chilli commercialisation encourages investment in livestock rearing. The extensive management of livestock rearing in these communities, as well as in other communities in Calakmul, together with the influence of rainfall variability, have led to diversification of pasture grass seeds, moving cattle across fields, or the building of infrastructure to protect sheep from jaguar attacks. Households undertake these adaptive responses in different ways and according to their resources, assets and personal abilities. Households in possession of several land titles are able to move cattle across various fields, while other households cannot. This latter group of households develop a rotation plan to move them within the same field. However, these management choices depend in turn on the investment capacity of resources (human and materials) and the mosaic of farming activities undertaken in these agricultural fields. This cascade process exemplifies the complex relationship between stresses, and how households' assets are deployed to implement adaptive responses.

6.2 Household agency for adaptation

This section draws on Brown and Westaway (2011) to analyse local adaptive capacity across household clusters, highlighting the intersection of household agency with the social structures in which households are embedded to undertake the reported adaptive processes and responses (Table 6.1). In doing so, most households across the four clusters recognise the need to adapt to locally identified stresses. However, the prioritisation of each of these stresses differs across clusters. This seems to influence which resources and to what end households mobilise their assets. The belief that adaptation is feasible and desirable also varies significantly across clusters; in general, the greater their adaptive capacity, the stronger the belief that adaptation is feasible and desirable.

Willingness to undertake adaptive responses is significantly high across clusters of households, but the availability of resources for mobilisation towards adaptation varies significantly between clusters (see section 5.2). The ability to properly deploy resources is determined by these households' access to obtaining a benefit from their surrounding resources. As Ribot and Peluso (2003) note, rights-based mechanisms are critical in determining who gains access, while structural and relational mechanisms play a key role in differentiating the "bundle of powers" of each cluster in terms of maintaining and

controlling access to local benefits. Finally, external constraints and enablers for implementation are multiple and diverse, such as some ecological, social-political, or economic conditions. The following sub-sections characterise the adaptive capacity of each cluster by focusing on their agency for adaptation; all the information is summarised in Table 6.2.

Table 6.2: Characteristics of household agency across clusters

Agency factors	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**
Recognition of the need to adapt	1st Conservation 2nd Market 3rd Climatic	1st Climatic 2nd Market and Conservation	1st Market 2nd Climatic 3rd Conservation	1st Climatic 2nd Market 3rd Conservation
Belief in adaptation	Very limited	Limited	Possible but only being active	Possible
Willingness to adaptation	74% (14 hh)	69% (11 hh)	100% (35 hh)	89.5% (17 hh)
Availability of assets	Savings Training	Material wealth (no *jagüey*) Social networks Healthy state	Livelihood diversity Knowledge and willingness Social-political status Social network	Economic investment capacity Recognised knowledge expertise Material wealth Social-political status Social network Healthy state Natural assets richness
Ability	Very limited	Limited	High	Very high

External enablers	No identified	No identified	**S**ubsidies and programmes oriented to farming activities and infrastructures improvement	Public investment in path leading to the agricultural fields **S**ubsidies and programmes oriented to farming activities and infrastructures improvement
External constraints	Communication system is controlled by authorities Most programmes and subsidies follow a co-funding system Local associations are located in *Xpujil* and required of a membership fee	Temporal land borrowing arrangements Most programmes and subsidies follow a co-funding system Local associations are located in *Xpujil* and required of a membership fee	The CBR restrings the appropriation of land and responsible agent of the resettlement that form *Sacrificio* Most programmes and subsidies follow a co-funding system. Adverse topography (*Sacrificio*)	Control of local markets by intermediaries

6.2.1 Cluster 1, the "marginalised households"

Conservation regulations are very often recognised by this cluster as the most harmful stress they face. Eight out 17 reported adaptive responses are then oriented to deal with conservation rules and enforcement. Interestingly, a large percentage of households do not recognise the impact of climatic and market stresses. This cluster is characterised by the physical disability of some household members, and an overall negative perspective in terms of their perceptions of their capacity to improve their living conditions. Some households in this cluster said they did not care about adaptation, while other households explained that adaptive responses are very difficult to pursue unless those responses have external support. In other words, the belief that adaptation can be only conducted with external support influences their reported willingness to undertake adaptive responses. As a result, they would like to carry out activities such as husbandry, livestock rearing or small trade shops, which are all potentially supported by external agents.

Indeed, of all clusters, Cluster 1 households have the lowest adaptive capacity. Households in this cluster present low economic, educational, material, social, workforce, and natural assets (see section 5.2). The general shortcomings in other indicators have a critical impact on the ability to adapt of households in this cluster. This can explain that these households are not diversifying the planting area of maize or not engaging in long-term migration responses, conversely to the other clusters. The poorer health and the weak social networks of households in this cluster, together with the deficient communication system of subsidies and programmes, are crucial factors in understanding their very limited access to benefits from their livelihoods or potential activities. These factors impact negatively on livelihood diversification (including labour opportunities), reporting the households in this cluster the lower number of diversification responses (#7). This is especially acute among those considered unable to work properly due to being physically disabled or too old, and among landless households with restricted access to capital.

Moreover, the limited access to financial capital constrains their access to technology for agriculture, because they do not have the proper equipment or the cash to pay for it. Nonetheless, most of households of this cluster, alike the other clusters, are engaged in intensification responses by using agrochemicals, which are directly funded through a agricultural subsidy (i.e. Procampito). Indeed, the limited economic capacity of these households also constrains their capacity to co-fund some subsidies and governmental

programmes (i.e. building an artificial lagoon for livestock or renting a tractor). Furthermore, households in this cluster cannot pay the membership fee in local cooperatives or associations, nor the cost of transportation to *Xpujil* where these organisations are located.

Finally, the low proportion of landholders presented in this cluster (see section 5.2), and then their limited influential position within the community, is related to their reduced access to privilege and expert knowledge, which negatively influences their ability to negotiate better conditions for sharing benefits with other households. These households are therefore excluded of collective responses as beekeeping in *Sacrificio*, or the experimental project for agriculture innovation in *Once*.

6.2.2 Cluster 2, the "young households"

Most households in this cluster consider rainfall variability as the most harmful stress they face, followed by market and conservation stresses in same proportion. Ten of 27 reported adaptive responses are then oriented to confront the impact of this climatic stress. The belief that adaptation is feasible and desirable is not widely shared, and it is related to migrating abroad to invest remittances in a property title and/or in husbandry activities. However, some households reported that adaptation can also be pursued through innovation and entrepreneurship, which is reflected in their willingness to undertake adaptive responses such as livestock rearing and investment in new productive activities (e.g. beekeeping or small trade shop).

Of all clusters, this one has the second lowest adaptive capacity, and households present low economic and natural assets (see section 5.2). Households also have fewer education and social skills compared to clusters 3 and 4. These relatively poor economic, educational, social and natural conditions have a negative impact on the cluster's adaptive capacity. This can explain their limited number of diversification responses (#9) similarly to households in Cluster 1. And, furthermore, this cluster highlights for being the only one that is not yet reducing planting area of chilli, showing their high economic dependency from chilli production.

Moreover, the cluster encompasses the youngest and healthiest households, who often lack tenure rights and have limited decision-making power in the two settlements. Most of these households are thus highly dependent on *ejidatarios* and "landowners" to gain

access to land and engage in their livelihoods, as well as finding wage work. Planting in high fields or investing in long-term livelihood activities such as beekeeping or livestock rearing (cow) are then highly restricted.

In sum, for households in this cluster, the main external enablers and constraints for implementing adaptation are directly or indirectly linked to their general lack of land or land titles. Landless households have no security over their borrowed land and they do not have sufficient economic capacity to undertake mechanised agriculture or invest in *jagüey*. "Landowners" in the cluster have comparatively greater land security but their limited economic capacity restricts their opportunities to invest and become a member of local livestock and beekeeping associations. This thus constrains both landowners' and landless households' economic status and ability to access markets, making them dependent on other intermediaries.

6.2.3 Cluster 3, the "households on the edge"

Uncertainty about chilli prices is recognised by this cluster as the most harmful stress, followed by climatic and conservation stresses. 17 of 36 reported adaptive responses are then oriented to deal with this market stress. As in Cluster 2, Cluster 3 households believe that adaptation through innovation and entrepreneurship is feasible, so they adopt an active attitude towards new income-earning opportunities (e.g. selling vegetables and/or animals or working in fire prevention). Households in this cluster are thus willing to undertake responses such as hairdressing, cooking and selling bread, or beginning lemon cultivation, in order to improve their living conditions.

Furthermore, the "landowners" interviewed in *Sacrificio* tend to be less optimistic about overcoming their vulnerability than *ejidatarios* in *Once* due to their limited access to federal support to productive and conservation activities very often tied to tenure rights (see section 4.1). Households in *Once* have benefited from governmental support in the form of matching grants for farming activities and livestock rearing infrastructure. By contrast, households in *Sacrificio* have not been able to benefit from government co-financing schemes, because the adverse local topography restricts mechanised agriculture, while their lack of economic capacity limits people's ability to invest in livestock infrastructure.

Of all clusters, households in Cluster 3 present high educational, social and workforce assets (see section 5.2), which households deploy to develop the highest number of adaptive responses reported (#36) across clusters. And, although households of this cluster have high access to labour opportunities due to their good health conditions, strong social networks and powerful political status are not reflected in their overall income (see section 5.2). This is explained by the limited profitability of their livelihood activities and bad access to markets. Selling dry chilli, instead of green chilli, is then an adaptive response developed to gain a higher farm gate price from the production of this cash crop, as households in Cluster 1 and 2.

The large percentage of landholders (67%) in this cluster control the channels of information and decision-making processes: many household members have influential internal positions, which substantially increase their access to privileged information. Despite their relative empowered position, they are excluded from collective responses such as the experimental project for agriculture innovation or the commercial agreement to sell chilli.

As in other clusters, the CBR is identified as a constraint for adaptation, since the existence of the protected area limits people's ability to obtain a land title in *Sacrificio* or to develop certain resource management strategies in both communities. Specifically, households in *Sacrificio* therefore believe that adaptation should be supported by the CBR, since the latter drives their vulnerable condition.

6.2.4 Cluster 4, the "empowered households"

Rainfall variability is the most frequently mentioned harmful stress by this cluster, as in Cluster 2. 13 out 34 reported adaptive responses are then confronting this climatic stress. Nevertheless, a considerable number of households reported only being affected by conservation regulations. Households in this cluster widely believe that adaptation is feasible and desirable, but *Sacrificio*'s "landowners" consider some adaptation options to be less feasible than others due to their insecure tenure status (e.g. building infrastructures in their agricultural fields). A large percentage of households (89.5%, 17 hh) reported their willingness to adapt by implementing new productive projects (e.g. ecotourism or handcraft sales), vegetable cultivation, livestock rearing and other activities. Moreover, some households would like to engage in conservation activities. This reflects that these

empowered landholders gear their efforts towards both diversifying, innovating and intensifying their livelihood activities, especially across *ejidatarios*.

Households in Cluster 4 are characterised by a high adaptive capacity in comparison to the other clusters, presenting high economic, material and natural assets (see section 5.2). These households have then the greatest ability to gain access to benefits from their natural and social-political resources, which is translated in responses such as buying land out of the community or building infrastructures in their agricultural fields. Moreover, their access to powerful positions in the community reinforces their access to privileged knowledge. This explain that households of this cluster from *Once* are the only one engaged in the commercial agreement to sell chilli or involved in the experimental project for agriculture innovation both led by CRIPX.

The relatively high economic status of these households means that they are able to engage in a diverse portfolio of livelihood activities, which reduces their dependence on external labour in comparison to other clusters. Several households from *Once* in fact control a large proportion of the wage work available in the community. Furthermore, government investment in improving the condition of paths leading to the communities' agricultural fields has enabled these landholders to intensify on-farm practices and increase their productivity. Therefore, this is the only cluster that did report to sell dry chilli to gain a better farm gate price because they have found alternatives to not exclusively depend from this cash crop. However, households in this cluster are still constrained by intermediaries' control over farm gate prices, despite local productive associations' attempts to negotiate better market conditions for them and to provide relevant training. For those household in *Once*, land titles also allow these households to apply for a considerable number of subsidies aimed at improving livestock or farming activities.

6.3 The double-edge role of conservation for local adaptation

Conservation initiatives can facilitate local adaptation through labour and/or income-earning opportunities that can impact positively on households' well-being (Christensen 2004; Muradian et al. 2013; van de Sand et al. 2014), but they can also become a barrier to adaptation, given the restrictions they impose on access to and use of natural resources (López-Carr et al. 2012; Reyes-García et al. 2013; Speelman et al. 2014; Ruiz-Mallén et

al. 2015a) (see section 2.4). Conservation initiatives and restricted natural resource management regulations can influence the ability of a household to deploy and use different available assets. The following subsections describe the influence of conservation initiatives as an "external force" that can either facilitate or hinder agency and adaptive responses in both communities. This analysis is conducted at community level because conservation regulations and practices exert their influence equally across households within each of the studied communities regardless of social differentiation patterns. Moreover, it was only possible to examine the influence of "win-win" conservation initiatives in agency and adaptation in *Once*, since *Sacrificio* does not have such conservation programmes. Nonetheless, this analysis at community level is, when possible, rewarded with insights from the cluster-based analysis performed above and in the previous chapter.

6.3.1 *Sacrificio* and the Calakmul Biosphere Reserve

The CBR follows the principles established by the UNESCO Man and Biosphere Programme, according to which biodiversity conservation and the sustainable development of local communities living within and around its designed territory should be harmonised and pursued (UNESCO 2008). Under these premises, the CBR should be an example of an "inclusive" conservation governance system, where any relevant stakeholders, including communities, should be engaged in the design and implementation of sustainable livelihood activities (see section 2.4). However, and as highlighted in previous chapters, my research findings reveal the complex relationship that the CBR has maintained with *Sacrificio*, showing the constraining influence of this protected area on household and collective agency, and the existing adaptive processes.

In *Sacrificio*, and particularly among "landowners", the CBR is commonly perceived as an external adaptation barrier due to its negative influence on settlers' ability to gain formal property titles. The CBR was responsible for the resettlement process that formed this community and, subsequently, a mistake in the design of the perimeter of *Sacrificio* resulted in the standstill of the land entitlement process because a small portion of the provisionally granted lands was still inside the CBR core area I (see section 4.1). To date, "landowners" reported to have unclear information about the responsibilities of the CBR in their unsuccessful resettlement, and the subsequent duty to the community. Interestingly, however, these households are informally recognised as "landowners" by

the CBR. The use of land within the perimeter of *Sacrificio*[20] is thus allowed by the CBR, which Director argues that is trying to honour an unofficial "social deal" (CBR, Interview guide 3, #2). Nevertheless, these "landowners" are not aware of this informal deal, and refuse to abide by official land regulations. In practice, this means that "landowners" and landless dwellers from *Sacrificio* continue to use lands within this perimeter (i.e. those lands from which they might receive a property title in the future) and lands outside (i.e. those lands that belong to the CBR core area I and will be excluded from the formal titling process). The use of natural resources within the CBR core area I has nevertheless increased surveillance of the community's lands and the surrounding forests by the PROFEPA. As a representative in charge of the forest sector in Campeche argued, "*the use of protected resources for consumption could be justified in most cases, while commercialisation should not be allowed*" (SEMARNAT, Interview guide, 3 #18).

The fact that land titling demands have still not been dealt with by the CBR or any other government body influences local agency for adaptation. *Sacrificio* is currently a community characterised by weak governance, low trust, and accountability, which are factors deeply rooted in the resettlement process of 1999 and its unfolding consequences. This is not a trivial issue, since the resettlement has triggered several social conflicts that still persist, but at a lower intensity (see section 4.1). These internal conflicts have furthermore undermined its belief in adaptation as a feasible solution to overcome their overall vulnerable condition and improve their well-being. In this sense, there is a widespread understanding that adaptation should be - indeed, must be - supported by external organisations including the CBR as the agent responsible for their resettlement. In particular, households in Clusters 1 and 3 question whether the CBR should exist, and demand support to remedy the historical damage caused.

These households consequently face limitations when applying for external support, particularly for some subsidies related to productive activities, and to conservation initiatives, except restoration programmes (SEMARNAT, Interview guide 3, #18). The lack of land titles, however, has not limited external support from the CBR. It has supported the community through two subsidy-oriented programmes: *Brecha Cortafuegos* programme (i.e. equipment and economic rewards provided to the community to develop a fire-break between the boundary of the community with the CBR

[20] The current CBR administration is promoting modification of its boundaries in order to formalise this deal. At present, this modification is awaiting review by the federal government.

core area I), and the Programme for the Conservation of Creole Maize (PROMAC), commonly known as Maíz Criollo (i.e. economic reward and creole seed provision for cultivating maize in the dry season). Both subsidies are shared equally between households, regardless of their tenure status. Despite the relevance of this source of income for households in Clusters 1 and 2, interviewees argued that none of these programmes provides a sufficiently high income-gain to significantly increase household material assets or encourage livelihood diversification. Indeed, as the CBR's Director acknowledged, the poverty and marginalisation of these households is so extensive that every subsidy is aimed at covering households' most immediate needs (CBR, Interview guide 3, #2).

The CBR could become a source of labour and an instrument for improving the access to markets, with ecotourism activities or sustainable management of forest and non-forest resources through logging concession or encouraging Environmental Management Units (UMAs in Spanish) for conservation and/or sustainable exploitation. However, none of these activities have ever been proposed by the CBR in *Sacrificio* or demanded by the community. Instead, the CBR provides very few labour opportunities to local people. The CBR marginally contributes to reducing households' needs *Sacrificio's* households, which these households respond to by looking for wage labour opportunities outside *Sacrificio*. Furthermore, as a result of the historical conflicting relationship between *Sacrificio* and the CBR, households from *Sacrificio* across clusters reported a marginal interest in sustainable forest management and conservation initiatives as potential adaptation actions. Only two households in Cluster 3 and one in Cluster 4 showed interest in reforestation practices, while 22 households across clusters would like to invest in livestock rearing.

