Land degradation in the Highlands of Central Mexico: How Mazahua farmers manage, value and trade-off their control technologies

Belina Garcia Fajardo

February 2011

Thesis submitted to the School of International Development, University of East Anglia, in partial fulfilment of the requirements for the degree of doctor of Philosophy

Abstract

Land degradation is a local problem with global implications. This thesis sets out better to understand the local land management decisions of farmers, specifically their land degradation control (LaDC) practices, multiple values attached to practices and trade-offs. The geographical context is the Mazahua farming community in the Highlands of Central Mexico, but implications are drawn both methodologically and thematically for application to hillside communities more widely.

Using a combination of quantitative and qualitative techniques, involving interviews with key informants and advanced statistical techniques such as logistic regression and cluster analysis, the research investigated the adoption of LaDC technologies as a livelihood strategy. A sample of 101 farming households participated which managed 291 units of production. 31 household were involved in more intensive analysis of values and trade-offs made in technology adoption. In order to investigate how these values operate, 17 LaDC practices in the study area, along with the drivers for adoption of these technologies, were identified and categorised into 4 types. Technologies varied from soil amendments to regular adjuncts to farming practice and major earth-moving activities, all of which are fully described.

Farmers' values are shown to be related to economic as well as intrinsic personal interests, motives and norms. The values attached to technologies vary according to spatial, temporal and intrinsic perspectives, and the influences of external factors and the implications for livelihood sustainability. The multiple values associated with the practices influence how farmers respond to land degradation, and the type of technology they choose and where they apply it.

The major findings of this research show that the multiple values and trade-offs made according to perceived values control adoption and choice of technology. Some trade-offs contribute to sustainable land management and improved livelihoods. Understanding the rationale behind the adoption of LaDC practices helps to identify the implications of local action for sustainable land management and the development of farming livelihoods.

Acknowledgements

Reaching this point has got great significance in my professional and personal life. Above all I would like to express my utter gratitude to God Jehovah for giving me the opportunity and the strength to complete this work. I am grateful to Him for all those who have supported me and have in many ways contributed to complete my research project.

I am deeply grateful to my supervisors Prof. Michael Stocking and Dr. John McDonagh for all their input, support and patience throughout my research project. Working under their guidance has given me an invaluable source of knowledge and experience. Their help and trust were crucial during this challenging journey. Special appreciations to Michael for his personal commitment and care throughout this period. I have been honoured to work with both of you.

I would like to thank the *Consejo Nacional de Ciencia y Tecnologia* (CONACYT) for its sponsorship to undertake my research project at the University of East Anglia (UEA). I am also grateful to *Programa de Formacion de Talentos Universitarios* of the *Universidad Autonoma del Estado de Mexico* (UAEM) for providing part of the sponsorship necessary to enrol in the PhD project and to the *Secretaria de Educacion Publica* (SEP) for their partial support with the scholarship.

My deep gratitude to Dr. Carlos Arriaga, Mtra. Patricia Mireles, Dr. Gabino Nava, for their confidence, support, help and encouragement to start with this project and during fieldwork and to Mtra. Maru Valdez for her support too. Thank you to Mtro. Leon and Dr. Cristina Chavez for their contributions to the case study data. I would also like to thank the *Facultad de Georgrafia de la UAEM* for their institutional support and for facilitating some of the means to carry out my fieldwork.

During my fieldwork I was fortunate to count with the help and support of many people, all those who took part in the research project and also those who helped me to collect data and capture information. My deep gratitude to people in San Pablo Tlalchichilpa, in particular to Mr Olegario, Mrs Berta and Mrs Glenda for their invaluable and unconditional help and friendship during my time in the community, their caring love has been a great source of inspiration. I am also grateful to Yola, Aline, Jose, Mr Teodoro & family, Mrs Mary and Ana Pedraza. I appreciate the help of the research assistants from the *Facultad of Geografia*, the academic staff from *Universidad Intercultural del Estado de Mexico* (IUEM-San Felipe del Progreso) and also of Geog. Karina Ruiz and Arq. Carlos Molinar in the data collection.

I am grateful to Dr. Baruch Ramirez, Dr. Peter Moffat and Dr. Bereket Kebede for the statistical advice given at different stages of this research. Also thanks to Mandy and all PGR Office for their assistance in administrative procedures. I want to thank the Dean of Students and UEA Nursery for the special support during the last year of studies. Thank you to Amanda, Paul Binney and specially Sally Sutton for their proofreading at different stages of the thesis.