Far from its official participatory and collaborative governance principles, the CBR is locally identified as a source of stress to which households reported specific responses to reduce experienced and envisioned damage (see section 6.1). In short, the CBR restricts rather than enables local agency and adaptation in *Sacrificio*. Households resist conservation regulations: they demand land tenure rights, and they continue to access and use resources in conserved target areas. Under these circumstances, households continue to engage in subsistence agriculture, migrate for labour opportunities, and those more able to mobilise their already limited resources diversify their livelihoods.

6.3.2 *Once*, the Calakmul Biosphere Reserve and other conservation initiatives

As noted in section 4.1, the *ejido Once* is partially located inside the CBR buffer area and next to the CBR core area I. As in *Sacrificio,* the CBR should provide an institutional framework that promotes biodiversity conservation and sustainable livelihoods (see section 2.4) (UNESCO 2008). My findings, however, show that the influence of the CBR on enabling sustainable livelihood practices is marginal, whereas its conservation regulations constrain household and collective agency, and the resulting adaptive processes.

In *Once* the CBR is also commonly perceived as an external barrier to implementing adaptation because its conservation regulations forbid access to and use of both the CBR core area I and the buffer zone. The highly restrictive conservation regulations have strongly constrained the opportunities of landless households to gain access to land or to obtain permits from engaging in sustainable conservation activities, such as beekeeping. Similarly, the conservation regulations on the use of the CBR buffer zone have limited agriculture and livestock practices, since most agricultural fields overlap with this area. This means that *ejidatarios* have seen their agency and adaptive responses constrained by restrictions to permanent cover change. This restriction mainly affects the use of heavy agricultural mechanisation and the practice of slash-and-burn for agriculture, for which farmers need to apply for permits. In fact, the first permanent inhabitants of *Once* reported that they were not consulted by the government about the implementation and the boundaries of the CBR before 1989, or about the implementation of the first management plan in 1999. To date, households from *Once* across clusters reported continuing to be poorly informed about their rights and duties in relation to the CBR.

As in *Sacrificio*, the CBR has given limited support to local agency and adaptive capacities in *Once* through one of the incentive-based programmes mentioned above, i.e. *Brecha Cortafuegos.* The resulting annual payment is also equally divided across households, but they reported that this payment is small, and consequently has no significant impact on their investment capacity. The CBR has also promoted the creation of a permanent team for fire prevention in *Once*, which represents a significant income-earning activity for approximately a dozen households, regardless of land tenure rights. Apart from these two incentives, households reported that the CBR has historically provided very few labour and training opportunities to this community, as in *Sacrificio*.

In particular, *ejidatarios* complain about the CBR's limited support for sustainable productive activities, such as ecotourism and non-timber forest products. In fact, only four *ejidatarios*, in Clusters 3 and 4, saw the CBR as a potential opportunity for ecotourism.

Additionally, *ejidatarios* in *Once* are enrolled in two different "win-win" conservation initiatives located on *Once*'s lands - PES and EC programmes. Both federal government programmes focus on climate change mitigation and forest conservation, while financially compensating local users for the opportunity costs of preserving their local forest cover as carbon sinks and biodiversity reservoirs. These two conservation programmes also influence household and collective agency and adaptive capacities. Unlike the CBR, these "win-win" conservation initiatives are recognised by *ejidatarios* from *Once*, mostly in Cluster 4, as a significant boost for their economic capacity, which leads to relatively higher levels of investment in new productive activities and related equipment. In the EC programme in particular, conservation payments are tied to specific restoration activities. This divides opinion among *ejidatarios* in terms of considering this programme as an enabler or constraint, according to households' workforce-payment balance.

Although conservation payments have significantly increased the *ejidatarios'* household economy, only two *ejidatarios* from Cluster 4 declared an interest in conservation-related initiatives as a means for adaptation. Despite this marginal interest in ensuring forest conservation initiatives, *ejidatarios* acknowledged that they would continue to engage with more economically rewarding "win-win" conservation initiatives. Moreover, these conservation payments have also reinforced the belief in adaptation as a feasible and desirable solution among *ejidatario's* households due to the above-mentioned increased investment capacity. This has enabled them to invest in livestock rearing or mechanised agriculture rather than ensuring conservation initiatives. Conservation payments have been crucial in intensifying and diversifying on-farm livelihood, as most *ejidatarios* in Cluster 4 reported.

The fact that both incentive-based programmes are based on land ownership means that landless households, mostly represented in Clusters 2 and 3, depend on *ejidatarios'* decisions to obtain benefits from these initiatives (see section 4.1). Moreover, the overall lack of conservation enforcement among both landless members and *ejidatarios* has

triggered the implementation of more restrictive rules regarding access to and use of communal forests (see section 4.1). This unexpected decision was taken by the *ejidal* assembly due to a fear among *ejidatarios* of being sanctioned by governmental administrations. Only agricultural fields can currently be used for forest and non-forest exploitation. Landless households therefore tend to be less optimistic about their adaptation options since, as I discussed in section 5.4, the *ejidatarios*' enrolment in "win-win" conservation initiatives has exacerbated their dependency on *ejidatarios'* decisions, deepening social divisions and fuelling conflicts over access to and use of communal forests.

To conclude, in the light of the reported costs and benefits of the studied conservation initiatives, households in *Once* also identified conservation rules and enforcement from such initiatives as a source of stress to local livelihoods, and reported specific responses to reduce current and future damage from both CBR and "win-win" conservation initiatives. On the one hand, some households resist these conservation regulations by free-riding, as I detailed in section 5.1, and by doing so they have debilitated communal resource governance. On the other hand, enrolment in "win-win" conservation initiatives has allowed *ejidatarios* to offset any losses related to downward chili prices with new conservation-driven revenue generating activities, and even compensate for what *ejidatarios* consider to be their unpaid preservation of the forest since they settled in *Once*. However, *ejidatarios* have attempted to increase conservation compliance, while restrictions to access to and use of communal forest have increased the vulnerability of landless households. As a result, landless households have to deal with not only the conservation regulations of the CBR, but also those associated with the PES and the EC programmes, as well as the internal rules to ensure those conservation initiatives.

6.4 Discussion

This chapter turns now to address the third, and last, research question of this dissertation, "*How are local adaptation and household agency influenced by conservation initiatives in a context of multiple stresses?"* This discussion provides, first, insights into how responses to multiple stresses might be considered (un)successful; second, it discusses the role of human agency in analysing the ability of households to transform their adaptive capacity into adaptive responses; and third, it considers the double-edge role of the

conservation initiatives studied in facilitating or inhibiting household and collective adaptive responses.

6.4.1 Adaptation success to multiple stress

My findings demonstrate that households in both communities are active agents in dealing with the identified climatic, market and conservation stresses. They diversify their occupational activities and practices in response to both climatic and market stresses. They exchange their resources (human and natural) to gain new access to markets, and/or ration their resources to confront these climatic, market and conservation stresses. These are some examples that point in the same direction showing that natural-resource dependent societies, such as *Once* and *Sacrificio*, are engaged in a process of livelihood diversification and market openness as a result of globalisation processes (Ellis 1999; Borras et al. 2012).

Although oriented by past experiences (Adger et al. 2004; Nelson et al. 2007) and future expectations (Brown and Westaway 2011), these locally-developed adaptive processes might have undesired consequences for local livelihoods (Muradian et al. 2013; Börner et al. under review). Longitudinal and context-specific studies, in particular, have highlighted the negative trade-offs of some of these past and current responses undertaken on multiple scales on ecological and social systems (e.g. Fazey 2011; Juhola et al. 2016). For instance, vulnerability theory suggests that adaptation implies a cascading decisions across actors, from individuals to collectives (Adger et al. 2005). My findings further reveal that adaptation to multiple stresses implies a cascading of adaptive responses across these stresses. As a result, a household in either of the two communities wishing to begin livestock rearing as an alternative commercial activity to chilli production becomes sensitive to rainfall variability and conservation regulations, due to water and land demand for livestock and natural resource use restrictions aimed at biodiversity conservation. Adaptive responses modify households' current conditions, which may expose human systems to new stresses, may intensify their sensitivity to new and old stresses and/or may reduce their adaptive capacity to potentially face such stresses. This cascading effect means that effectiveness (the goal to achieve) and efficiency (the cost-benefit balance) of adaptation are re-oriented over time with each response.

The capacity to manage the trade-offs arising from these cascades of adaptive responses to multiple stresses depends on households' capacities for planning, as well as their sense

of collectiveness (Mosimane et al. 2012). Recent research has provided new evidence identifying collective adaptive capacities (Mountjoy et al. 2013), or more specifically the relationship between transformative processes and social identity (Marshall et al. 2012). Evidence from this research suggests a remarkable tendency to engage individually in adaptive responses and to facilitate vicious cyclic processes of short-term adaptive responses (e.g. annual self-evaluation for chilli cultivation instead of developing a household or a collective response to avoid the household's dependence on this cash crop). This finding highlights the weakness of the local governance systems studied in this dissertation (see section 4.1), which are characterised by low trust, social cohesion and accountability, and the challenge to collective transformative processes. As Adger and colleagues (2005) note under similar circumstances, management of collective resources entails a high transition cost for gaining trust and negotiating stakeholders' values and expectations about resource uses and regulations, which reduces the efficiency of these adaptive responses.

In previous chapters I have highlighted the presence of socially differentiated groups, whose heterogeneity makes collaboration between them difficult. This is not a trivial matter, because as Thomas and Twyman (2005) show, responses aimed at reducing damage by a particular group in a society may unexpectedly reinforce the vulnerability of another socially differentiated group. Adaptive responses may thus increase socio-economic and political inequalities at community level and over time. The analysis of (un)successful adaptive processes should therefore be also informed by principles of distributional and procedural justice across those scales (Adger et al. 2005; Thomas and Twyman 2005). Insights from this research show how several responses regarding the access and the use of land by households holding land rights influence the area and the quality of land available for landless households. In *Once*, for example, increased investment in livestock rearing requires a large area of land due to the soil's low bearing capacity. This means that the access to land among landless households seems to be limited by the diversification of on-farm practices among *ejidatarios*. In *Sacrificio*, the intensification of agricultural practices together with the high demographic pressure, the adverse topography, and the soil's low quality are reducing the quantity of land available for agriculture. Consequently, land available to "landowners" for sharing with landless households is being reduced. Additionally, in the two communities studied, but particularly in *Once*, collective decisions regarding land management are decided at the

assembly where the voices of landless households are not represented (see section 4.1). This situation undermines the landless' political empowerment and their opportunities for recognition of their increasing vulnerability at both community level and beyond.

6.4.2 The role of human agency

As regards the role of human agency for adaptation, the findings of this chapter suggest that households' adaptive capacity is strongly shaped by the social and the legal status that households have (see section 5.2). Contrary to what is expected, however, households with radically different adaptive capacities have similar responses in a context of equal exposure. Moreover, households with similar adaptive capacities develop different adaptive responses under similar exposure conditions. This shows that having assets is not the same as the ability to mobilise them. I therefore argue that human agency has a role as an explanatory link between adaptive capacity and local adaptive processes (see section 2.3) (McLaughlin and Dietz 2008; Brown and Westaway 2011).

Indeed, the analysis of household agency to identify the ways in which households freely decide between their adaptation options suggests that, first, the envisioned adaptive responses are thus initially shaped by a range of socio-cognitive factors related to households' recognition of being damaged by a stress, their adaptive appraisal, and their willingness and ability to deal with harmful situations (e.g. Grothmann and Patt 2005; Brown and Westaway 2011; Frank et al 2011). For instance, almost half of the reported adaptive responses are oriented primarily at coping with market stress (see Table 6.1). This research finding argues that damage to cash crop production is the primary concern (see section 4.3), as well as the increased motivation for implementing adaptive responses (e.g. Tucker et al. 2010). Nevertheless, as I published elsewhere (Ruiz-Mallén et al. 2015b) this finding contrast with the opinion of the participants in the scenarios focus group where rainfall variability and conservation regulations were identified as main drivers of change, underestimating the influence of the uncertainty about cash crop prices. Evidence that highlights the relevance of exploring people's perceptions across scales for assessing local willingness for adaptation.

In this regard, the sense of control over household assets and the ability to mobilise them is reported as a key factor in households' adaptive appraisal (e.g. Grothmann and Patt 2005; Nelson et al. 2007). In *Once* and *Sacrificio*, households' desire to implement adaptive responses may be positive if it is a result of a personal decision between the

potential options, but it may be considered negative when it is perceived as the only solution. This is consistent with the results of a growing body of research that has discussed the drivers and the (lack of) success of wage labour activities as a means for adaptation (e.g. Black et al. 2013), particularly when such activities involve the migration of at least one household member (e.g. López-Carr et al. 2012; Warner and Afifi 2014). Insights from my research suggest that while some households are willing to migrate temporarily to improve their human and economic capacities, other households feel forced to do so to survive because of their limited opportunities to earn cash from their own on-farm activities and the scarce demand for labour within the community. Most households in *Sacrificio* reported that migration is currently essential for their subsistence rather than an option, regardless of their land tenure.

Additionally, households' willingness to engage in adaptive processes, such as diversification or intensification of their livelihoods, seems to be deeply rooted in social-cultural issues (Thronton and Manasfi 2010; Adger et al. 2012), such as what they understand by wealth, fairness, or occupational identity, which in natural resource-dependent societies is mostly oriented towards on-farming activities. As I noted in section 4.3, landholders are unwilling to give up maize cultivation because it is a cultural symbol of their identity as farmers, which guarantees their subsistence and in turn makes them resistant to market pressures (Schoomk et al. 2013; Ruiz-Mallén et al. 2015b). This finding echoes Marshall and colleagues' (2012) remarks that social and occupational identity can become critical barriers to individuals' willingness to undertake transformational activities.

As mentioned earlier, the presence of socially differentiated groups within communities emphasise the inherent connection between household and collective agency illustrated in the jealousies apparent in *Sacrificio* and the political marginalisation of landless households in *Once*, which significantly reduce those households' belief in adaptation and thus their ability to adapt. For instance, although interviewees often regret working individually when negotiating with chilli intermediaries, they are not enthusiastic about developing collective adaptive responses in other activities (see section 4.1). In this sense, disempowered households, particularly in Clusters 1 and 2, and sometimes in Cluster 3, are strongly influenced by this collective failure of agency, which undermines their already limited belief and willingness to adaptation.

Second, local agency influences how individuals achieve adaptation through informed and reasoned decisions about their available resources and their ability to mobilise them (Brown and Westway 2011) based on their power to gain, control and maintain such resources (Ribot and Peluso 2003). Households may therefore arrive at the same adaptive process in different ways. For example, households across clusters cope with uncertainty about chilli prices by diversifying their livelihoods. However, households in Clusters 1 and 2 seem to be significantly limited to raising cattle, beekeeping or joining the fire prevention team. These limitations are based on the fact that these households own fewer assets and their ability is limited or very limited. As a result, they diversify their livelihoods mostly working abroad and raising sheep with external support. To overcome their limited access to resources, households across clusters also engage in multiple adaptive processes through social networks (Adams et al. 1999). This illustrates that landless households have access to land for agriculture, but only a few of them are able to farm livestock, keep bees, or hunt and collect forest resources.

Based on this evidence, both households' access to assets and their ability to deploy them adequately have a strong influence on adaptive responses. As argued by Ribot and Peluso (2003), this thesis advocates the need to identify rights-based, structural and relational mechanisms that generate and reinforce unequal access to rights and resources based on power relations (e.g. Adger and Kelly 1999; Leach et al. 1999; Scoones 2009), as well as the mechanisms related to behavioural aspects. Some landholders in both communities, especially belonging to Cluster 1 and 2, have access to land through right-based mechanism, but lack of capital, technology or even knowledge undermine their power to use for their benefit those resources. Or conversely, landless households who lack of right-based mechanisms for accessing to land, however find alternative structural and relational mechanisms for gaining access, where social mechanisms play a key role on empowering them. This finding hints at the existence of both empowered and disempowered households regardless of their tenure status and across clusters and communities.

6.4.3 The double-edge role of conservation initiatives

This study also sheds light on how the conservation initiatives studied (i.e. the Biosphere Reserve, the PES programme and the EC programme) influence households' available resources and mechanisms for gaining, controlling and maintaining access to benefits

from local resources and institutions in this specific context and time. This chapter has provided key insights for understanding why these conservation initiatives act as enablers or constraints on human agency and adaptive capacity (Muradian et al. 2013; Costedoat et al. 2016; Börner et al. under review), thus influencing local adaptive processes and responses (Kaimowitz et al. 2003; López-Carr et al. 2012; Ruiz-Mallén et al. 2015a).

On the one hand, conservation initiatives such as the PES and EC programmes enable household adaptation by providing new sources of income (e.g. Christensen 2004; Corbera et al. 2009; Speelman et al. 2014). Households invest these conservation revenues in implementing the envisioned livelihood diversification processes, which as mentioned above, are mostly oriented towards dealing with uncertainty about chilli prices. Since livestock rearing is by far the most valuable livelihood across clusters (see section 6.2), interviewees reported spending these conservation revenues on this activity. Paradoxically, this means that conservation initiatives are indirectly promoting the increase in livestock farming instead of more sustainable and less climate-sensitive livelihoods, such as beekeeping. Similarly, Turner II and colleagues (2001) link PROCAMPO payments with the expansion of pasture, even when it is not used. For beekeeping in particular, conservation initiatives can contribute to reducing the high transition costs that interviewees reported as being involved in acquiring this expertise and a high perceived risk for this household economic investment. However, this support is still marginal in the two communities studied.

On the other hand, these conservation initiatives studied have partially constrained household and collective agency and adaptation by interfering in the local governance system, and thus, in who access to natural resources and how to use them (Adams and Hutton 2007; Corbera et al. 2009, Börner et al. under review). The analysis of household adaptive responses together with local environmental histories in section 4.1 have reflected the confrontation between the development expectations of these migrant families and the government's conservation goals, which undermine the legitimacy of local conservation approaches (e.g. Adger et al. 2003; Kaimowitz and Sheil 2007; Bunce et al. 2010). These migrant inhabitants arrived there seeking land tenure rights, and their offspring have been growing knowing that they are not allowed to appropriate, or even use, free lands because they are located within the CBR core areas.

In *Sacrificio*, the historical conflict with the CBR provides a means to collectively legitimate the lack of conservation compliance, supporting the use of their provisional but unofficial lands, and even resources within the core area I (see section 4.1). In *Once*, the internal criminalisation of using target areas conserved under PES and EC programmes has increased every year because *ejidatarios* obtain conservation revenues, and they consequently have an interest in reinforcing conservation compliance (see section 4.1 and 5.1). While *ejidatarios* complain about the use of conserved target areas by landless households, the latter group regrets the concentration of economic benefits by *ejidatarios* and the criminalisation of past social conventions that gave them to access to forest resources on communal lands for subsistence purposes. Under these circumstances, landless households demand land within the CBR core area I or the opportunity to manage it for subsistence and commercial purposes, such as beekeeping.

In sum, my findings confirm that conservation activities in the two communities studied exacerbate inequalities in access to and use of target resources (e.g. Corbera et al. 2007; Bulte et al. 2008; Börner et al. under review), because landholders, who are mostly older and male, control the collective "bundle of powers". In *Once*, PES and EC payments reflect the privileged position of households with land tenure rights, which are mostly classified in Cluster 4, the "empowered households". As shown elsewhere (Thomas and Twyman 2005; Wunder 2005; Corbera et al. 2009), conservation initiatives are also unexpectedly reinforcing existing power relations due to the generation of inequalities in the distributional and the procedural mechanisms for accessing to conservation benefits. This, in turns, has a remarkable influence on household agency for undertaking adaptation, and overcome household and collective vulnerability patterns.

6.5 Summary

This chapter has outlined the adaptive processes and responses to which households are embedded to confront the locally perceived stresses, as well as the influence of the studied conservation initiatives in their agency for undertaking adaptation. The insights in this regard have shown that households and communities are active agents in dealing with the three locally identified stresses – i.e. uncertainty about chilli prices, rainfall variability, and conservation regulations. A myriad of adaptive responses have been identified across households and communities dealing with one or multiple stresses. Indeed, the research findings have revealed that households are often tied to a cascade of adaptive processes

that have unexpected effects in terms of the exposure of these households to new or even more intense stresses, and critically questioning the success of household and collective adaptive responses in a context of multiple stresses.

This chapter has also highlighted the relevance of human agency for understanding how and why individuals and socially differentiated groups implement one and no other adaptive process and response. In this regard highlight that less able and empowered households (Cluster 1 and 2) tend to have a lower belief in adaptation as a feasible and desirable solution to overcome their vulnerability in compare to more able and empowered households (Cluster 3 and 4). Despite that the potential support and the value of wealth or occupational identity play a key role in households' willingness for adaptation mostly oriented to diversify their livelihoods and intensify livestock rearing. Nevertheless, to achieve that adaptive purpose households deploy their available assets in different ways within, or challenging, the social structures of the social-ecological system. The previously identified factors differentiating agency across clusters (i.e. land tenure rights and personal skills) are here key for understanding the "bundle of powers" distributing access to benefits unequally across clusters. Moreover, the influence of external actors has a remarkable influence orienting the household adaptive appraisal and facilitating or inhibiting households' ability.

This chapter has finally argued that the studied conservation initiatives (i.e. CBR, and PES and EC programmes) have played a key double-edged role in local agency and adaptive capacities, which ultimately have an influence over local adaptive processes and vulnerability patterns. On the one hand, they facilitate new subsistence and commercialisation practices by providing financial revenue. On the other hand, the unequal distribution of conservation benefits deepens the social differentiation across households, exacerbating internal conflicts, weakening collective action, which ultimately reinforce socially differentiated groups. This is particularly evident in *Once*, where "win-win" conservation initiatives have constrained landless adaptation not only due to their restrictions on use of natural resources, but also because of fuelling conflicts with *ejidatarios*, which exacerbate social hierarchies and undermine collective empowerment. In short, distributional and procedural justice regarding conservation regulations need to be further assessed to minimise social and political conflicts while conservation legitimacy is ensured. This research provides insights advocating a review of the mechanisms that participatory and collaborative conservation initiatives are

promoting in order to achieve successful and sustainable adaptive livelihoods in rural areas linked to conservation initiatives. The following chapter concludes this dissertation by providing a summary of findings and drawing some theoretical and methodological implications derived from this research, as well as some potential areas of future research.

7 Conclusions

A deepening process of social globalisation has contributed to increase the connection between rural and urban areas, and has resulted in multiple social-ecological impacts over rural households and rural environments around the world. In parallel, a new generation of conservation initiatives, including "inclusive" protected areas and incentive-based conservation approaches such as payments for ecosystem services, have contributed to change resource access and use patterns. This multi-faceted context has influenced rural households, which are undergoing rapid, irreversible and unprecedented changes.

This research has analysed how two communities located in and around Mexico's Calakmul Biosphere Reserve differ in their vulnerability patterns and adaptive processes to confront locally perceived stresses. Using a mixed-methods approach, this dissertation has first investigated the environmental histories and livelihood activities to identify the most relevant locally perceived stresses on local livelihoods. Second, it has analysed households' sensitivity to such stresses and identified the communities' main adaptive capacity factors, using a Household-level Vulnerability Index (HVI) and insights from grounded research. Third and finally, it has explored in detail how conservation initiatives have influenced local agency for adaptation. The following sections summarise the main research findings and present the theoretical and methodological contributions of my work. Some policy implications of the research findings and future research avenues are also drawn.

7.1 Summary of findings

Grounded on political ecology, this dissertation has generated new empirical data to shed light onto the relationship between social vulnerability and adaptation in a conservation context. In Chapter 4, findings from local environmental histories have revealed the various perceived stresses that the studied communities face at present (i.e. the uncertainty about chilli prices, rainfall variability, and conservation rules) and the ensuing analysis has shown that household and community vulnerability patterns to such stresses are strongly influenced by Mexico's land tenure counter-reforms and the promotion of conservation initiatives.

In Chapter 5, the measurement of household vulnerability patterns has shown the relevant influence of conservation rules and enforcement on households' livelihoods, as well as the pivotal role that tenure rights and personal skills (i.e. health, age, knowledge, motivations and entrepreneurship) play in differentiating household potential adaptive capacities. Nevertheless, this chapter has underscored the importance of understanding social vulnerability as a strong subjective condition, given the apparently contradictory result found when "perceived" and "measured" vulnerability are compared. Current vulnerability is a result of households' assets, past experiences, and adaptations that ultimately have an impact of how people experience and interpret harmful situations.

Finally, in Chapter 6, findings have revealed that households are actively engaged in a process of livelihood diversification in order to confront such perceived stresses. Furthermore, it has been shown that adaptation trade-offs exist in the studied communities: certain adaptive responses to one specific stress (e.g. livestock rearing) have triggered a cascade of adaptive responses that exacerbate in turn the vulnerability to other stresses or limit the capacity to adapt of other households. This chapter has also demonstrated that socio-cognitive factors and the unequal distribution of power are tied to land tenure rights. Households' ability and willingness for adaptation is then socially differentiated across and within communities. Conservation regulations and enforcement are then identified as key for enabling or constraining household and collective ability for adaptation. Conservation initiatives have further exacerbated social differentiation and fuelled internal conflicts, instead of fostering local flexible and sustainable livelihood practices.

7.2 Theoretical contributions

This dissertation makes four distinct theoretical contributions. First, it advances the research fields of social vulnerability and adaptation by integrating the literature of political ecology of conservation. Scholars have highlighted the potential negative impacts of conservation initiatives over rural livelihoods worldwide (Bunce et al. 2010; Muradian et al. 2013; Börner et al. under review). However, such analyses have looked at conservations initiatives as contextual factors rather than active processes influencing local vulnerability and adaptive responses. In this regard, previous social vulnerability and adaptation studies lack in-depth analyses of whether and how conservation initiatives represent a stress to rural communities and what is their role in local adaptation. To fill

this gap, in this thesis, conservation governance has been approached as a cross-cutting element in the analysis of vulnerability and adaptation throughout all empirical chapters (Chapter 4, 5 and 6).

Second, the dissertation demonstrates that rural societies are simultaneously exposed to different social and ecological stresses derived from the globalisation process, building upon two seminal works (Adger 1999; O'Brien and Leichenko 2000), and in doing so it adopts a constructivist approach that permits to understand the key stresses that individuals and rural societies face through local perceptions. Chapter 5 shows the synergic effect of these identified stresses: in *Sacrificio*, vulnerability to rainfall variability and uncertainty about chilli prices translates into a high dependency on one single cash crop, while in both communities vulnerability to conservation regulations and rainfall variability turns into the intensification of agricultural practices and the resulting limitation of available lands. Furthermore, the relationship between the individual risk appraisal and the implementation of adaptive responses undertook in Chapter 6 also reveals that, in order to adapt to one stress, households can generate a cascade of adaptive processes in order to deal with the trade-offs resulting from this initial adaptive response.

The third theoretical contribution of this dissertation relates to the fact that there is not a direct and simple relationship between households' sensitivity and adaptive capacity, suggesting the presence of unsuccessful adaptive responses or also called mal-adaptations. The analysis of the Household-level Vulnerability Index (HVI) seems to contradict the intuitive idea from the literature on human adaptation by which the more able households may deploy their assets in adaptive responses that decrease their sensitivity or their exposure to the source of damage (Eakin and Bojórquez-Tapia 2008; Notenbaert et al. 2013). In this regard, conservation rewards facilitate the intensification of agricultural practices and livestock rearing in *Once,* in response to volatile chilli prices. However, in doing so, households increase their sensitivity to rainfall variability and conservation regulations. Therefore, the evidence of these adaptation trade-offs opens the door to further explore whether and how households engage in maladaptive responses that exacerbate their vulnerability (Adger et al. 2005; Thomas and Twyman 2005; Barnett and O'Neil 2010).

Fourth, and last, this research contributes to a deeper understanding of the linkages between vulnerability and adaptation patterns from the perspective of human agency and

structuralism (McLaughlin and Dietz 2008; Brown and Westaway 2011). Adaptation is not the result of one combination of assets (Nelson et al. 2007) but a context-specific process undertaken in a particular time and space where psychological, political, cultural and historical experiences play a key role (Adger et al. 2005; Chowdhury and Turner 2006). Research on human agency implies considering humans as active agents who decide between feasible options and implement such adaptive responses (McLaughlin and Dietz 2008), influenced by such experiences as well as by what others have called "bundles of powers" (Ribot and Peluso 2003). The studied communities have been found to be heterogeneous entities, where such powers are unevenly distributed and critically mediated by the tenure regime and household property rights. The latter critically limit the landless' access to political power and deepen their vulnerability condition.

7.3 Methodological contributions

This research has two relevant methodological contributions. First, it shows the usefulness of applying a mixed-methodology for assessing vulnerability patterns at household level. The use of quantitative and qualitative data as complementary perspectives provides a better understanding of the gap between the current degree of damage households are facing (measured vulnerability) and the degree of damage households believe themselves to be experiencing, based on their past and recent experiences (perceived vulnerability). Vulnerability is thus a perceived condition (O'Brien and Wolf 2010), shaped by local environmental histories (O'Brien et al. 2004; Adger 2006).

Second, this research contributes to the quantitative assessment of household vulnerability patterns by designing and analysing a Household-level Vulnerability Index (HVI). The HVI has been designed in order to accommodate three distinctly and locally perceived stresses, drawing on previous research (O'Brien et al. 2004). The design and application of the HVI, however, should not omit its limitations. I acknowledge that vulnerability is a dynamic condition that varies over time and space (Adger et al. 2004) and, as such, it cannot be fully captured with a time-bound index. Limited resources and time did not enable me to collect longitudinal household data and calculate the HVI several times over a longer period. They also constrained my ability to collect data from both male and female household heads to calculate the index, which has been calculated with the information provided by the former only. However, in order to address such

caveat, I encouraged female household heads to participate in other research activities (i.e. semi-structured interviews and focus groups) and used such information to contrast and contextualise information gathered from male household heads.

7.4 Policy implications and future research

As argued earlier, this research has contributed to better understanding how conservation initiatives influence rural environmental governance systems, which ultimately impact on local vulnerability patterns and adaptation options. Therefore, from a policy perspective, its findings suggest that conservation policies and practices should make an effort to identify the drivers of local vulnerability and people's willingness and ability to adapt, being sensitive to social differences within communities. There is also a need to legitimise conservation institutions by increasing the participation of local communities, and particularly of the landless, in natural resource management, and by specifically addressing people's adaptation needs.

This may also allow to identify factors encouraging maladaptive practices in relation to biodiversity conservation and rural development, and to revert land management trends that impact negatively on conservation objectives. This is the example of the agricultural and livestock intensification due to the limited access to markets and the weak promotion of sustainable livelihood practices across landowners and landless.

Related to these insights above, the research findings also hint at the need to integrate in conservation institutions social and political mechanisms based on distributional and procedural justice principles, which can help bridging the gap between winners and losers while increasing the legitimacy of conservation policies (Lemos and Agrawal 2006). A more socio-politically grounded and justice-sensitive conservation can also contribute to limit the extent to which certain actors, such as reserve management boards or NGOs, unconsciously reinforce social hierarchies and patterns of inequality across households and communities (Christensen 2004; Corbera et al. 2009).

As regards future research, there is a need to investigate if other forms of so-called "inclusive" and incentive-based conservation initiatives, such as eco-tourism or voluntary conservation areas, also result in similar effects on the vulnerability and adaptive responses of households and communities. Additionally, when replicating this research in other contexts, more emphasis could be placed on gender differences and rural-urban

interdependencies. First, gender issues have been recognised as an emerging area of research within the field global environmental change studies, and specifically in those assessing social vulnerability. Future research should go beyond how women interpret their environment and focus on structural and socio-cognitive factors shaping their vulnerable condition. There is also a need for further research on how the so-called feminisation of agriculture and rural areas (Crehan 1992; Radel 2011; Radel et al. 2012) influences adaptation possibilities and women's perceptions of conservation. Second, the deepening inter-dependencies between rural and urban areas, through migration flows and more connected and informed peoples and markets, is transforming rural livelihoods. Rural people are not only changing their access to income or (new) assets, but also experiencing key socio-cognitive changes that may have implications on adaptation preferences and visions of both development and conservation (Ho et al., 2015). Such changes deserve further scrutiny.

In sum, this dissertation has shown that social vulnerability, adaptation and conservation initiatives are inextricably linked, and that conservation regulations can enable as well as constrain local agency for adaptation. In the studied communities, such initiatives have provided some additional economic revenues to some households and thus facilitated new livelihood activities and adaptive processes. However, they have also deepened the social differentiation across households, exacerbated internal conflicts, weakened collective action, and ultimately increased the vulnerability of some households. By critically scrutinising the effects of conservation regulations on vulnerability and adaptation, this thesis has tried to inform rural development and biodiversity conservation policies so that these become more sensitive to the heterogeneity of rural societies, and particularly to the lives and characteristics of the most exposed and disempowered households.

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Appendix I: Interview guides

Interview guide 1: The environmental history and local governance system

Objective: develop an environmental historical story of the communities and their board context, highlighting socio-economic, ecological, cultural and institutional aspect essential in the community evolution. This interview guide also focus on the natural resources management and the conservation initiatives followed to the creation of the CBR.

1. Interviewee and interviewer data

Community:	Date of interview:	
Name:	Age:	Sex:
Ethnicity:	Religion:	
Education (years):		
Principal livelihood activity:		
Authority (currently):	Organisation, place:	Year:
Birthplace:		
If he/she did not born in the community: How long are you living here?		
In which other places did you live before?		
For how long you were living in these other places?		

2. The history of the settlement

2.1. What do you know about the first families that settled here?

2.2. A) *If he/she didn't born in the community:* How was the landscape of the community when you arrived? How has the life in the community changed since that time?

2.3. B) *If he/she bore in the community:* How has the life in the community changed since you were a child?

2.4. Could you tell me more about why people wanted to arrive here?, and why some of those families decide to leave?

3. Collective governance

3.1. When there is a problem in the community, how is it solved?

3.2. For example, if you would have a problem with someone else in the community about the use of your land, to who do you communicate it?

3.3. How would you describe the life in the community considering the different groups of people living together in the same community? What has it changed? Why?

3.4. How is the relationship with the surrounded communities?

3.5. How often is the assembly of the community? What are you talking about in this assembly?

3.6. How are decision made in the assembly? Are there inhabitants with different rights (to vote, to voice)? Why?

3.7. How is communicated the information and decisions arranged in the assembly to other members of the community?

3.8. What types of problems do you have in the community to ensure decisions arranged in the assembly?

3.9. How does the community monitoring that households are following the rules? Are there monitoring mechanisms developed in the community by the CBR and other governmental organisation?

3.10. How has the organisation of the community around the assembly changed? Why?

3.11. Is there in the community another time and place to meet and talk about more regular things? For example, where do you talk with your neighbourhoods about your agricultural production or eventual contingencies?

3.12. How does the community manage the different public services (health clinic, education facilities or water tanks as examples)?

3.13. *Only for the Authority:* Which subsidies and programmes are taking place in the community?

3.14. *Only for the Authority:* Which other subsidies or programmes do you think that are necessary in the community? Why?

3.15. Could you tell me what do you know about the CBR? When did you know of the form of the CBR and that the community was located within it? How would you describe the relationship between the community and the CBR? How do you think that the CBR has changed the way of living in this community? And, why do you think that?

3.16. Leaving aside the conflicts and collaborations with the CBR, could you tell me if this community has had other type of conflicts and experiences of collaborations? How have these experiences changed the life to you and to other community members?

4. Land and water management and livelihood activities

Land distribution

4.1. How much land does the community have?

4.2. In which tenure situation?

4.3. How much land are agricultural fields? How much land is under communal tenure?

4.4. Could you tell me, how was the granted land distributed among the families living in the community?

4.5. Are there families with more land than others? *If this is the case,* why?

4.6. Does each family know the boundaries of their own land? Is it physically delimited?

4.7. Are there any problems with the delimitation of communal land between communities? If it is the case, how are these issues solved?

4.8. Nowadays, is there any distribution of land to new families (e.g. sons/daughters of *ejidatarios*, women without land tenure)? How is decided the distribution of land to these new families?

Land counter-reforms

4.9. How do the people of the community know who can and cannot use the land? Which documents do you have to demonstrate the land granted? and which are the duties and rights?