I am really grateful to MIND for their incredible support and help which was crucial in the final stage, special thanks to Joy, Alex, Tripuri, Sue, Andrew and Kate and GP. Paul Coathup.

I am profoundly grateful to my family who have been incredibly supportive and are a very important pillar in my life. A very special thank you to my mothers Agus and Velia and father-in law Eliezer without your help this could have not been possible. *Me inspiran!* Also thank you to my lovely sisters Silvia and Patricia for their unconditional love, cheering and confidence. Diego, Mau, Melisa, Daniel, Dana, Emilio and Vania thanks for bringing me such joy in stressful times. To my in-laws Jair, May, Jorge, Luis, Vicky and Anis receive all my gratitude. *Abuelo* Verulo thank you very much for your support during these years, we are blessed to have you in our lives. *Muchas gracias, es un privilegio tenerlos como familia!*

Very special thanks to my dear beloved husband Josias and my daughter Abril, you are my strength, my life; thanks for giving much of the inspiration to do this work. Jos thanks for being my rock, for your patience and unconditional love and help. Abril hope you could be proud of mummy. This is for our family, *los amo mucho familia!*

Without the support of my friends completing this work would have been more difficult. I am deeply grateful to Xochitl, Fabiola, Rafael and Citlalli for your kindness, encouragement and for being there when needed. I give thanks to Celeste, Gandhi, Baruch, Karla, Paty Almaguer, Alejandra Trejo, Oscar, Maria Adelaida, Tere, Cristobal, Pablo, Paty Agapusi, Akil, Hemant, Prajna, Naxelli, Lorena, Arlette, Denis, Kalu, Adriana Alvarez, Susanty, Gloria, Hector, Rafa Guerrero, Alfonso Mercado, Liz, Alicia, Rocio, Joe, Dyton and Amhed. Special thanks to my English colleagues and friends Elizabeth Westaway Mike Robins, Jenny Aldana and Stuart and Vicky Weaver for sharing your culture, friendship, support and knowledge with us, thanks for the encouragement too. Finally, I have also been blessed of having the support of many from Chapel Field Methodist Church, Norwich Central Baptist Church and el Divino Salvador, thank you.

For from Him and
through Him and
for Him are all things
Rom. 11:36

I dedicate this thesis to my Father Jesus Garcia who is enjoying this success from a very special place and to my Mother Agustina Fajardo with all my admiration and love.

In memory of my beloved Grandmother Catita 'an expert farmer of the Mexican Highlands' who taught me the value of rural life.

Also in memory of wonderful people in my life: Lulu, Tio Sam, Eric Payton, Tio David, Angelita, Xadanii, Tia Noemi, Les Snelling and my little Guru.

Table of Contents

List of Tables

List of Figures

List of Acronyms

AMP	Agricultural Modernisation Period
ASERCA	Support and Services for Agricultural Trading (Mexico)
CBD	Convention on Biodiversity
CIMMYT	International Centre for Maize and Wheat Improvement
CIPA	InterEnvironment Institute (2010) formerly known as Californian institute of Public Affairs
CONAFOR	National Forestry Commission (Mexico)
CONASUPO	National Company of Popular Subsistence (Mexico)
CONAZA	National Commission on Arid Zones (Mexico)
COP	Commercial Opening Period
CP	Colonial Period
CR	Crop Rotation
DFID	Department for International Development
FAO	Food and Agriculture Organization
GEF	Global Environment Facility
H	Household
HH	Household Head
IC	Intercropping
ICAR	Institute of Agriculture and Rural Sciences formerly (CICA)
IFAD	International Fund for Agricultural Development
IG	Infilling Gullies
INEGI	National Institute of Statics and Geography (Mexico)
IP	Independence Period
LADA	Land Degradation Assessment in Drylands
LaDC	Land Degradation Control
LT	Long Term
LUT	Land Utilization Type
MEA	Millennium Ecosystem Assessment
MV	Multiple Values
NAFTA	North American Free Trade Agreement
NRM	Natural Resource Management
OECD	Organisation for Economic Cooperation and Development
OPORTUNIDADES	Human Development Programme (Mexican Government)