4.10. *If agrarian certificate is not mentioned*: What do you know about the agrarian certificate? Did you request them?

4.11. Do you remind any change in the community land plots?

4.12. Did the community have any problems with the CBR regarding land tenure rights?

Use of urban plots, agricultural fields and communal lands

4.13. Which are the livelihood activities that you develop in your agricultural field/borrowed or rented land? *(Draw the land and the distribution of livelihood activities with he/she, if need)*

4.14. Which are the productive cycles in each crop and activity? *(Fill supplementary material)*

4.15. How have land uses changed in the recent years? Why?

4.16. Which are the uses of common land?

4.17. How do you regulate the access and use of common land? (For example, are all the families in the community able to get the same amount of resources or are there variations? Are there rules over the access and use of this land?)

4.18. Is there land dedicated to conservation in the community? How do the community members know about this conserved target land? Are there rules regarding its management? Who set these rules? Has every family access to this land? How do the community regulate the use of this land? Is there a surveillance system? What happens when someone do not compliance the established rules?

Water management

4.19. How is the collective water supply managed? Who establishes how much water distribute and how? Is the water distributed equally among households?

4.20. Is water an issue of conflict in the community? And in relation to the livelihood activities developed in the community?

4.21. Which are the livelihood activities more limited by the scarcity of water or by floods?

4.22. Do households control how much water they use? What are you doing to limit the use of water? Or to increase the amount of accumulated water?

4.23. Which improvements have been developing during the last years to decrease conflicts for water access and use?

Livelihood activities

4.24. Could you explain me which are the main productive activities in the community? Do you know when this activity started? Why? Are all the households in the community developing such activity?

4.25. Is there any organisation that collective manage this activity?

4.26. Which has been the impact of developing this activity to households and to the community as a whole?

4.27. In which aspects have influenced the CBR over the access to and use of natural resources in the communal forest and agricultural fields? Has it enhanced or inhibited the use of those resources? Which ones? How? Which have been the effects in the communities?

4.28. How do you think that PES programme has affected the live in the community? Has it enhanced or inhibited the uses of those resources? Which ones? How? Which have been the effects in the communities?

4.29. Do you think that your knowledge about their surrounding environment is a useful help to gain benefits and reduce impacts from adverse situations?

4.30. Which are the opportunities and barriers presented in the community to manage the available natural resources?

5. Environmental and climate changes

5.1. Reminding all your life in the community, what do you consider to be the main environmental and climate changes (including natural disasters) that affected the community until now?

5.2. Which were the effects in the community? And in the families?

5.3. Who or what has been more affected? ¿Why?

5.4. How did you cope with these problems?

5.5. Does the community obtain any type of help or support to prevent or resolve problems from environmental or climate changes?

5.6. Is your own knowledge about the near environment useful to cope with these problems? In which way? Could you give me an example?

Notes:

Interview guide 2: Household's adaptive responses and agency to multiple stresses

Objectives:

1. Understand the reasons that motivated the distribution of pebbles between the studied stress (Block 1 and 2)
2. Gather information (not very detailed) about the historical relationship that the interviewee and his/her household has with the studied stresses (Block 3)
3. Understand how the household has been responding to these stresses, and if they are undertaking adaptive responses to deal with these stresses (Block 4)
4. Understand the cultural aspects (values, perceptions and believes) associated with the livelihoods that the households develop or that they would like to do, and how these cultural aspects influence in the maintain or innovation of some activities more than others (Block 5)
5. Understand the perception about their adaptive capacity in relation to land tenure rights and gender, as well as the influence of external organisations (Block 6)

Preparation:

This interview aims at exploring in details some aspect emerged from the household survey. Interviewer then should acknowledge the responses that household heads provided before to guide the interview.
At the begging of the interview, interviewer should remind to the interviewee the distribution that he/she develop in the pebble exercise within the household survey.

Block 1 explores the overall motivation to distribute the pebbles among the stresses (i.e. uncertainty about chilli prices, rainfall variability, and conservation regulations):

1. Generally speaking, why did you decide this distribution of the maize seeds between these perturbations impacting the well-being of your household?

Block 2 attempts to understand in depth why the interviewee had distributed such among of maize seeds among each stresses. It implies to understand why he/she say that it affects or not their household:

2. How does the *stress* affect to your household to distribute these maize seeds?
3. Why does the *stress* more have more/less maize seeds than the other stresses?
4. Example, if he/she rear cattle: how does the rainfall variability influence this activity?

Block 3 explores the temporal dimension of each stress in relation to each livelihood activity developed and for those that the interviewee would like to develop in a future

5. During the last years, have you initiated any livelihood activity that is more impacted by the *stress*? Which one? Why?
6. If they say that he/she have not initiated any activity, but that contradict his/her answers in the household survey, for example because they keep bee: How did you start to keep bees? Why did you decided to start to develop this activity?
7. Would you like to change or give up any activity that you currently develop to reduce your level of impact by the *stress*?

Block 4 explores the adaptive responses that the household has developed and relate them to the stresses, including questions developed from the review of these set of questions of the household survey: livelihood activities, economic dimension, human dimension, social dimension, potential adaptive strategies. For example:

8. You said me that you started with a new livelihood activity to generate new incomes for the household, which one?
9. Why did you decide to apply for a livestock subsidy?
10. I understood that the cultivation of maize and beans was mainly for the food of the household, why have you started to sell it?
11. For your answers in the household survey there are several household members working abroad, why did they leave away for a wage labour? How do they invest the money when they come back? Could be possible to earn this money working in the community?
12. Regarding the communal forest and the Calakmul Biosphere Reserve, do your household use wild plants, timber, firewood or hunting in these areas? Even when you do not do it regularly, have you ever used these lands? Why?

Block 5 explores the meaning that to develop or to give up each activity has for the interviewee, examples:

13. If the household cultivates *milpa*: what does the *milpa* mean for you?
14. If the household does not have livestock: what would mean for you to rear cattle?
15. In particular, what has meant for your household to engage in livestock rearing, payment for ecosystem services, etc.?
16. In particular, what has meant for your household the restrictions from the Calakmul Biosphere Reserve to not burn or cut down the forest in your agricultural fields?

Block 6 explores the interviewee's perceptions about their marginalisation and empowerment, for example:

17. Do you believe as woman/man living in this community that you have the capacity to reduce the impact of this stress to your household? Why?
18. Which is your opinion as a head of household with land tenure rights/without land tenure rights about the opportunities that you have to improve your live in the community? Do you think that there are more opportunities outside the community?
19. Which is your opinion as a head of household with land tenure rights/without land tenure rights about the distribution of benefits in the community? How do these benefits affected positively or negatively to the communal living? Why?
20. Only in *Sacrificio*: how do you feel about the delay in the land title process? Do you think that the lack of official land title affects the improvement of your household living conditions?

Notes:

Agricultural calendar (Complementary material)

Farm tasks	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Land preparation												
***Temporal* (maize)**												
***Tornamil* (maize)**												
Beans												
Chihua												
Chilli												
Beekeeping (harvest)												
Hurricanes												
Floods												

Note: C = cultivation; H = harvest

Interview guide 3: Opinions regarding conservation, development and vulnerability patterns in Calakmul

Objectives:

1. Explore the perception that governmental and non-governmental organisations have about the idea of biodiversity conservation and rural development, and how their intervention, themes and priorities are influenced by this conception.
2. Identify the mechanisms of communications and decision-making processes that relate these organisations with the municipality and local communities.
3. Explore the perception about both the vulnerable condition of the households and communities located in Calakmul and the role of the organisation helping them to overcome such condiction

Preparation:

The interviewer should acknowledge which are the main programmes and subsidies that the organisation provides in the region. The interview could be also more profitable is the interview knows, in advance, which is the influence of this support in the communities.

Block 1 explores which is the main interpretation that this organisation has around the idea of biodiversity conservation and rural development:

1. Could you explain me which is the conception that the organisation has about the idea of biodiversity conservation and rural development, if are they complementary, synergic or conflicting for example?

Block 2 identifies which are the main themes and priorities regarding the intervention of the organisation at different scales (state, municipality, and communities):

2. Could you tell me about the main themes and priorities that *the organisation* has? (and department when relevant)
3. Could you tell me about the principal projects/subsidies that *the organisation* provide to the municipality of Calakmul?
4. Have all the households and communities access to this support? Which are the criteria to select them? Who and how do you selected these criteria?

Block 3 identifies which are the principal channels of communication and participation between the organisation and the local people:

5. Of these projects and subsidies that you explained me, could you explain me which are the principal channels of communication between *the organisation* and the municipality, and with the communities as well?
6. How do the people in the local communities participate in the design, execution and evaluation of these projects and subsidies?

7. How is *the organisation* monitoring the execution of its intervention in the communities?

Block 4 explores which is the perception of the organisation about the vulnerability condition of the communities located in Calakmul, and which are the advantages and disadvantages of these communities for overcoming such vulnerable condition:

8. For your experience working in *the organisation*, could you explain me which is your perspective about the vulnerable condition of households and communities located in the municipality of Calakmul?
9. In your opinion, which are the main problems that these households and communities face?
10. Which are, in your opinion, the main advantages and disadvantages of that these households face to overcome their vulnerable condition?
11. How does *the organisation* influence to overcome this vulnerable condition?

Notes:

Appendix II: Focus group guide

Focus group guide 1: The environmental history of the community – Timelines

Description	Qualitative research method that allows for exploring the main milestones in the community, and how these milestones have influenced the development and relationship with the surrounding environment.
Objectives	1. Identify the main milestones and when they happened. 2. Identify how these milestones have influenced (or not) the community in terms of their landscape, access to resources, collective organisation, productive activities, etc. 3. Identify which have been the household and collective responses. 4. Identify the organisations playing a relevant role in these identified household and collective responses.
Selection of participants	Open to every community member. Participation should be encouraged through the contact facilitated by CRIPX, and the previous interviewees.
Materials	• Flip chart • Flip chart with the objectives of the workshop • Masking Tape • Marker • Camera y video camera (if possible)
Staff	• Facilitator • Note-taker • Photographer • Translator (if needed)
Time	3 hours
Preparation	
- Identification of the main milestones and their impacts in the community found in the literature and in the conducted interviews (Interview guide 1). - Identification of local stakeholders from the conducted interviews (Interview guide 1).	
Procedure in steps	
Step 1 **15 min**	**Welcome:** The facilitator should: 1. Present the research team and invite to the participants to introduce themselves to the team. 2. Explain the objectives of the workshop and the use of data gathered to the development of the research within the COMBIOSERVE research project.

<table>
<tr><td></td><td>3. Ask for the permission to take photos and to use of a tape-recorder and the video camera.
4. Encourage for the active participation of the participants regardless of status, gender or age.</td></tr>
<tr><td>Step 2

15 min</td><td>Working in small groups:

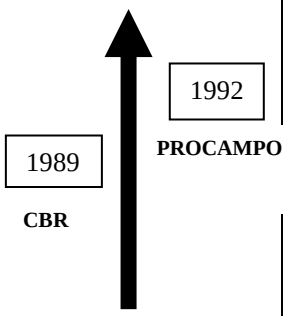
The facilitator requests to the participants to work in groups. These groups should reflect the diversity of the communities in terms of different criteria, such as access to resources, knowledge, social networks, agency, etc, in order to reflect different vulnerability and adaptation conditions.

A priori, in Mexico the most relevant criteria are: land tenure rights, gender, and age.

In case to identify tensions among participants within a group, they should be divided in different groups.

Ideally, each group should be bigger than 3 and smaller than 10 participants.</td></tr>
<tr><td rowspan="3">Step 3

30 min</td><td>Exercise 1: Milestones
Each group should discusses about the milestones that influenced in the fife of the community through two motivational questions:
- What do you know about the begging of the community and about the first settlers?
- Since then, which have been the most relevant events influencing the live in the community? And why?</td></tr>
<tr><td>Each group selected who should paint in the flip chart the timeline generated in the discussion.
The note-taker gather the information in template facilitated (Table 1).

 
</td></tr>
<tr><td>The facilitator should:
- Support the group to identify the date orienting them with the information previously gathered from the literature review and interviews, and remembering events at higher scales.
- Highlight the relevance of identify positive and negative milestones, as well as failed responses (e.g. if they tried to do a collective activity and it did not work).
- Guide the discussion to identity ecological, social, economic and political milestones.</td></tr>
</table>

<table>
<tr><td rowspan="6">Step 4

45 min</td><td colspan="2">Exercise 2: Impacts
The facilitator should guide the discussion around the identified milestones and reflect on their impacts through some motivational questions:</td></tr>
<tr><td>Which kind of issues changed this milestone?</td><td>Identify the social and ecological impacts.</td></tr>
<tr><td>Who or which things were more affected? And benefited?</td><td>Identify who won and who lost.</td></tr>
<tr><td>How did households and collectives respond?</td><td>Relate the impacts to the development of adaptive responses at household and collective level.</td></tr>
<tr><td>Did you receive support from external organisations?</td><td>Identify the support or rejection of external support, and the related consequences.</td></tr>
<tr><td colspan="2">The note-taker should write the information in the template facilitated (Table 1).
Note: It is possible that part of the information could be mentioned when participants are identifying and selecting the milestones. This information should captured by the note-taker to avoid repetitions in the debate.</td></tr>
<tr><td>Step 5
15 min</td><td colspan="2">Break</td></tr>
<tr><td>Step 6

40 min</td><td colspan="2">Exercise 3: Sharing ideas
Each group present their timelines.
The note-takers captured the events mentioned in a common timeline.
The facilitator makes a synthesis of the main similarities and differences. Participants are encouraged to comment these common timeline, while note-takers captured their observations.</td></tr>
<tr><td>Step 7

20 min</td><td colspan="2">Exercise 4: Close
The facilitator presents compromise to return the information in a poster or other format agreed with the community.
If participants are not tired, facilitator should ask to the participants which are their opinion about the workshop.
Ending the workshop acknowledging to all participants their collaboration and interest.</td></tr>
<tr><td colspan="3">General recommendations</td></tr>
<tr><td>Guiding the discussions

(Facilitator)</td><td colspan="2">▪ Avoid personal conflicts; an attempt to join ideas more that generate a debate.
▪ Facilitate their intervention by establishing turns, show that their effort to ask their turn is recognised and speak to them by their names.
▪ Encourage to participate to those less talkative.</td></tr>
</table>

	▪ Be sure that the group is analysing the next milestone when they finish with the last one. ▪ Help to clarify ambiguous interventions. ▪ Try to fit the activities to the time established. ▪ If the discussion starts to be chaotic, talking all at same time or generating parallel discussion invites them to realise what is happening.
Gathering information **(Note-taker)**	▪ Write down the information captured in the discussion in the template provided (Table 1). It is important to capture agreements and disagreements and from which parts. ▪ Take pictures in important moments of the activity. ▪ Take pictures of every flit chart elaborated to be sure that information is captured. ▪ Flit chart will be save in mark envelops specifying: name of the activity, group, name of the community, and date.
Divulgation of results	▪ Discusses in the general assembly which is the format preferred by community members to return the results. In both communities, they decided that the information should be return in a newsletter. In *Sacrificio*, they ask for translating the information in Chol. ▪ Scientif publication (including the timeline of Once): Delgado-Serrano, M. M., Oteros-Rozas, E., Calvo-Boyero, D., Ruiz-Mallén, I., Ortiz-Guerrero, C. E., Escalante-Semerena, R. I., and Corbera, E. (under review). Social-ecological resilience in community-based natural resource management in Latin America. *Regional Environmental Change*, (under review).
References	Chambers, R. (2002). *Participatory Workshop. A sourcebook of 21 sets of ideas & activities*. Earthscan, London. Newing, H., Eagle, C., Puri, R., and Watson, C. W. (2011). *Conducting Research in Conservation: A Social Science Perspective*. London and New York: Routledge. Ruiz-Mallén, I. (2011). Manual operativo proyecto CONSERVCOM. Paquete 1. Diseño metodológico y capacitatión local. Available at URL: https://issuu.com/serbaoaltepetl/docs/manual_conservcom_94395.

Table 1: Template for capturing the data (including examples):

Milestone	**Date (year)**	**Impact (Positive: P; Negative: N)**	**Beneficiaries**	**Loses**	**Adaptive response (scale)**	**External organisations**
Starting of chilli cultivation	1975	Selling of chilli means a new household income (P) The use of agrochemical inhibit beekeeping activities (N)	*Ejidatarios*	*Pobladores*	Some pobladores migrate abroad	SAGARPA

Focus group guide 2: Potential scenarios of global change in Calakmul for 2030

<table>
<tr><td>Description</td><td colspan="2">Qualitative research method that allows for exploring future scenarios understood as reasonable and hypothetic descriptions of the future based on a set of factors and dynamics that may characterised these reality. The scenarios are then not predictions but tools for exploring the implications from specific policies and actions.</td></tr>
<tr><td>Objectives</td><td colspan="2">1. Analyse the perception toward a) the future change, and b) the vulnerability of the household with the CBR to multiple stresses.
2. Explore how household and collective adaptive capacity and ability varies in relation to different conservation and policy scenarios.</td></tr>
<tr><td>#Workshops</td><td>Workshop 1: scenarios building</td><td>Workshop 2: deliberative focus group at village level</td></tr>
<tr><td>Selection of participants</td><td>Selecting local and regional representatives of key organisations by their work in Calakmul and specifically in the two studied communities.</td><td>Selecting the participants in terms of their potential vulnerable condition taking into account land tenure rights and gender criteria. These participants must belong to the previous surveyed households.</td></tr>
<tr><td>Time</td><td>Workshop 1: 4 hours</td><td>Workshop 2: 3 hours (max)</td></tr>
<tr><td>Materials</td><td colspan="2">• Flip charts
• Masking Tape
• Marker
• Post-its
• Camera y video camera (if possible)
• Coffee and food
• Visual support of scenario narratives (only workshop 2)</td></tr>
<tr><td>Staff</td><td colspan="2">• Facilitator
• Note-taker
• Photographer
• Translator (if needed)</td></tr>
<tr><td colspan="3">Preparation</td></tr>
<tr><td colspan="3">- Identification of the main drivers of change in both studied communities: rainfall variability, uncertainty about cash crop prices, conservation rules, and infrastructure development (Interview guide 1 and focus group guide 1).
- Identification of local stakeholders and from the conducted interviews (Interview guide 3).</td></tr>
</table>

- Identification of the main groups of community members with diverse potential vulnerable conditions (Interview guide 1 and 2).