PAN	National Action Party (Mexico)
PET	Temporal Employment Programme
PHP	Pre-Hispanic Period
PLEC	People, Land Management and Environmental Change
PRI	Institutional Revolutionary Party (Mexico)
PROCAMPO	Farmers Direct Support Programme (Mexico)
PROCEDE	Programme for Certification of *Ejido* Land Rights and Titling of Urban lots (Mexico)
RPRP	Revolution and Post-revolution Period
RS	Reinstatement of Sediments
SAGARPA	Department of Agriculture Livestock Rural Development, Fisheries and Food (Mexico)
SEMARNAT	Secretariat of Environment and Natural Resources (Mexico)
SPT	San Pablo Tlalchichilpa
SRL	Sustainable Rural Livelihood
ST	Short Term
TLU	Tropical Livestock Units
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Program
VIF	Variance Inflation Factor
WOCAT	World Overview of Conservation Approaches and Technologies
WSSD	World Summit on Sustainable Development

Chapter 1. Introduction

The aim of this research is to achieve a comprehensive understanding of the land management decisions made by farmers in hillside communities affected by land degradation, specifically in relation to their management, values and trade-offs linked to land degradation control (LaDC) technologies. This chapter presents the background to this research, establishing its place in academic debate and defining the research aim. It specifies the research objectives, which create links between key bodies of theory and the research, discusses the relevance of the study and presents an outline of the thesis.

1.1. Background of the research

The 2002 World Summit on Sustainable Development reaffirmed that land degradation is one of the major global environmental and sustainable development challenges of the 21st century, due to its impact on food security, environmental quality and development (Gisladottir and Stocking, 2005).[1] There is a wide range of definitions of the term land degradation that varies across disciplines and actors. It is broadly defined as environmental change that, temporarily or permanently, degrades or reduces the natural potential of land and of the primary renewable natural resource components (especially, water, soil and vegetation), affecting ecosystem integrity and reducing the sustainable ecological productivity that supports society and development (Scherr and Yadav, 1996, Stocking, 2002a, GEF, 2005).[2] Land degradation is a complex issue because it is linked not only to biophysical but also to socioeconomic drivers and impacts. There is evidence that land degradation triggers migration, disrupts economic development, increases regional instability and threatens

[1] Scherr and Yadav (1996) estimate that around 2 billion hectares worldwide (22 per cent of all cropland, forest and woodland) were degraded during the second half of the 20th century. Africa and Latin America appear to have the highest portion of degraded agricultural land.

[2] Generally, land degradation is referred to as the decrease or loss of the economic productivity and complexity of land resulting from land use or processes or combinations of processes of human activities or ecosystem patterns; or as reduction in the capacity of the land to perform or provide ecosystem functions and services that support society and development (MEA, 2005; LADA, 2008).

traditional livelihood systems (GEF, 2005).[3] International conventions (CBD, UNCCD) have recognised the threats of land degradation and its impact on the integrity and functioning of ecosystems and the human development of people. O'Riordan (2000) states that land degradation has been advanced as "the single most pressing current global environmental problem". Considering that an environmental problem only becomes globally significant through cumulative effects (Lambin et al. 2002), land degradation is at the fore of current environmental discourses worldwide. The urgent need to address land degradation at the global level has grown considerably as intrinsic links with other global environmental problems such as climate change, biodiversity loss, desertification and water depletion have been identified (WSSD, 2002, UNDP, 2010).

International and regional efforts to combat land degradation have had mixed results, but there has been a prevalence of inequitable and ineffective methods in these efforts (Lapar and Pandey, 1999, Mangisoni and Phri, 1996). In particular, the controversial nature of land degradation has led to problems in the policy arena regarding how to control it: it is "a situation exacerbated by uncertainty in the data and the lack of any authoritative and widely accepted assessment of the extent and causes of land degradation" (FAO, 2004; see also Gleenn et al. 1998).

National governments and international organisations have provided funding to assist in the prevention and control of land degradation, particularly in developing countries where there are many vulnerable areas (GEF, 2005). Special attention is now being paid to promoting sustainable land practices and to the involvement and participation of different stakeholders at local, national and global levels. Global desire to address land degradation has led to the recognition that the top-down approach is not an appropriate way of tackling the problem.

In the search for sustainable global environmental management, international conventions are focusing on developing joint programmes to tackle land

[3] There is evidence that land degradation is an important factor in rural-urban migration in Mexico and to the Mexico-US migration stream (700,000-900,000 people migrate annually). There is a strong correlation between environmental stress, poverty and migration (Campbell and Berry, 2003)

degradation to directly or indirectly achieve multiple global benefits, including poverty alleviation and preservation of the stability, functions and services of the ecosystem through measures such as soil and watershed protection, carbon storage, biodiversity conservation and climate regulation (Pagiola, 1999, GEF, 2005).[4] Strategies to control land degradation and/or address its effects focus on promoting synergies in global environmental management. From the global perspective, land degradation control (LaDC) involves assorted benefits at the global level which also respond to social responsibility for the generations to come. Addressing land degradation should contribute significantly to the Millennium Development Goals of reducing poverty and the loss of environmental resources and ensuring environmental sustainability (UNDP, 2003).

Different arguments arise when exploring land degradation at the local level, particularly in vulnerable and marginal environments such as rural highlands. It has been assumed that land degradation is the result of local farmers' inadequate land management. Hagos et al.(Hagos et al., 1999) suggest that farmers may not perceive land degradation as an immediate problem and therefore they may not be inclined to act to reverse it. Even if farmers recognise the problem, LaDC practices may be expensive, reducing their opportunities for adoption and influencing their attitude to controlling and reducing land degradation. Political and scientific dominant narratives often see land users as irrational, ignorant and perpetrators of the long-term environmental implications of their resources use (Blaikie, 2001, Stocking *et al.*, 2005). In these narratives land degradation is seen as a local issue.

Past experience has shown that scientific knowledge and external interventions cannot be effective unless they are put to use by local practitioners (Robbins et al., 2002). The need to explore and understand the local scope of the problem has been appreciated. The development of bottom-up approaches in examining the social relations that shape the opportunities and constraints in people's livelihoods is essential. Thus alternative, people-centred approaches have been developed to understand the local dimensions and implications of land

[4] The 2002 World Summit on Sustainable Development encouraged the United Nations Framework Convention on Climate Change, the Convention on Biological Diversity and the Convention to Combat Desertification to explore and enhance synergies in the elaboration and implementation of plans and strategies to tackle land degradation and desertification.

degradation.[5]

Current approaches focus on local contexts and strategies which can contribute to demonstrating important global implications at the local level (Eswaran et al., 2001, Stocking et al., 2005). Farmers may not regard land degradation as a problem, but its consequences – declining yields and low soil fertility – are major concerns for them (Kiome and Stocking, 1995). Land degradation affects land users' livelihoods because it impacts directly on their resources such as the availability of food, shortage of labour and migration, among others. Historical and socioeconomic evidence indicates that farmers often respond actively to degradation by modifying their farming systems or practices and through land-improving investment (Stiles, 1995, Reij et al., 1996). Some farmers may have an attitude that favours conservation; they may obtain positive benefits from taking action to conserve their land, regardless of the economic benefit (Brookfield et al., 2002). Successful examples of local land management to reduce degradation in developing countries have been maintained over long periods of time, thanks to the farmers' adaptability in light of political, economic and environmental uncertainties and their ability to change and to adopt innovation (Barrera-Bassols and Zinck, 2003). Likewise, local initiatives may develop more adequate LaDC practices which are more likely to be linked to an improvement in livelihoods than those from international level (Glenn et al., 1998).[6]

According to the political ecology approach, analysing the perceptions, values and influences of different actors helps in overcoming some of pitfalls of conventional conservation policy. Research into land users' perceptions and attitudes regarding the degradation of their land and their different ways of managing their immediate environment are central to appreciating the intrinsic

[5] A people-centred approach was required in order to concentrate on land user's decision-making context to explain rather than to impose a theoretical perspective (Jones, 2002a).

[6] There has been some success in developing effective solutions for a variety of environmental problems based solely on observations of small-scale systems (Young, 2002). A better appreciation of technologies has already led to rehabilitation projects that combine elements of local knowledge and formal science (Stocking, 2002b). For instance, farmers in Zimbabwe have adapted existing contour ridges using an innovation tested by local farmers, and subsequently adapted ridging technologies designed by a research station, with good results (Hagmann and Murwira, 1996)

relations between this problem and people's livelihoods (Blaikie, 1985).[7] However, there are problems in research of dismissing or overstating the credibility of local perceptions, knowledge and management (Reynolds *et al.*, 2003). Seeking the right intervention for the appropriate LaDC, especially in rural farming area, is the major challenge for land managers who operate on the basis of their own models (Robbins *et al.*, 2002). This demands better understanding of local management systems, farming livelihoods and local approaches to controlling land degradation.