Procedure in steps

Step 1

Key stakeholders identification:

Identification of main regional and local stakeholders in Calakmul to invite them to participate in the scenarios-building workshop (Step 2).

Step 2

Workshop 1, Scenario-building workshop execution:

The facilitator should:

1. Present the research team and invite to the participants to present themselves.
2. Explain the objectives of the workshop and the use of data gathered to the development of the research within the COMBIOSERVE research project.
3. Ask for the permission to take photos and to use of a tape-recorder and the video camera.

Exercise 1: Ranking drivers of change

4. Explain to the participants the drivers of change (i.e. rainfall variability, uncertainty about cash crop prices, conservation rules, and infrastructure development), and the dynamic by which participant should rank them by their influence on future local livelihoods.
5. If there is consensus among participants facilitator should ask for a couple of opinion to know which their motivations are. If there is no consensus, facilitator should try to bring their opinions closer.

Exercise 2: Building four plausible scenarios

6. In the workshop dynamic, I first set out four drivers of change over local livelihoods identified during my fieldwork I then selected the two higher ranked stresses - i.e. rainfall variability and conservation regulations - to generate four plausible scenarios through a two-axes approach varying the degree of impact (Ruiz-Mallén et al. 2015b).

		Driver 1	
		Maintain	Intensification
Driver 2	Maintain	SCENARIO 1	SCENARIO 2
	Intensification	SCENARIO 3	SCENARIO 4

8. Scenario by scenario, participants should reflect about scenario through two motivational questions: 1) **how** will Calakmul be in 2030 under this scenario, and 2)

	why do participants believe that? It was also structured around local livelihoods, i.e. subsistence agriculture, commercial agriculture, livestock, beekeeping, firewood and timber extraction, hunting, harvesting wild forest plants, other employments (education, wage labour, etc.). They should write both opinions in two post-its that the facilitator should put in a flip chart develop to this purpose.  9. The note-taker should gather the information of the discussion and pots-its, when possible, to fil Table 2 – 4.
Step 3	**Scenario narratives generation:** I employed the information gathered to generate a local narrative about potential social-ecological changes and visual support for each scenario. A Visual material should be also developed from the scenario narratives generated to conduct the discussion with the focus group a village level (Step 4, Workshop 2).  Scenario narratives were sent to all participant stakeholders to validate them, although feedback was not received.

Step 4	**Deliberative focus groups at village level:** The facilitator should: - Introduce the team, the purpose of the workshop and explain the motivation to generate spaces to discuss among members of similar vulnerable conditions. - Explain the scenario's narrative supported by the visual material and discusses it. When the discussion of one scenario is saturated, facilitator should help them to finish with the discussion and strart with the next one. - Help them to clarify which are the main differences among scenarios. - After discussing all the scenarios, facilitator should encourage them to identify which is their most preffered scenario - Then the facilitator should guide the discussion to reflect on potential policy actions that they consider adecuate to overcome their vulnerable condition and enhance their adaptive process for this particular scenario.
Step 5	**Compilation of locally suggested policy options:** Design and develop a video to oriente policy makers and other relevant stakeholders to understand local drivers of change and their implications for overcoming vulnerability enhancing adaptation.
General recommendations	
Guiding the discussions (Facilitator)	▪ Avoid personal conflicts; an attempt to join ideas more that generate a debate. ▪ Facilitate their intervention by establishing turns, show that their effort to ask their turn is recognised and speak to them by their names. ▪ Encourage to participate to those less talkative. ▪ Be sure that the group is analysing the next milestone when they finish with the last one. ▪ Help to clarify ambiguous interventions. ▪ Try to fit the activities to the time established. ▪ If the discussion starts to be chaotic, talking all at same time or generating parallel discussion invites them to realise what is happening.
Gathering information (Note-taker)	▪ Write down the information captured in the discussion in the templates provided (Table 2-5). It is important to capture agreements and disagreements, and from which parts. ▪ Take pictures in important moments of the activity. ▪ Take pictures of every flit chart elaborated to be sure that information is captured. ▪ Flit chart will be save in mark envelops specifying: name of the activity, group, name of the community, and date.

Divulgation of results	▪ Executive report of the Scenario-building workshop (Workshop 1) shared with all participants looking for feedback to improve the generated scenario narratives. ▪ Video oriented to disseminate the results among local and regional representatives of governmental and non-governmental organisations. ▪ Local newsletter to disseminate the results in the two studied communities. ▪ Scientific publication: Ruiz-Mallén, I., Corbera, E., Calvo-Boyero, D., and Reyes-García, V. (2015b). Participatory scenarios to explore local adaptation to global change in biosphere reserves: experiences from Bolivia and Mexico. *Environmental Science and Policy*, 54, 398-408.
References	Carvalho-Ribeiro et al. (2010). Multifunctional forest management in Northern Portugal: Moving from scenarios to governance for sustainable development. *Land Use Policy*, 27, 1111-1122. Malinga, R., Gordon, L. J., Lindborg, R., and Jewitt, G. (2013). Using participatory scenario planning to identify ecosystem services in changing landscapes. *Ecology and Society*, 18(4), 10. Newing, H., Eagle, C., Puri, R., and Watson, C. W. (2011). *Conducting Research in Conservation: A Social Science Perspective*. London and New York: Routledge. Tompkins, E. L., Few, R., and Brown, K. (2008). Scenario-based stakeholder engagement: Incorporating stakeholder preferences into coastal planning for climate change. *Journal of Environmental Management*, 88, 1580-1592.

Table 2: Ranking of the drivers of change

	Position of the driver of change in the ranking: 4 means more relevance and 1 less relevance						
	Stakeholder 1: _____	Stakeholder 2: _____	Stakeholder 3: _____	Stakeholder 4: _____	Stakeholder 5: _____	Stakeholder N: _____	Why do participants select this as first driver of change?
Rainfall variability							
Conservation rules							
Volatility of cash crop prices							
Infrastructures development							
First driver of change selected:							
Second driver of change selected:							
Observations (e.g. the main points of consensus of disagreement, etc.):							

Table 3: "How will it be?" #Scenario ___ (fill four times this table (one table for each scenario) copying the post-its that every participant wrote)

Description of each scenario	Stakeholder 1 _____	Stakeholder 2 _____	Stakeholder 3 _____	Stakeholder 4 _____	Stakeholder N _____	Degree of consensus (high, medium, low)
Subsistence agriculture						
Commercial agriculture						
Livestock rearing						
Non-timber forest production						
Timber forest production						
Hunting						
Other productive activities (ecotourism, wage labour, etc.)						

Table 4: "Why will it be like you think?" #Scenario ___ (fill four times this table (one table for each scenario) copying the post-its that every participant wrote)

Description of each scenario	Stakeholder 1 _____	Stakeholder 2 _____	Stakeholder 3 _____	Stakeholder 4 _____	Stakeholder N _____	Degree of consensus (high, medium, low)
Subsistence agriculture						
Commercial agriculture						
Livestock rearing						
Non-timber forest production						
Timber forest production						
Hunting						

Table 5: Locally perceived impact of each scenario (fill four times this table; one table for each scenario)

Date (dd/mm/yy):
Community:
Group:
Participants:

	Scenario N
Winners	
Losers	
Adaptive responses of the participants	
Adaptive responses of other households	
Transaction costs of adaptation (specify which one and which kind of cost)	
Responsibility of these responses (who should assume the responsibility/costs?)	
Types/Level of acceptable changes	
How many voted: unreal, probable, and very probable, and why?	
Policy actions *(only for the most preferred scenario)*	Government: CBR: ONGs: CRIPX: Their own community:

Appendix III: Governmental and non-governmental organisations contacted. Note: These organisation were interviewed using interview guide 3 or they were participants in the scenarios-building workshop (focus group guide 2)

#	Organisation	Work field	Scale	Interview guide 3	Date	Focus group guide 2
1	Agriculture Municipal Committee	Agrarian	Municipal	0	-	No attendant
2	Calakmul Biosphere Reserve (CBR)	Conservation	Federal	2	29/09/2012 04/04/2014 05/12/2013	No attendant
3	Consejo Regional Indígena y Popular de *Xpujil*, S.C. (CRIPX)	Civil Society	Municipal	1	22/11/2013	Participant
4	El Colegio de la Frontera Sur (ECOSUR)	Research	State	2	25/03/2014	Participant
5	Instituto para el Desarrollo Sustentable de Mesoamérica, A.C. (IDESMAC)	Research	Federal	1	12/04/2014	Participant
6	Fondo para la Paz	Development	Federal	1	24/01/2014	Participant
7	Local beekeeping association of Calakmul	Beekeeping	Municipal	1	30/03/2014	Participant
8	Local livestock association of Calakmul	Livestock	Municipal	1	01/04/2014	Participant
9	Municipal Secretary of Economic Development	Economic development	Municipal	1	14/02/2014	Participant
10	Municipal Secretary of Planning and Infrastructure	Infrastructure	Municipal	0	-	No attendant
11	National Commission to the Development of Indigenous People (CDI)	Indigenous people	Municipal	1	18/02/2014	No attendant
12	National Forestry Commission (CONAFOR)	Forest conservation	Federal	2	16/02/2014	Participant

#	Organisation	Work field	Scale	Interview guide 3		Focus group guide 2
13	National System for the Integral Family Development of Calakmul (DIF)	Vulnerable groups	Municipal	1	17/02/2014	No attendant
14	Productores Forestales de Calakmul, A.C.	Forest consultancy	Municipal	1	31/03/2014	No invited
15	Pronatura Sur, A.C.	Conservation	Regional	1	26/03/2014	No invited
16	Secretary of Agrarian, Territorial and Urban (SEDATU)	Land rights	Federal	1	25/03/2014	No invited
17	Secretary of Agriculture, Livestock and Rural Development (SAGARPA)	Agricultural development	Federal	1	20/02/2014	No attendant
18	Secretary of Environment and Natural Resources (SEMARNAT)	Conservations	Federal	3	22/02/2014	No attendant
19	Secretary of Environment and Sustainable Development (SMAAS)	Beekeeping	State	2	27/03/2014	No invited
20	Secretary of Industrial and Commercial Development (SEDICO)	Economic development	State	1	20/02/2014	No attendant
21	Secretary of Social and Regional Development (SEDESORE)	Development	State	1	26/03/2014	No attendant

Appendix IV: Household survey guide

COD. Household: _____ Date (dd/mm/yy):_____ Field researcher: _____

Notes to interpret the household's questionnaire template: 1) Don't know/No opinion: DK/NO = -9. 2) SAC: means that this question is only developed to household heads living in Sacrificio. 3) NP: means that this question should not asked for those households without land tenure rights (pobladores). 4) Questions which number is in blue colour means that this question was also developed to female household head, when possible, and only in the case that she was not the main household head surveyed. 5) Questions which number is in red colour means that it was conducted despite that this household was not currently developing this livelihood activity.

1. GENERAL INFORMATION

#	Questions	Instructions	Male	Female
1.	Where did you born?	State		
2.	For how long are you living in the community?	Years		
3.	How long did you establish your household in the community?	Years		
4.	SAC: Was your household resettled?	0=No, 1=Yes		
5.	SAC: In which community was living before the resettlement?	1= *San Isidro*, 2= *Las Delicias*, 3= *Aguas Turbias*, 4= *22 de Abril*		
6.	Sex	1=Male, 2=Female		
7.	How old are you?	Years		
8.	Which studies do you have completed?	0=None, 1=Primary, 2=Secondary, 3=*Cobach*, 4=Technical studies		
9.	Are you …?	1= *Chol*, 2= *Tzeltal*, 3= *Tzotil*, 4= *Zoque*, 5=*Mestizo*, 6=*Tsimane*, 7=*Mosetene*, 8=*Tacana*, 9=Other *(To specify)*		
10.	What is your religion?	0=None, 1=Catholic, 2=Presbyterian, 3=Pentecost, 4=Pentecost (independent), 5=Evangelist, 6=Other *(To specify)*		

2. HOUSEHOLD'S MEMBERS

#	Questions	Instructions	Answer
11.	How many people lived in the house?	Number	
12.	How many male members older than 16?	Number	

13.	How many female members older than 16?	Number	
14.	How many male members younger than 16?	Number	
15.	How many female members younger than 16?	Number	

3. HOUSEHOLD'S MATERIALS

#	Question	Instructions	Question	Instructions	Question	Instructions
16: Do you have…?		0=No, 1=Yes	17: **If have it,** did you lend or rent it?	0=No, 1= Yes (lend), 2= Yes (rent), 3=Service *(To specify)*	18: **If not have it,** did you borrow or rent it?	0=No, 1=Yes (borrow), 2=Yes (Rent), 3=Pay service *(To specify)*
A	Car		Car		Car	
B	Motorcycle		Motorcycle		Motorcycle	
C	Bicycle		Bicycle		Bicycle	
D	Horse		Horse		Horse	
E	Electric saw		Electric saw		Electric saw	
F	Rifle		Rifle		Rifle	
G	Tractor		Tractor		Tractor	
H	Fumigation equipment		Fumigation equipment		Fumigation equipment	
I	Radio					
J	Television					
K	Fridge					
L	Grinder					
M	Washing machine					

4. LAND TENURE

#	Questions	Instructions	Answer
19.	Do you have land tenure rights?	0=No, 1=Yes	
20.	And, any other household member?	Number	
21.	Have you ever sold any land rights of agricultural field or urban plot?	0=No, 1=Yes, agriculture field, 2=Yes, urban plot, 3=Yes, both	

22.	Have you ever bought any land rights of agricultural field or urban plot?	0=No, 1=Yes, agriculture field, 2=Yes, urban plot, 3=Yes, both	
23.	In which community?	Name of the community	
24.	NP: How many hectares did you lend to someone?	Hectares	
25.	NP: To who?	Name and surname /type of kinship	
26.	NP: How many hectares did you rent to someone?	Hectares	
27.	NP: To who?	Name and surname /type of kinship	
28.	NP: How much did you earn from the rent of land?	Local currency/ha	
29.	In how many agricultural fields did you borrow land?	Number	
30.	To who?	Name and surname /type of kinship	
31.	In how many agricultural fields did you rent land?	Number	
32.	To who?	Name and surname /type of kinship	
33.	How much did you pay for renting this land?	Local currency/ha	

#	Question	Instructions	Rented L.	Borrowed L.	Field 1	Field 2	Field 3
34.	How many hectares did you/have you …?	Hectares					
35.	Which was the distance between the house and the …?	Kilometres					
36.	Did you have a good path leading to the ...?	0=No, 1=Yes, all, 2=Yes, partially					
37.	Had you got any source of water in the …?	0=None,1=Lake, 2=Artificial lake, 3=Stream, 4=Tank					

5. HOUSEHOLD'S LIVELIHOODS *(Using livelihood pictures)*

	Livelihoods	38. Which of this livelihood did you do?		39. In which livelihoods did you spend more time?		40. Which livelihoods did you provide more economic income?	
		0=No, 1=Yes		Ranking, 1 means more time than 2		Ranking,1 means more economic income than 2; -44= No sell	
		Male	**Female**	**Male**	**Female**	**Male**	**Female**
a	Agriculture						
b	Ranching cattle						
c	Backyard animals care						

d	Beekeeping						
e	Wage labour						
f	Conservation						
g	Small trade						
h	Other activities *(To specify)*						

6. AGRICULTURE

#	Question		Instructions	Maize (wet)	Maize (dry)	Beans	Squash	Chilli
41.	How many hectares of … did you cultivate?		Hectares					
42.	How much of … did you harvest?		Number *(Unit of measure)*					
43.	How much of… did you sell?		0=Nothing, 1=Few, 2=Mostly, 3=All					
44.	Approximately, how much?		Number *(Unit of measure)*					
45.	Which crops did you cultivate in the same land?		1=Asociation 1, 2=Asociation 2					
46.	Which household member was caring the …?		1=Father, 2= Mother, 3=Son/s, 4= Daughter/s, 5=All, 6=Other family members; 7=Other					
47.	Did you apply liquid (agrochemicals) to …?		0=No, 1=Yes					
48.	Did you mechanised the land of …?		0=No, 1=Yes					
49.	Did you cultivate less/equal/more than 5 years ago?		0=Less, 1=Equal, 2=More, 3=Not have it					
50.	Did you harvest less/equal/more than 5 years ago?		0=Less, 1=Equal, 2=More, 3=Not have it, 4=Varies a lot					
51.	Did you sell less/equal/more than 5 years ago?		0=Less, 1=Equal, 2=More, 3=Not have it, 4=Not sell it					
52.	During the last 5 years, have you cultivated …?		0=No, 1=Yes					
53.	Which vegetables, roots and fruit plants do you have in the agricultural field?	Names	Male:					
			Female:					

54.	And, in the home garden?	Names	Male:
			Female:

7. LIVESTOCK REARING AND BACKYARD ANIMALS

#	Question	Instructions	Chicken	Turkey	Pig	Sheep	Cow
55.	How many head of … did you have?	Number					
56.	Which household member was taking care of…?	1=Father, 2= Mother, 3=Son/s, 4= Daughter/s, 5=All, 6=Other family members; 7=Other					
57.	How many head of … did you sell?	0=Nothing, 1=Few, 2=Mostly, 3=All					
58.	Approximately, how many?	Number *(Unit of measure)*					
59.	Did you have less/equal/more than 5 years ago?	0=Less, 1=Equal, 2=More, 3=Not have it					
60.	Did you sell less/equal/more than 5 years ago?	0=Less, 1=Equal, 2=More, 3=Not have it, 4= Not sell it					
61.	During the last 5 years, have you had …?	0=No, 1=Yes					

8. BEEKEEPING

#	Questions	Instructions	Answer
62.	How many apiaries did you have?	Number	
63.	Which household member was caring the apiaries?	1=Father, 2= Mother, 3=Son/s, 4= Daughter/s, 5=All, 6=Other family members; 7=Other	
64.	How much of honey did you harvest?	Kilogram/apiary	
65.	How much of honey did you sell?	0=Nothing, 1=Few, 2=Mostly, 3=All	
66.	Approximately, how much?	Number *(Unit of measure)*	
67.	Did you have less/equal/more apiaries than 5 years ago?	0=Less, 1=Equal, 2=More, 3=Not have it	
68.	Did you harvest less/equal/more honey than 5 years ago?	0=Less, 1=Equal, 2=More, 3=Not have it	
69.	Did you sell less/equal/more honey than 5 years ago?	0=Less, 1=Equal, 2=More, 3=Not have it, 4= Not sell it	
70.	During the last 5 years, have you had apiaries?	0=No, 1=Yes	

9. WAVE LABOUR

#	Question	Instructions	Within the community	Close communities	Near cities	USA
71.	Which household members did go out to work?	1=Father, 2= Mother, 3=Son/s, 4= Daughter/s, 5=All				
72.	How much time did he/she spend working in the harvest of chilli?	Days				
73.	Which activities did you do as for a daily wage?	Type of activity				
74.	How much time did you spend doing such activities?	Days				
75.	Approximately, how much?	Local currency				
76.	Did you go for a wage labour less/equal/more than 5 years ago?	0=Less, 1=Equal, 2=More, 3= No wage labour				
77.	Which household members have gone out to work during the last 5 years?	1=Father, 2= Mother, 3=Son/s, 4= Daughter/s, 5=All				
78.	How long did you come back?	Months/Years				
79.	How long did you be away?	Months/Years				

10. SMALL TRADE

#	Question	Instructions	Handcrafts	Food	Small shop
80.	How much did you earn from …?	Local currency (approx.)			
81.	Which household member was carrying …?	1=Father, 2= Mother, 3=Son/s, 4= Daughter/s, 5=All, 6=Other family members; 7=Other			
82.	Did you sell it in/out/or both the community?	1=In, 2=Out, 3=Both			
83.	Did you sell less/equal/more than 5 years ago?	0=Less, 1=Equal, 2=More, 3= Not sell it			
84.	During the last 5 years, have you done …?	0=No, 1=Yes			

11. THE USE OF FOREST AREAS

#	Question	Instructions	Firewood	Timber	Hunting	Wild plants

85.	Where did you get/extract/gather …?	1=Own land, 2= Familiars' land, 3= Neighbourhoods' land, 4= School land, 5=UAIM land, 6=communal land, 7=in the RBC, 8=other place *(To specify)*				
86.	Who was the owner of this land?	Name and/or kinship				
87.	Which household members did get/extract/gather …?	1=Father, 2= Mother, 3=Son/s, 4= Daughter/s, 5=All, 6=Other family members; 7=Other				
88.	How much of… did you collect?	Number *(Unit of measure)*				
89.	How much of… did you sell?	0=Nothing, 1=Little, 2=Mostly, 3=All				
90.	Approximately, how much?	Number *(Unit of measure)*				
91.	During the last 5 years, have you did…?	0=Same place, 1=Own land, 2=Familiars' land, 3=Neighbourhoods' land, 4=School land, 5=UAIM land, 6=Communal land, 7=in the RBC, 8=Other places *(To specify)*				
92.	Did you get/extract/gather less/equal/more than 5 years ago?	0=Less,1=Equal, 2=More, 3=No use				
93.	Did you sell less/equal/more … than 5 years ago?	0=Less, 1=Equal, 2=More, 3=No use, 4=Not sell it				

12. ECONOMIC DIMENSION

#	**Questions**	**Instructions**	**Answer**
94.	How much did you earn from other activities developed?	Local currency	
95.	How many people did you pay wage labour for the harvest of chilli?	Number	
96.	To which other activities did you need wage workers?	Activities	
97.	How many workers?	Number	
98.	During the last 5 years, have you received money from other household members working abroad?	0=No, 1=Yes	
99.	How much did you receive?	Local currency	
100.	During the last 5 years, have you lent money to someone in the community?	0=No, 1=Yes	
101.	To who?	Name and surname	
102.	How much money did you receive last year from this loans?	Local currency	
103.	During the last 5 years, have you borrowed money to someone in the community?	0=No, 1=Yes	

104.	From who?	Name and surname	
105.	How much money did you borrow?	Local currency	
106.	How much money did you save last year?	(MXN) 0=No savings; 1=All expended in inversion	
107.	Did you save more money than 5 years ago?	0=No, 1=Equal; 2=Si	

13. OTHER ECONOMIC QUESTIONS OF INTEREST

#	**106. How much did you received from…?**	**Instructions**	**Answer**
A	PROCAMPO	Local currency	
B	*Procampito*	Local currency	
C	PROGAN	Local currency	
D	Reforestation	Local currency	
E	OPORTUNIDADES	Local currency	
F	Payment for Ecosystem Services (PES)	Local currency	
G	*Maíz Criollo*	Local currency	
H	*Brecha Corta Fuegos*	Local currency	
107.	During the last 5 years, have you got another project or subsidy?	0=Less, 1=Equal; 2=More *(To specify)*	

14. HUMAN DIMENSION

#	**Questions**	**Instructions**	**Answer**
108.	Could you say me the name of 3 members of the community that you considered as the most experts in agricultural practices	Name and surname	
109.	Could you say me the name of 3 members of the community that you considered as the most experts in forestry practices	Name and surname	
110.	In the last 5 years, have you attended to any training?	0=No, 1=Si *(To specify)*	
111.	Do you have a project or an idea that you would like to do in a near future to improve the life conditions of your family?	0=No, 1=Si *(To specify)*	Male: Female:

15. SOCIAL DIMENSION

#	Questions	Instructions	Answer
112.	How many households within the community have a kinship relationship with you or your partner?	Number	
113.	Do your family members often provide food and /or come to eat with your household?	0=No, 1=Yes, they come; 2=Si, we go	
114.	Are any household head a member in an organisation/group?	0=No, 1=Yes	
115.	Which activity do you develop in group?	Activity	
116.	To who you would ask to keep safe your house and your family if you will be abroad for a while?	0=None, 1=Everyone, 2=Parents; 3=Son/s; 4=Other family members, 3=Other neighbourhoods *(To specify)*	
117.	Do you attend to the local assembly?	0=No, 1=Yes, 2=Yes, when he can attend	Male: Female:
118.	Do you participate in the local assembly to share your opinion?	0=Never, 1=Few, 2=Often; 3=I cannot do it	Male: Female:
119.	During the last 5 years, have any household head had a charge in the community?	0=No, 1=Yes *(To specify)*	

16. POTENTIAL ADAPTIVE STRATEGIES: During the last 5 years…

#	Question	Instructions	Male	Female
120.	Have you started a new activity that provides an economic income?	0=No,1=Yes		
121.	Have you cultivated new crops or seeds?	0=No,1=Yes		
122.	Have you cultivated new pasture seeds?	0=No,1=Yes		
123.	Have you invested on the activities developed in the field such as buying tools, building an artificial lake, etc.?	0=No,1=Yes		
124.	Have you invested in the home such as buying a water tank, concrete house, fridge, etc.?	0=No,1=Yes		

125.	Have you applied for a project to improve your labour in the field?	0=No,1=Yes		

17. PERCEIVED VULNERABILITY: PEBBLE METHODS

#	**Male**	**Instructions**	**Nº**	**Answer**
126.	Rainfall variability	Maize seeds		
127.	Uncertainty about the chilli price	Maize seeds		
128.	Conservation regulations	Maize seeds		
#	**Female**	**Instructions**	**Nº**	**Answer**
129.	Rainfall variability	Maize seeds		
130.	Uncertainty about the chilli price	Maize seeds		
131.	Conservation regulations	Maize seeds		

#	**Questions**	**Instructions**	**Answer**
132.	Number of houses (without considering latrine and kitchen)	Number	
133.	Condition of the main house	1=Good, 2=Regular, 3=Bad	
134.	Have they got a concrete house?	0=No, 1=Yes	
135.	Type of the roof in the main house	1=Plant (*Huano*), 2=Zinc metal , 3=Cardboard	
136.	How do they light up in the house?	1=Electricity, 2=Candles, 3=Oil lamp, 4=Others *(To specify)*	
137.	Have they got good floor in the home/s?	1=Good floor, 2=Good floor but not in all the rooms, 3=Bad floor	

Observations:

Appendix V: Variables of Household-level Vulnerability Index (HVI)

		Code	Variable definition	Unit of measurement	Meaning in HVI	Source of information	Limitations and suggestions	References
SENSITIVITY INDEX	**S_rainfall**	Dependency _ratio	Dependency ratio	Ratio	Pressure over productive household members	How many people younger/older than 16 lived in the house?	It can be improved adding data about adults who are not able to work	Notenbaert et al. 2013
		Land_crop	Proportion of agriculture land	Percentage	Size of agriculture land from the total available household's land	How many hectares of ___ did you cultivate?	Land dedicated to beans is not taking into account because it is marginal	Eakin 2005; Ruiz-Mallén et al. in rev
		Income _crop	Proportion of income from agriculture	Percentage	Economic dependence on agriculture	How many kilograms/number of ___ did you sell?	Prices are the average of the information collected during the fieldwork	Eakin 2005
		Livestock _sheep	Number of sheep	Sheep	Proxy of water demanded by sheep rearing	How many sheep did you have?	It can be improved adding data about real water demand by small cattle	
		Livestock _cow	Number of cows	Cows	Proxy of water demanded by cattle rearing	How many cows did you have?	It can be improved adding data about real water demand by big cattle	
		Income _livestock	Proportion of income from livestock	Percentage	Economic dependence on livestock	How many cows/sheep did you sell?	Prices are the average of the information collected during the fieldwork	Eakin 2005; Notenbaert et al. 2013
		Maize _season	Times of maize cultivation	Dummy: 0=twice/year; 1=once/year	Temporal diversification of maize cultivation	How many hectares of maize in summer/winter season did you cultivate?		
	S_chili	Dependency _ratio	Dependency ratio	Ratio	Pressure over adult household members	How many people younger/older than 16 lived in the house?	It can be improved adding data about adults who are not able to work	Notenbaert et al. 2013
		Land_chilli	Proportion of planting area of chilli	Percentage	Size of cultivation from the total available household's land	How many hectares of chilli did you cultivate?		Eakin 2005

Appendix

		Income _chilli	Proportion of income from chilli	Percentage	Economic dependence on chilli's trade	How many kilograms/number of___ did you sell?	It can be improved through daily/weekly chilli's price measures	Eakin 2005; Notenbaert et al. 2013
	S_conservation	Dependency _ratio	Dependency ratio	Ratio	Pressure over the productive household members	How many people younger/older than 16 lived in the house?	It can be improved adding data about adults who are not able to work	Notenbaert et al. 2013
		Size_hh	Household size	Individuals	Proxy of firewood household demand	How many people live in the house?	Data collected of scarce quality. Excluded temporal inhabitants	Notenbaert et al. 2013
		Forest_use	Use of natural resources in restricted areas	Dummy: 0=no; 1=yes	Using forest resources or hunting in restricted areas and /or buying wood	Where did you collect firewood/wood/hunt/wild plants?	Low willingness to answer by respondent	
		Forest_use_ 5y	Use of natural resources in restricted areas 5 years ago	Dummy: 0=no; 1=yes	Using forest resources or hunting in restricted areas 5 years ago	Five years ago, where did you collect firewood/wood/hunt/wild plants?	Low willingness to answer by respondent	
		Livestock _sheep_5y	Potentially damaged by jaguar attacks	Dummy: 0=no; 1=yes	Jaguars have been damaged sheep rearing during the last 5 years	During the last five years, have you had sheep?	It can be improved adding data about the frequency of jaguar attacks	
ADAPTIVE CAPACITY INDEX	**AC_economic**	Savings	Savings	Dummy: 0=no; 1=yes	Capacity to money storage during the last year to pay and to invest	Did you save money last year?	The cycling character of rural economy challenging the idea of savings	Eakin 2005; Tucker et al. 2010; Notenbaert et al. 2013
		Income_div	Economic income diversity index	Index	Number of activities where household obtain its economic income	Which of these activities provide more economic income last year?		Eakin 2005; Notenbaert et al. 2013
		Income_hh	Total income in the household	Mexican pesos	Economic income collected in the household from productive activities and subsidies	Which was the quantity that the household sell of….last year? How much do you receive from each subsidy?	This measure is sensible to the price's measure quality	Eakin and Bojórquez 2008
	AC_education	Education	Education level	Discrete: 0=not completed; 1=primary; 2=secondary; 3=higher	Formal education level completed	Which studies do you have completed?	It can be improved asking about the real capacity to read and write	Eakin 2005; Eakin and Bojórquez 2008;Tucker et al. 2010

		Trainining	Training courses	Dummy: 0=no; 1=yes	Informal education	In the last 5 years, have you attended to training?		Smit and Wandel 2006
		Fluent _spanish	Household heads speaking fluent Spanish	Dummy: 0=no; 1=yes, both	Capacity to understand issues out of the familiar atmosphere	By observation and informal conversations		
		Entreprerou-ness	Entrepreneurness	Dummy: 0=no; 1=yes	Proxy of motivation and innovation by household head to develop new activities	Do you have a project or an idea that you would like to do in a near future to improve the life conditions of your family?	Respondents may be associate this question with programmes and subsidies taken in place	Ruiz-Mallén et al. in rev
		Recognition _agriculture	Knowledge and status in agriculture	Dummy: 0=no; 1=yes	Recognition as person with more knowledge about agricultural practices	Could you say me the name of 3 members of the community that you considered as the most experts in agricultural practices	Respondents may associate this knowledge with the use of technology	Ruiz-Mallén et al. in rev
		Recognition _forest	Knowledge and status in forest practices	Dummy: 0=no; 1=yes	Recognition as person with more knowledge about forest and its resources	Could you say me the name of 3 members of the community that you considered as the most experts in forestry practices	Respondents may are not comfortable answering this question which is related to conflictive issues	Ruiz-Mallén et al. in rev
	AC _materials	Car	Car	Dummy: 0=no; 1=yes (unpaid or owner)	Transportation and potential source of money	Do you have a car? (If not) Do you borrow or rent it?		Eakin 2005; Eakin and Bojórquez 2008 (similar)
		Motor _bicycle	Motorcycle or bicycle	Dummy: 0=no; 1=yes (unpaid or owner)	Transportation and potential source of money	Do you have a motorcycle /bicycle? (If not) Do you borrow or rent it?		Eakin 2005; Eakin and Bojórquez 2008 (similar)
		Electric_ saw	Electric saw	Dummy: 0=no; 1=yes (unpaid or owner)	Capacity to accumulate forest resources and potential source of money	Do you have an electric saw? (If not) do you borrow or rent it?		Eakin 2005; Eakin and Bojórquez 2008 (similar)
		Water _system	Water catchment system in the agricultural field	Dummy: 0=no; 1=yes	Potential capacity to have animals in the agricultural field	Do you have any source of water in the agricultural field?	It can be improved adding data about its water capacity and if it is dry in the driest months	Eakin 2005; Eakin and Bojórquez 2008 (similar)
	AC _social	Land_right _hh	Household land rights	Dummy: 0=no; 1=yes	Right to access, use and take decisions about natural resources	Do you have land tenure rights? And, any household member?		Eakin and Bojórquez 2008
		Assembly _attendant	Assembly attendance	Dummy: 0=no; 1=yes	Level of knowledge about community's matters	Do you participate in the local assembly to share your opinion?		Ruiz-Mallén et al. 2014

		Assembly_ participation	Participation in the assembly	Discrete: 0=no, 1=sometimes, 2=always	Leadership and empowerment proxies	During the last 5 years, have any household head had a charge in the community?		Ruiz-Mallén et al. 2014
		Authority	Authority in the community	Discrete: 0=no, 1=yes, but not authority; 2=yes, authority	Key agents in the community	During the last 5 years, have any household head had a charge in the community?		Ruiz-Mallén et al. in rev
		Memberhicp_female	Membership to any organisation or group	Dummy: 0=no; 1=yes	Social network of female household head	Are any household head a member in an organisation/group?		
		Membership_male	Membership to organisation or group	Dummy: 0=no; 1=yes	Social network of male household head	Are any household head a member in an organisation/group?		
		Exchange_lend	Social Exchange Index (lending)	Number	Number of items (materials and land) lending by the household	Have you lent (materials and land) during the last year?	It can be improved adding data about the frequency of each exchange item	Smit and Wandel 2006 (similar)
		Exchange_borrow	Social Exchange Index (borrowing)	Number	Number of items (materials and land) borrowing by the household	Have you borrowed (materials and land) during the last year?	It can be improved adding data about the frequency of each exchange item	Smit and Wandel 2006 (similar)
		Loan_lend	Social Networks Loans (lending)	Dummy: 0=no; 1=yes	Loans lending by the household	Have you lent money during the last 5 years?	It can be improved adding data about the frequency	Smit and Wandel 2006 (similar)
		Loan_borrow	Social Networks Loans (borrowing)	Dummy: 0=no; 1=yes	Loans borrowing by the household	Have you borrowed money during the last 5 year?	It can be improved adding data about the frequency	Smit and Wandel 2006 (similar)
	AC_workforce	Adults_work	Human workforce	Persons	Number of adults in the household	How many people older than 16 are living in the house?		Eakin and Bojórquez 2008
		Age_hh_head	Age of the household head	Years	Potential physical capacity of the household head	How old are you? (female and male household head)	It can be improved excluding adults unable to work	Eakin and Bojórquez 2008
		Health	Health status of household heads	Dummy: 0=not healthy; 1=healthy	Potential capacity of household heads to work	Observation and informal conversations		

		Distance _field	Distance to the closest labour field	Kilometres	Potential capacity to develop some activities and proxy of economic investment by some activities	Which was the distance between the house and the agricultural field?	It does not consider the topography of the path leading to the agricultural field	
		Quality _path	Access to a good quality path leading	Discrete: 0=no; 1=partial; 2=total	Potential capacity to develop some activities and proxy of economic investment by some activities	Did you have a good path leading to the agricultural filed?		
	AC_natural	Farm_size	Farm size	Hectare	Potential capacity to develop some activities	How many hectares of land do you have?	It can be improved adding topographic and geological information	Eakin and Bojórquez 2008; Tucker et al. 2010
		Land_out	Property land out of the community	Dummy: 0=no; 1=yes	Potential capacity to develop and diversify livelihoods	Do you have land out of the community?		
		Water _access	Access to water in the agricultural field	Dummy: 0=no; 1=yes	Potential capacity to develop some specific livelihoods	Do you have access to water in the agricultural field?	It can be improved adding data about its water capacity and if it is dry in the driest months	
		Plant_div _field	Plant crop diversity in the agricultural field	Species	Potential capacity to cover household's fee and/or selling activities	Which vegetables, roots and fruit plants do you have in the agricultural field?	It can be improved asking species from a list prepared in advance	Eakin and Bojórquez 2008 (similar)
		Plant_div _home	Home garden diversity	Species	Potential capacity to cover the household's fee and/or selling activities	Which vegetables, roots and fruit plants do you have in the home garden?	It can be improved asking species from a list prepared in advance	Eakin and Bojórquez 2008 (similar)

Appendix VI: Technical procedural establishing HVI ranks

Example: Overall Household Vulnerability Index (*HVI_overall*)

Variable	N	Mean	Std.Dev.	Min	Max
HVI_overall	86	0.641	0.338	0	2.031

The *HVI_overall* undertakes values between 0 and 2.03, its range being 2.03.