1.2. The research issue

Alongside the debates about the differences in land degradation approaches, new research areas are emerging. The appreciation that land degradation is a local problem with global implications brings new perspectives to the paradigm of land degradation and indicates the importance of including local people in research (Alemneh *et al.*, 1997). Land users are now recognised as a major asset in reversing the trend towards degradation (Eswaran *et al.*, 2001). Their inclusion contributes to a common vision of how best to interact with the environment given the constraints of the particular social context and to viewing land degradation in an appropriate context. Local perceptions of land degradation and its control remain implicit and overlooked, particularly in marginal areas such as highlands in developing countries. Local responses to, and knowledge and views of, land degradation are fundamental to developing options to reverse it, as well as to enhance sustainable land management and improve farming livelihoods. The international community requires evidence of the potential global benefits of measures to control land degradation. Therefore a better understanding of people's rural livelihoods, their agricultural processes and other related resource management is required in order to explain how their actions have impacts at first the local level and then the national and global levels.

The interest in showing the potential benefits of local LaDC in global environmental management has increased the demand for studies focused on the valuation of the

[7] The identification and understanding of local management and technologies have been put forward as one answer to the extensive problem of land degradation (Critchley et al, 1994).

functions, benefits and costs involved in local practices. Most local LaDC practices such as soil conservation have designs that reflect their multiple functions in land users' livelihoods (Reij et al., 1996, Hengsdijk et al., 2005). The functions, benefits and costs associated with land degradation and its control are likely to appear rather different to the vulnerable groups most affected in rural communities than to external actors such as scientists, administrators and politicians looking at the problem (Stiles, 1995). The participation of land users is gaining recognition in efforts to identify and appreciate the diverse functions of LaDC in people's livelihoods, since land users are considered part of the solution rather than the problem (Erenstein, 1999). In local communities land degradation involves gains and losses to different groups of people and, more importantly, winners and losers (Barraclough, 1995, Wolf and Allen, 1995, Stocking and Murnaghan, 2003). Different economic approaches have been applied to measure the costs and benefits of local LaDC in monetary terms, and ecological studies value their contribution to natural resource conservation such as soil and biological diversity and the stability of ecosystems. However, Jones (2002a) argues that studies generally lack explanatory values as they underestimate the specific links and mechanisms between social variables and land degradation.

Regarding the measurement of benefits and cost of LaDC at the local level, Dahlberg (1994) emphasises that it is not enough to value what land users do; researchers and other stakeholders also need to understand why a land user selects a particular conservation strategy at a particular time and in a particular space and the socioeconomic and biophysical factors related to their choices. It is necessary to examine what influences land users' decisions and choices around LaDC practices in agricultural areas and to understand the different ways in which they feel they benefit or lose by controlling land degradation. Tenge (2005) considers that the capture of land users' values may reflect the benefits/costs of LaDC technologies (e.g. land lost to LaDC practices, increased crop production or labour) and expose the rationale behind their choices. This requires examining people's attitudes to and perceptions of LaDC and analysis of the decision-making processes involved in LaDC adoption. The importance of acknowledging the socioeconomic environment of the land users involved is central to recognising the positive and negative values encompassed in their practices and livelihoods. As land functions support more than just agricultural production, farmers may value other, non-productive functions related to it, and this may be reflected in their LaDC approach. This research focuses on multiple values associated with land in order to show and acknowledge local responses to land degradation. Appreciating the values and trade-offs associated with control practices contributes to understanding the links between land-users' coping strategies and management of the resource base. This thesis endeavours to contribute to better appreciation of the multiple values involved in local land and other related resource management which could help to reverse current trends of land degradation, enhance local participation in decision-making and find alternative ways of achieving sustainable development goals.

1.3. The research context

The research focuses on LaDC in hillside communities, as land degradation is one of the most important problems in environments with steep slopes, high vulnerability and suggested over-exploitation of scarce natural resources (Blaikie and Brookfield, 1987b, Becerra, 1998a, Amsalu, 2006). Highlands have been a primary target of conservation measures because of the perceived relationship between cultivation practices, poverty and land degradation (Lestrelin and Giordano, 2007). Severe land degradation and mismanagement of the landscape is expected to occur in hillside communities. However, the restrictions of the hillside environment drive farmers to develop interesting and original natural resource management, including LaDC practices, since the complexity of the environment and poverty makes them willing to innovate to survive (Brookfield et al., 2002, Stocking, 2002a). This makes hillside environments important and interesting areas whose diversity and complexity are reflected in the compound values and transformation of resources that occur in LaDC.