The next step is to distribute this range (2.03) between the 3 ranks, considering that each means a third of this range. Thus the numerical values that divide up each category are calculated following these formulas:

- Threshold between rank 1 and rank 2 = *HVI_overall* range *0.3333 = 0.68
- Threshold between rank 2 and rank 3 = *HVI_overall* range *0.6666 = 1.36

Thus, households were classified among ranks based on this rationality:

- Rank 1: Low (L) = [0 , 0.68]
- Rank 2: Medium (M) = (0.68 , 1.36]
- Rank 3: High (H) = (1.36 , 2.03]

Appendix VII - Environmental timelines for Once. Note: Published elsewhere (Delgado-Serrano et al. under review).

Environmental context	Year	Ecological milestones	Social-political milestones
Tropical forest landscape. There were timber and *chicle* extraction. The place was a *chicle* (gum) extraction camp	**<1981/82**		
From 1981to early 1991: Slight demographic growth despite the emigration flow of some families due to extremely hard living conditions	**1981**	Slight deforestation near the settlement due to new agricultural fields	First permanent inhabitants
From 1985 to 1991: Moderate deforestation process to settle the urban area, to expand the agricultural fields *From 1985 to 1994:* Hardwood deforestation was also undertaken by external actors	**1985**	Beginning of illegal logging in the community forests (supported by the community)	Community members initiated the land entitlement process
From 1989 to date: The influence of the CBR was initially focus on limit settlements and to reduce timber extraction	**1989**	Gilberto hurricane: It brought intensive rainfall and strong wind that affect *milpas*	Creation of the CBR by the federal government
From 1991 to 1994: 4-year intensive drought (< 600 mm of accumulated annual rainfall and < 800 mm in the 3 previous years) *From 1991 to 2008:* Moderate deforestation in the agricultural fields for developing farming activities	**1991**		Provisional recognition as an *ejido*, and official land distribution between the recognised 55 *ejidatarios*
	1993	Farmers opened new agricultural fields along the road	Road connection with the municipality Creation of a plot worked by women (UAIM), where women obtained a reforestation subsidy

Increased households' impoverishment due to the drought's negative impact on agriculture and livestock rearing	**1994**	The extreme drought year affected on-farm and domestic activities	Official recognition of the community's land tenure rights as *ejido.* 2012.17 hectares were set aside as communal forest lands
From 1995 to date: Slight deforestation in the expanded urban area as soon as landless households are moving in	**1995**	Roxana hurricane: floods and strong wind It also destroyed the bridge living this community without road connection	Some households participated in the demonstration in *Xpujil* to claim by the marginal conditions of the region and their suffering by the lack of water Expansion of the urban area to provide a half of the standard urban plot (50x50 meters) to *pobladores*
From 1996 to date: Increasing vegetable diversity of home gardens by some women household heads	**1996**	A non-governmental organisation (PRONATURA) distributed vegetable seeds among female household heads, and encouraged them to use of green fertilise techniques	Creation of the Calakmul Municipality Chilli price collapse (under 2 MXN)
Progressive marginalisation of *pobladores*	**1997**		Internal rule limiting forest extractive practices and hunting to *ejidatarios'* agricultural fields or communal forests
The community fire regulation decreased the rate of deforestation by uncontrolled fires	**1999**		Fire prevention training by the CBR, and internal rules increasing control in forest clear-and-burn practices
From 2000 to date: Increasing external support as a result of the Calakmul's municipality and strength the relationship with the CBR Decreasing chilli profitability by the increased uncertainty about chilli prices and the intensification of pests Progressive increase of internal conflicts among households resulting in a low willingness to work	**2000**	Slight deforestation to create pastures for livestock rearing	Creation of an UMA to wildlife conservation supported by CBR, located in the communal forest area and North agricultural fields

collectively and to develop conservation practices no rewarded *From 2000 to 2008:* Increasing the long-term migration to the USA			
	2001		Chilli price collapse (under 2 MXN)
	2005		Chilli price collapse (under 2 MXN)
From 2006 to date: The access to farming subsidies encouraged farmers to invest in livestock activities. Progressive transformation of some agricultural fields into pasture fields. Many households engaged with a mosaic of landscapes in their fields: grass, agriculture and forest. The improvement of living conditions decreased local people's migration to the USA	**2006/09**	Slight deforestation along the new paths	Government and NGOs provided financial support to households to improve their livelihoods (building houses, water tanks, etc.) First subsidy for water tanks in agricultural fields (*jagüeyes*) and first 10 Km of a good quality path leading to labour fields
From 2008 to date: Progressive restrictions of accessing and using forest and non-forest resources out of agricultural fields due to the lack of internal accountability Progressive marginalisation of *pobladores* in relation to the new conservation initiatives implemented The PES scheme has decreased the deforestation and stabilised the size of fields under labour	**2008**		First PES programme located in the communal forest lands, but also in North agricultural fields, promoted by CONAFOR Improvement of the road connection with other communities
From 2012 to date: Increased water accumulation capacity for domestic purposes Increased sanctions for timber and firewood extraction out of agricultural fields, which has led to new conflicts among *ejidatarios* and *pobladores*	**2012**	Reforestation activities promoted by CONAFOR within the Environmental Compensation programme Few experimental plots for agricultural innovation in some fields supported by CRIPX and the municipality	EC programme promoted by CONAFOR CRIPX facilitated an alternative intermediary for chilli trade to some members living in *Once* Building household water tanks

From 2013 and expected to continue: Increased conflict between *ejidatarios* and landless households by the high restriction of accessing to forest resources in areas of well accessibility	**2013**	Increasing planting area of chilli due to the high price obtained during the last season Floods ruined the harvest of maize and chilli	Second PES programme. It took place in two separated areas within the communal forest lands located along the road

Appendix VIII: Environmental timelines for *Sacrificio*

Environmental context	Year	Ecological milestones	Social-political milestones
From early 1990s to 1998: Leadership conflicts, and slight demographic instability due to the extremely hard environmental conditions Intensive deforestation period around these communities clearing the forest cover to establish the urban area and to develop agricultural practices	**Early 1990s**		Migrant families formed *El Sacrificio*, and the four communities inside of the CBR core area I (i.e. *Las Delicias, 22 de Abril Aguas Amargas,* and *Aguas Turbias*)
	1995	Roxana hurricane: it affected slightly these settlements	Some households participated in the demonstration in *Xpujil* to claim by their marginal conditions and their suffering by the lack of water
	1996		Chilli price collapse (under 2 MXN)
From 1997 to 1999: Negotiations with SRA to select a proper settlement area advised by CRIPX Progressive resettlement of these illegal settlements in *El Sacrificio*	**1997**		The CBR and SRA staff communicated in the four settlements located inside of the CBR core area I that their situation was illegal. The resettlement process was initiated
	1998	Mitch hurricane: it affected slightly the *milpa* cultivation	
	1999 (Dec)		Ending of the resettlement of L*as Delicias, 22 de Abril Aguas Amargas,* and *Aguas Turbias* in *El Sacrificio* to form the community called *Santo Domingo – El Sacrificio* (refereed herein as *Sacrificio*)
From 2000 to date: Intensive deforestation of forest in the agricultural fields	**2000**	Intensive deforestation to clear the urban area, and to open fields for farming purposes	Distribution of agricultural fields among "landowners"

Ongoing exploitation of forest and non-forest resources inside of the CBR core zone I			
From 2001 to mid-2000: Marginalisation of *Sacrificio* as a result of vandalism events From 2001 to date: Arise the conflict between *Sacrificio's* inhabitants and the CBR by the lack of official land rights and the no compliance of CBR's promises	**2001**		Subsidies of metal layers and concrete First collective water tank Chilli price collapse (under 2 MXN)
	2002	Isidoro Hurricane: it strongly affected *milpas*	Road connection to *Xpujil*
From 2004 to date: Progressive access to governmental support (e.g. OPORTUNIDADES) Occasional vandalism conflicts within the community	**2004**		Electricity, and collective facilities (assembly house and a second water tank)
	2005		Chilli price collapse (under 2 MXN)
From 2006 to 2012: Increased water accumulation capacity for domestic purposes	**2006**		First domestic water tanks provided by the CBR Official resolution to inform that some agricultural fields are located inside of the CBR core area I
	2007	Drought: it affect *milpas* Dean Hurricane: it strongly affected chilli cultivation	
	2011	Agricultural pests strongly affected maize harvest	Wide distribution of household water tanks by the municipality, the CBR and a non-governmental organisation Maiz Criollo subsidy by the CBR and Procampito subsidy by SAGARPA
	2012	New and locally unidentified agricultural pest to maize plantation	Household water tanks to every households without this facility by Fondo para la Paz Beekeeping collective project of women Increased of good quality path leading to labour fields

From 2013 and expected to continue: Reinvigoration of the internal union to claim for land tenure rights	**2013**		Initiation of a dialogue between *Sacrificio* and CRIPX to advice in the process of land entitlement

Appendix IX: Non-parametric analysis in the HVI

Table 1: Significant variables for each specific sensitivity across communities

	Once **(mean) N=35**	***Sacrificio*** **(mean) N=52**	***Overall*** **(mean) N=87**	***p-value***	**Analysis**
Dependency_ratio**	0.184	0.302	0.255	*0.0102*	Kruskal-Wallis test
S_rainfall**	**0.292**	**0.225**	**0.254**	***0.0279***	Kruskal-Wallis test
Land_crop	0.386	0.403	0.396	*0.3808*	Kruskal-Wallis test
Income_crop	0.372	0.400	0.389	*0.6337*	Kruskal-Wallis test
Livestock_sheep	0.060	0.040	0.048	*0.4308*	Kruskal-Wallis test
Livestock_cow***	0.138	0.000	0.055	*0.0001*	Kruskal-Wallis test
Income_livestock*	0.158	0.046	0.091	*0.0534*	Kruskal-Wallis test
Maize_season**	0.743	0.404	0.540	*0.002*	Chi-square test
S_chilli	**0.173**	**0.191**	**0.184**	***0.2439***	Kruskal-Wallis test
Land_chilli	0.128	0.081	0.100	*0.6706*	Kruskal-Wallis test
Income_chilli	0.207	0.189	0.196	*0.5737*	Kruskal-Wallis test
S_conservation	**0.323**	**0.301**	**0.308**	***0.4459***	Kruskal-Wallis test
Size_hh**	0.286	0.400	0.353	*0.0081*	Kruskal-Wallis test
Forest_use	0.171	0.269	0.230	*0.288*	Chi-square test
Forest_use_5y**	0.686	0.346	0.483	*0.002*	Chi-square test
Livestock_sheep_5y	0.256	0.173	0.218	*0.212*	Chi-square test

Note: * indicates significance of variables in distinguishing sensitivity profiles across community in non-parametric tests (*p<0.1; **p<0.05; ***p<0.01)

Table 2: Significant variables in the comparison of adaptive capacity profiles across communities

Variables	***Once*** **(mean) N=38**	***Sacrificio*** **(mean) N=52**	**Overall mean N=90**	***p-value***	**Analysis**
AC_economic	**0.378**	**0.319**	**0.344**	***0.176***	Kruskal-Wallis test
Saving	0.368	0.308	0.333	*0.546*	Chi square test
Livelihood_div	0.539	0.545	0.543	*0.416*	Fisher's exact test
Income_hh**	0.225	0.105	0.156	*0.0083*	Kruskal-Wallis test
AC_education	**0.421**	**0.365**	**0.388**	***0.151***	Kruskal-Wallis test
Education	0.211	0.250	0.233	*0.459*	Fisher's exact test
Training**	0.579	0.327	0.433	*0.017*	Chi square test
Fluent_spanish	0.895	0.904	0.900	*0.578*	Fisher's exact test
Entreprerounes	0.658	0.596	0.622	*0.551*	Chi square test
Recognition_agriculture	0.158	0.058	0.100	*0.118*	Chi square test
Recognition_forest	0.316	0.058	0.044	*0.435*	Fisher's exact test
AC_material* **	**0.586**	**0.288**	**0.414**	***0.000***	Kruskal-Wallis test
Car**	0.316	0.135	0.211	*0.038*	Chi square test
Motor_bicycle**	0.947	0.673	0.789	*0.001*	Fisher's exact test
Electric_saw***	0.763	0.327	0.5011	*0.000*	Chi square test
Water_system***	0.316	0.019	0.144	*0.000*	Fisher's exact test
AC_social	**0.367**	**0.370**	**0.369**	***0.950***	Kruskal-Wallis test
Land_right_hh	0.605	0.615	0.611	*0.923*	Chi square test
Assembly_attendant**	0.789	0.981	0.9	*0.004*	Fisher's exact test
Assembly_participation	0.316	0.260	0.283	*0.6572*	Chi square test
Authority	0.263	0.231	0.244	*0.778*	Fisher's exact test
Membership_female	0.079	0.115	0.100	*0.422*	Fisher's exact test
Membership_male**	0.395	0.173	0.267	*0.019*	Chi square test
Exchange_lend	0.298	0.257	0.274	*0.4893*	Kruskal-Wallis test
Exchange_borrow	0.289	0.285	0.287	*0.9199*	Kruskal-Wallis test
Loan_lend	0.189	0.288	0.289	*0.992*	Chi square test
Loan_borrow	0.342	0.500	0.433	*0.100*	Fisher's exact test

Variables	*Once* (mean) N=38	*Sacrificio* (mean) N=52	Overall mean N=90	*p-value*	Analysis
AC_demographic	**0.646**	**0.653**	**0.650**	***0.743***	Kruskal-Wallis test
Adults_work	0.300	0.307	0.304	*0.4643*	Kruskal-Wallis test
Age_hh_head	0.658	0.755	0.714	*0.499*	Fisher's exact test
Health	0.842	0.942	0.900	*0.114*	Fisher's exact test
Distance_field	0.653	0.598	0.621	*0.5231*	Kruskal-Wallis test
Quality_path	0.776	0.663	0.711	*0.124*	Chi square test
AC_natural**	**0.283**	**0.183**	**0.225**	***0.049***	Kruskal-Wallis test
Farm_size***	0.279	0.102	0.177	*0.0008*	Kruskal-Wallis test
Land_out	0.053	0.000	0.022	*0.176*	Chi square test
Water_access***	0.526	0.077	0.267	*0.000*	Fisher's exact test
Plant_div_field***	0.240	0.365	0.312	*0.0004*	Kruskal-Wallis test
Plant_div_home	0.317	0.372	0.349	*0.2326*	Kruskal-Wallis test

Note: * indicates significance of variables in distinguishing adaptive capacity profiles across communities in non-parametric tests (*p<0.1; **p<0.05; ***p<0.01)

Table 3: Significant adaptive capacity variables in the comparison across clusters

Variable	C1 Mean N=16	C2 Mean N=19	C3 Mean N=36	C4 Mean N=19	Over-all mean N=90	*p-value*	Analysis
AC_economic**	**0.219**	**0.337**	**0.336**	**0.471**	**0.344**	***0.0015***	Kruskal-Wallis test
Savings**	0.063	0.474	0.278	0.526	0.333	*0.011*	Fisher's exact test
Livelihood_div*	0.510	0.456	0.583	0.579	0.543	*0.065*	Fisher's exact test
Income_hh***	0.084	0.080	0.147	0.308	0.156	*0.0001*	Kruskal-Wallis test
AC_education***	**0.330**	**0.237**	**0.483**	**0.412**	**0.388**	***0.0001***	Kruskal-Wallis test
Education	0.291	0.158	0.287	0.158	0.233	*0.150*	Fisher's exact test
Training***	0.250	0.053	0.694	0.474	0.433	*0.000*	Fisher's exact test
Fluent_spanish	0.875	0.947	0.917	0.842	0.900	*0.679*	Fisher's exact test
Entrepreneurship***	0.500	0.263	0.889	0.579	0.622	*0.000*	Fisher's exact test
Recognition_agriculture**	0.000	0.000	0.056	0.368	0.100	*0.001*	Fisher's exact test
Recognition_forest	0.063	0.000	0.056	0.053	0.044	*0.830*	Fisher's exact test