This thesis studies land degradation in the Highlands of Central Mexico[8], which has been the core area for the development of a series of civilizations in Mexico since pre-Hispanic times. The Aztec Empire, the Spanish *conquistadores*,

[8] At the national level 65 per cent of Mexico is estimated to be affected by this problem, of which 70 per cent is categorised as moderate to severe (Semarnat, 2002; Anaya Garduno, 2003; Sanchez Colon, 2007; Campbell and Berry, 2003).

minority indigenous and *mestizo*[9] groups have all built their principal settlements in this region. The Highlands has been a place of integration, change and conservation for the different cultures that have shaped today's Mexican society. The main political and economic systems of the country have been based here up to now (e.g. in Mexico City); however, poverty and challenging socioeconomic and environmental conditions characterise the rural farming communities settled here and the agricultural areas are affected by land degradation. The multicultural context of the Highlands has influenced local farmers' land management strategies. Today traditional, indigenous and promoted land management, including LaDC activities, are intertwined in current farming systems (Anaya-Garduno, 2003, Hudson and Alcantara-Ayala, 2006, Sommer et al., 2007).

My research interest in LaDC in hillside communities is linked to participation in previous research into land management and soil conservation practices in indigenous *Mazahua* farming communities located in the Highlands of Central Mexico. The complexity of the environmental, socio-economic and cultural conditions of these indigenous communities affected by land degradation manifests in the farmers' land management. I observed farmers responding to land degradation with specific, original practices as part of their agricultural system, generating positive outcomes for their livelihoods. *Mazahua* management is derived from the integration of indigenous and *mestizo* value systems. My interactions with *Mazahua* farmers and their land management, especially LaDC, inspired my interest in investigating local links between land degradation and rural livelihoods.

1.4. Objectives and of the study

This research contributes to better understanding of land management, farmers' decision-making regarding LaDC and the implications of natural resource management in the Highlands context.

[9] The racial mix of Spanish and indigenous people created *Mestizo* society

The aim of this research is:

- To appreciate how an understanding of farmers' management, valuing and trade-offs of LADC technologies can contribute to better natural resource management in hillside communities.

It endeavours to show how farmers' decisions regarding LaDC and related management practices affect the sustainability of natural resource use, and to provide further insight into the dynamics of the relationship between people and the environment by targeting the following research objectives:

- provide an overview of land degradation, historical land management changes and households' current assets, particularly of land, in order to identify and characterise the principal types of LaDC in the case study area as perceived by land users, and examine influential factors affecting the adoption of control technologies.
- measure multiple values of LaDC and develop indicators to analyse the values that drive farmers' decisions about adopting the technologies.
- analyse trade-offs associated with LaDC from the farmers' perspective in order to better understand their decisions about natural resource management and livelihood outcomes.

1.5. Relevance of the study

This research is based on a selected case study and presents insights into the local implications of farmers' management, value assessment and trade-off of technologies for tackling land degradation. The thesis examines land degradation in farming systems and related resource use, which is central to developing alternatives to land management and related resources use and encouraging positive trade-offs between conservation and production. Understanding farmers' management priorities and the conditions that influence their decisions is of paramount importance for Mexico's natural resources management and its national initiative to integrate local practices in national programmes to combat to land degradation (CONAZA, 2003; CONAFOR 2007) This study is relevant not only in the Mexican context but also in other areas, as rural farming livelihoods on hillsides affected by land degradation share challenges similar to those studied in this research. These findings contribute to the attempt to integrate local LaDC responses as livelihood strategies with sustainable land management and rural development.

1.6. Thesis outline

This thesis comprises eight chapters, as outlined below.

Chapter 2 sets the epistemological and ontological positions taken in this study, discusses core concepts in land degradation control at the local level and presents the research framework.

Chapter 3 describes the methodological approach used in this research and the case study area, and outlines the analytical research framework.

Chapter 4 explores the settings of LaDC in the case study by presenting a historical analysis of land management changes developed in specific periods of Mexico's history and by characterising farmers' livelihoods in the case study. It identifies potential issues related to the adoption of LaDC practices.