Appendix

Variable	C1 Mean N=16	C2 Mean N=19	C3 Mean N=36	C4 Mean N=19	Over-all mean N=90	*p-value*	Analysis
AC_material* **	**0.484**	**0.145**	**0.319**	**0.803**	**0.414**	***0.0001***	Kruskal-Wallis test
Car***	0.250	0.053	0.056	0.632	0.211	*0.000*	Fisher's exact test
Motor_bicycle**	0.750	0.526	0.861	0.947	0.789	*0.009*	Fisher's exact test
Electric_saw***	0.938	0.000	0.361	0.947	0.5011	*0.000*	Fisher's exact test
Water_system***	0.000	0.000	0.000	0.684	0.144	*0.000*	Fisher's exact test
AC_social* **	**0.291**	**0.227**	**0.434**	**0.453**	**0.369**	***0.0001***	Kruskal-Wallis test
Land_right_hh ***	0.313	0.368	0.667	1.000	0.611	*0.000*	Fisher's exact test
Assembly_attant	0.813	0.947	0.889	0.947	0.9	*0.562*	Fisher's exact test
Assembly_participation***	0.094	0.053	0.375	0.553	0.283	*0.000*	Fisher's exact test
Authority***	0.063	0.079	0.333	0.395	0.244	*0.000*	Fisher's exact test
Membership_female	0.063	0.000	0.139	0.158	0.100	*0.309*	Fisher's exact test
Membership_male**	0.063	0.053	0.472	0.263	0.267	*0.001*	Fisher's exact test
Exchange_lend**	0.229	0.167	0.319	0.333	0.274	*0.0203*	Kruskal-Wallis test
Exchange_borrow	0.396	0.342	0.259	0.193	0.287	*0.1004*	Kruskal-Wallis test
Loan_lend**	0.125	0.158	0.306	0.526	0.289	*0.036*	Fisher's exact test
Loan_borrow***	0.750	0.105	0.611	0.158	0.433	*0.000*	Fisher's exact test
AC_demographic*	**0.698**	**0.550**	**0.668**	**0.676**	**0.650**	***0.0749***	Kruskal-Wallis test
Adults_work	0.338	0.284	0.278	0.347	0.304	*0.4257*	Kruskal-Wallis test
Age_hh_head**	0.922	0.631	0.75	0.552	0.714	*0.003*	Fisher's exact test
Health_hh*	1.000	0.737	0.917	0.947	0.900	*0.074*	Fisher's exact test
Distance_field	0.574	0.518	0.645	0.719	0.621	*0.2297*	Kruskal-Wallis test
Quality_path	0.656	0.578	0.75	0.816	0.711	*0.323*	Fisher's exact test
AC_natural* **	**0.135**	**0.152**	**0.200**	**0.422**	**0.225**	***0.0001***	Kruskal-Wallis test
Farm_size***	0.102	0.069	0.133	0.430	0.177	*0.0001*	Kruskal-Wallis test
Land_out	0.000	0.000	0.028	0.053	0.022	*1.000*	Fisher's exact test
Water_access***	0.000	0.105	0.111	0.947	0.267	*0.000*	Fisher's exact test
Plant_div_field	0.315	0.284	0.301	0.358	0.312	*0.8581*	Kruskal-Wallis test
Plant_div_home**	0.258	0.302	0.429	0.320	0.349	*0.0046*	Kruskal-Wallis test

N.B: * indicates significance of variables in distinguishing adaptive capacity profiles across clusters in non-parametric tests (*p<0.1; **p<0.05; ***p<0.01)

Appendix X: Overall HVI measures

idhh	S_market	S_climatic	S_conservation	SI	AC_economic	AC_educational	AC_material	AC_social	AC_workforce	AC_natural	ACI	HVI_cimatic	HVI_market	HVI_conserva-tion	HVI_overall
12321	0,59	0,49	0,70	**0,59**	0,19	0,33	0,25	0,17	0,70	0,11	**0,29**	1,67	2,02	2,40	**2,03**
11391	0,59	0,27	0,53	**0,47**	0,19	0,17	0,50	0,17	0,63	0,11	**0,29**	0,91	2,02	1,82	**1,61**
12061	0,15	0,46	0,69	**0,42**	0,60	0,39	0,25	0,25	0,58	0,13	**0,37**	1,27	0,42	1,89	**1,13**
11351	0,49	0,44	0,17	**0,38**	0,13	0,39	0,50	0,25	0,58	0,14	**0,33**	1,33	1,47	0,52	**1,13**
12220	0,22	0,20	0,82	**0,41**	0,26	0,28	0,50	0,30	0,67	0,21	**0,37**	0,55	0,60	2,23	**1,11**
12071	0,15	0,06	0,57	**0,26**	0,46	0,22	0,25	0,15	0,34	0,06	**0,24**	0,26	0,62	2,38	**1,09**
12481	0,34	0,42	0,26	**0,33**	0,12	0,44	0,25	0,13	0,75	0,13	**0,31**	1,36	1,10	0,84	**1,08**
12381	0,19	0,21	0,21	**0,21**	0,19	0,17	0,00	0,18	0,49	0,18	**0,20**	1,06	0,93	1,05	**1,04**
12531	0,46	0,39	0,49	**0,45**	0,20	0,44	0,50	0,42	0,78	0,25	**0,43**	0,91	1,07	1,14	**1,04**
11171	0,64	0,47	0,33	**0,49**	0,59	0,50	0,50	0,35	0,78	0,12	**0,47**	0,99	1,36	0,70	**1,03**
11341	0,34	0,42	0,17	**0,30**	0,18	0,00	0,50	0,20	0,84	0,06	**0,30**	1,40	1,14	0,57	**1,03**
12131	0,38	0,46	0,37	**0,40**	0,53	0,22	0,50	0,18	0,82	0,12	**0,40**	1,16	0,95	0,94	**1,01**
12191	0,31	0,31	0,53	**0,38**	0,27	0,33	0,25	0,42	0,75	0,30	**0,39**	0,80	0,80	1,38	**0,98**
11301	0,26	0,34	0,23	**0,27**	0,20	0,17	0,25	0,30	0,64	0,09	**0,28**	1,22	0,95	0,85	**0,98**
12241	0,49	0,26	0,09	**0,29**	0,18	0,39	0,25	0,33	0,57	0,10	**0,30**	0,87	1,62	0,31	**0,97**
12421	0,15	0,36	0,37	**0,29**	0,51	0,17	0,00	0,33	0,68	0,14	**0,30**	1,20	0,49	1,22	**0,95**
12451	0,40	0,37	0,45	**0,41**	0,53	0,50	0,25	0,45	0,63	0,27	**0,44**	0,85	0,91	1,03	**0,94**
12081	0,15	0,35	0,17	**0,22**	0,10	0,22	0,00	0,27	0,78	0,04	**0,24**	1,48	0,63	0,73	**0,93**

idhh	S_market	S_climatic	S_conservation	SI	AC_economic	AC_educational	AC_material	AC_social	AC_workforce	AC_natural	ACI	HVI_cimatic	HVI_market	HVI_conservation	HVI_overall
12270	0,30	0,25	0,53	**0,36**	0,19	0,61	0,50	0,37	0,58	0,10	**0,39**	0,63	0,77	1,36	**0,91**
12111	0,34	0,16	0,37	**0,31**	0,22	0,50	0,00	0,48	0,73	0,12	**0,34**	0,46	0,98	1,07	**0,90**
12461	0,15	0,26	0,17	**0,20**	0,19	0,17	0,00	0,23	0,58	0,15	**0,22**	1,20	0,68	0,79	**0,89**
12401	0,37	0,45	0,09	**0,31**	0,51	0,33	0,00	0,33	0,57	0,37	**0,35**	1,28	1,06	0,27	**0,87**
12431	0,21	0,32	0,22	**0,24**	0,22	0,22	0,00	0,35	0,76	0,18	**0,29**	1,10	0,71	0,75	**0,85**
12201	0,19	0,08	0,59	**0,29**	0,53	0,22	0,00	0,32	0,80	0,16	**0,34**	0,25	0,55	1,74	**0,85**
12501	0,19	0,09	0,61	**0,30**	0,19	0,39	0,25	0,43	0,65	0,21	**0,35**	0,24	0,52	1,73	**0,84**
12361	0,08	0,32	0,51	**0,28**	0,28	0,33	0,25	0,28	0,71	0,19	**0,34**	0,92	0,24	1,48	**0,83**
11291	0,15	0,35	0,37	**0,28**	0,18	0,50	0,25	0,33	0,73	0,11	**0,35**	0,99	0,42	1,06	**0,81**
12440	0,22	0,25	0,25	**0,25**	0,19	0,39	0,50	0,10	0,62	0,06	**0,31**	0,79	0,71	0,80	**0,80**
12471	0,20	0,35	0,42	**0,32**	0,71	0,50	0,00	0,47	0,44	0,43	**0,42**	0,83	0,48	0,99	**0,75**
11381	0,11	0,46	0,53	**0,35**	0,59	0,50	0,50	0,23	0,78	0,18	**0,46**	0,99	0,24	1,15	**0,75**
11071	0,19	0,30	0,36	**0,28**	0,27	0,50	0,50	0,30	0,17	0,46	**0,37**	0,80	0,52	0,98	**0,75**
12031	0,31	0,29	0,23	**0,29**	0,26	0,17	0,25	0,60	0,79	0,21	**0,38**	0,75	0,81	0,61	**0,75**
11151	0,48	0,24	0,45	**0,40**	0,34	0,56	0,75	0,68	0,55	0,40	**0,55**	0,43	0,88	0,83	**0,74**
12161	0,30	0,18	0,29	**0,27**	0,52	0,50	0,00	0,35	0,60	0,25	**0,37**	0,49	0,81	0,77	**0,72**
11100	0,16	0,24	0,57	**0,32**	0,21	0,33	0,75	0,25	0,83	0,32	**0,45**	0,54	0,35	1,27	**0,71**
11051	0,07	0,24	0,49	**0,26**	0,58	0,72	0,25	0,12	0,43	0,10	**0,37**	0,65	0,20	1,35	**0,70**
12231	0,29	0,15	0,11	**0,19**	0,20	0,00	0,50	0,22	0,53	0,19	**0,27**	0,54	1,07	0,39	**0,69**
12211	0,35	0,34	0,17	**0,29**	0,24	0,56	0,50	0,43	0,75	0,09	**0,43**	0,79	0,81	0,40	**0,68**
11271	0,16	0,42	0,37	**0,31**	0,34	0,17	0,75	0,40	0,65	0,39	**0,45**	0,92	0,35	0,83	**0,68**

idhh	S_market	S_climatic	S_conservation	SI	AC_economic	AC_educational	AC_material	AC_social	AC_workforce	AC_natural	ACI	HVI_cimatic	HVI_market	HVI_conservation	HVI_overall
12101	0,15	0,30	0,37	**0,27**	0,24	0,56	0,25	0,40	0,86	0,16	**0,41**	0,73	0,36	0,91	**0,65**
11210	0,04	0,59	0,66	**0,40**	0,50	0,72	0,75	0,47	0,69	0,56	**0,62**	0,96	0,07	1,08	**0,65**
11121	0,07	0,35	0,29	**0,23**	0,17	0,39	0,50	0,18	0,81	0,07	**0,35**	0,99	0,21	0,83	**0,64**
11321	0,00	0,18	0,43	**0,19**	0,52	0,17	0,25	0,22	0,41	0,33	**0,32**	0,56	0,00	1,37	**0,59**
11041	0,22	0,32	0,53	**0,35**	0,74	0,33	0,75	0,38	0,76	0,57	**0,59**	0,54	0,37	0,91	**0,59**
12301	0,19	0,14	0,21	**0,19**	0,17	0,50	0,25	0,38	0,57	0,12	**0,33**	0,42	0,56	0,64	**0,56**
12291	0,00	0,19	0,40	**0,18**	0,54	0,22	0,25	0,37	0,40	0,18	**0,33**	0,59	0,00	1,22	**0,55**
12371	0,26	0,14	0,53	**0,31**	0,58	0,50	0,75	0,40	0,77	0,38	**0,57**	0,25	0,45	0,94	**0,54**
11021	0,04	0,20	0,66	**0,28**	0,55	0,61	0,25	0,60	0,68	0,41	**0,52**	0,38	0,07	1,27	**0,54**
11371	0,04	0,30	0,06	**0,12**	0,17	0,17	0,25	0,15	0,57	0,07	**0,23**	1,31	0,16	0,24	**0,53**
11221	0,16	0,29	0,66	**0,35**	0,62	0,67	1,00	0,75	0,45	0,53	**0,67**	0,43	0,24	0,98	**0,53**
11331	0,28	0,31	0,09	**0,23**	0,24	0,44	0,75	0,30	0,75	0,12	**0,44**	0,71	0,63	0,22	**0,52**
12331	0,07	0,24	0,53	**0,27**	0,59	0,33	0,75	0,68	0,48	0,25	**0,51**	0,47	0,14	1,03	**0,52**
12541	0,25	0,20	0,09	**0,19**	0,20	0,39	0,50	0,27	0,81	0,15	**0,39**	0,53	0,64	0,24	**0,48**
11241	0,12	0,36	0,51	**0,31**	0,73	0,39	1,00	0,57	0,76	0,50	**0,66**	0,55	0,18	0,77	**0,47**
11081	0,09	0,24	0,26	**0,19**	0,38	0,56	0,50	0,22	0,63	0,12	**0,40**	0,60	0,22	0,64	**0,46**
11031	0,11	0,19	0,38	**0,22**	0,57	0,56	0,50	0,48	0,70	0,14	**0,49**	0,39	0,23	0,78	**0,46**
12511	0,15	0,25	0,17	**0,19**	0,29	0,61	0,25	0,53	0,65	0,18	**0,42**	0,59	0,35	0,41	**0,45**
11141	0,13	0,06	0,26	**0,15**	0,04	0,22	0,50	0,42	0,52	0,41	**0,35**	0,18	0,38	0,76	**0,43**
11111	0,00	0,45	0,40	**0,56**	0,60	0,61	0,75	0,57	0,70	0,36	**0,60**	0,75	0,00	0,67	**0,43**
11010	0,07	0,20	0,31	**0,18**	0,19	0,33	0,50	0,53	0,87	0,16	**0,43**	0,28	0,17	0,71	**0,42**

idhh	S_market	S_climatic	S_conservation	SI	AC_economic	AC_educational	AC_material	AC_social	AC_workforce	AC_natural	ACI	HVI_cimatic	HVI_market	HVI_conservation	HVI_overall
12311	0,07	0,06	0,33	**0,15**	0,25	0,44	0,25	0,33	0,76	0,17	**0,37**	0,17	0,20	0,89	**0,42**
12151	0,00	0,30	0,22	**0,16**	0,20	0,61	0,25	0,45	0,60	0,17	**0,38**	0,79	0,00	0,57	**0,41**
12021	0,24	0,29	0,07	**0,20**	0,64	0,33	0,50	0,42	0,73	0,28	**0,48**	0,60	0,50	0,14	**0,41**
12011	0,01	0,28	0,05	**0,10**	0,55	0,17	0,00	0,23	0,40	0,19	**0,26**	1,08	0,04	0,19	**0,39**
12091	0,07	0,17	0,29	**0,17**	0,22	0,67	0,25	0,73	0,73	0,13	**0,46**	0,37	0,16	0,65	**0,38**
11281	0,16	0,31	0,06	**0,17**	0,19	0,33	0,75	0,40	0,78	0,38	**0,47**	0,66	0,35	0,12	**0,37**
12121	0,12	0,24	0,11	**0,15**	0,20	0,44	0,00	0,70	0,77	0,36	**0,41**	0,58	0,29	0,26	**0,36**
12041	0,11	0,20	0,13	**0,15**	0,18	0,56	0,25	0,58	0,81	0,08	**0,41**	0,49	0,27	0,33	**0,36**
11251	0,06	0,34	0,22	**0,19**	0,30	0,50	0,75	0,43	0,64	0,61	**0,54**	0,62	0,12	0,40	**0,35**
12261	0,04	0,22	0,06	**0,10**	0,12	0,22	0,25	0,17	0,78	0,15	**0,28**	0,78	0,13	0,20	**0,35**
12341	0,03	0,13	0,32	**0,15**	0,28	0,56	0,50	0,50	0,59	0,18	**0,43**	0,30	0,07	0,73	**0,35**
12521	0,21	0,11	0,13	**0,16**	0,26	0,61	0,50	0,57	0,68	0,18	**0,47**	0,23	0,46	0,29	**0,34**
11181	0,11	0,34	0,27	**0,22**	0,80	0,50	1,00	0,62	0,76	0,36	**0,67**	0,50	0,16	0,40	**0,33**
12491	0,03	0,14	0,29	**0,14**	0,38	0,44	0,50	0,30	0,84	0,19	**0,44**	0,31	0,06	0,66	**0,32**
12171	0,11	0,06	0,13	**0,11**	0,17	0,22	0,25	0,55	0,69	0,17	**0,34**	0,18	0,32	0,39	**0,32**
12350	0,04	0,05	0,26	**0,11**	0,26	0,39	0,25	0,35	0,76	0,14	**0,36**	0,15	0,10	0,71	**0,31**
12051	0,04	0,11	0,23	**0,12**	0,24	0,39	0,25	0,55	0,69	0,16	**0,38**	0,29	0,09	0,61	**0,31**
12411	0,23	0,11	0,16	**0,17**	0,66	0,33	1,00	0,43	0,67	0,40	**0,58**	0,19	0,39	0,27	**0,29**
11231	0,00	0,16	0,22	**0,11**	0,31	0,56	0,50	0,12	0,75	0,13	**0,39**	0,40	0,00	0,55	**0,29**
11311	0,09	0,20	0,02	**0,10**	0,24	0,17	0,75	0,35	0,45	0,34	**0,38**	0,53	0,24	0,04	**0,26**
11361	0,04	0,16	0,06	**0,08**	0,12	0,61	0,25	0,43	0,63	0,05	**0,35**	0,46	0,11	0,16	**0,23**

idhh	S_market	S_climatic	S_conservation	SI	AC_economic	AC_educational	AC_material	AC_social	AC_workforce	AC_natural	ACI	HVI_cimatic	HVI_market	HVI_conservation	HVI_overall
11261	0,07	0,24	0,03	**0,11**	0,60	0,50	1,00	0,40	0,51	0,50	**0,58**	0,41	0,12	0,06	**0,18**
12141	0,04	0,02	0,06	**0,04**	0,39	0,17	0,75	0,30	0,44	0,05	**0,35**	0,05	0,11	0,16	**0,11**
12390	0,00	0,06	0,02	**0,02**	0,24	0,17	0,00	0,28	0,47	0,27	**0,24**	0,26	0,00	0,07	**0,10**
12181	0,00	0,01	0,03	**0,01**	0,18	0,17	0,25	0,23	0,32	0,10	**0,21**	0,07	0,00	0,16	**0,07**
11201	0,00	0,00	0,00	**0,00**	0,17	0,33	0,00	0,12	0,00	0,03	**0,11**	0,00	0,00	0,00	**0,00**