Chapter 5 presents a detailed characterisation of LaDC technologies implemented by farmers, analyses associations between technologies, examines influential factors in the decision of what technology to adopt and categorises the technologies according to these factors.

Chapter 6 focuses on the multiple values associated with LaDC. It describes the methodology that farmers use to assess the value of LaDC technologies, the influence of socioeconomic factors in the appraisal of their value and how these relate to decisions about adopting to LaDC technology.

Chapter 7 concentrates on trade-offs in LaDC. It explains the framework designed to approach trade-offs according to spatial, temporal and intrinsic perspectives, including the external influences of political changes affecting land management. It presents trade-off decisions according to a farmer typology based on local perceptions, and their implications for farmers' livelihoods.

Chapter 8 presents a synthesis of the thesis and the most important research findings drawn from the analyses of empirical evidence. The findings are presented in accordance to the research objectives outline in this chapter. Finally it highlights the limitations of this research and further research issues.

Chapter 2. Land degradation: decisions in the adoption and trade-offs of control technologies

2.1. Introduction

This chapter presents an overview of studies on land degradation and its control. It presents the particular ontological considerations and epistemological foundations of this research and discusses the core concepts relevant to developing the research framework in order to analyse farmers' decisions about their adoption of LaDC technologies.

2.2. Perspectives and approaches to land degradation and its control

Overall Approach to Land Degradation Research

Land degradation is a complex problem that involves biological, socio-economic and political factors and encompasses international and local dimensions and effects. Land degradation substantially affects the productivity of many countries, especially in agricultural areas in developing nations[10] (Coxhead and Jayasuriya, 1994). The socio-economic, ecological and political dimensions of land degradation reveal the complex nature of the relationship between the environment and human societies. Generally land degradation and related environmental issues are seen from a technocratic/logical positivist view characterised by the universalism of knowledge. Traditionally from this epistemological stance, land degradation has been tackled as a natural issue where social and cultural dimensions are ignored or understated which has resulted in failure of imposed solutions (Lapar and Pandey, 1999, Lu, 2001).The

[10] It is estimated that around 2 billion hectares (22 per cent) of all cropland, forest and woodland worldwide have been degraded in the last 50 years. Africa and Latin America appear to have the highest portion of degraded agricultural land and Asia the highest proportion of degraded forestland (Scherr and Yadav, 1997). Degraded land is defined by FAO (1998) as land which due to natural or human activity is no longer able to properly sustain an economic function and/or the original natural ecological function.

scientific and economic conception of nature has dominated approaches to LaDC at the local level and the exclusion of social elements has undermined the understanding of the relationship between society and the environment. Questioning the impact of human intervention in conservation has now resulted in more attention being paid to the social dimension of conservation (Ghimire and Pimbert, 1997, Wilshusen, 2002). Efforts to incorporate social factors in land degradation research and to develop an integrative approach have led to an increase in the number of ways to assess the processes of and dynamics between land degradation and land users' livelihoods.

Practices designed to control land degradation are associated with sustainable land management and its role in sustainable development. Postmodern views of sustainable land management and sustainable development approaches have been applied in order to gain new insights into the relationship between nature and people where land degradation is concerned (Blaikie, 2001). Postmodernist stances provide useful tools for the analysis and integration of the social element of land degradation control. The combination of logical positivism and postmodernist views allows investigation of the composite ecological, economic and social aspects involved in land degradation. Therefore consideration of different epistemological approaches is essential to understanding the multiple values of LaDC.

2.3. Research Epistemological Foundations

Ontological Considerations

As part of this study's ontological stance, environment[11] and specifically land degradation issues are constructed and reconstructed by different actors and in different ways. The construction is not neutral but involves social, economic and political relations that accordingly give meaning to the environment (Castree and Braun, 1998). Dominant constructions of the environment are produced by scientific and political actors' power in a top-down manner. This research takes the view that those most affected by a policy or interventions should be involved in the

[11] This research takes the view that there is a reality "out there" called the environment, or nature, and there are changes that occur in it. Searle (1995) accepts that there is a physical reality irrespective of human behaviour which is affected in intentionally and unintentionally by human behaviour.

decision-making processes; land users' perceptions to other dominant narratives need to be taken into consideration, assuming that natural resource management and environmental change may be outputs of negotiations between different actors with specific claims to the environment (Blaikie, 2001).

This study accepts that human consciousness assigns values to the environment. According to Miranda-Dias (2002) nature provides the human habitat and is the major material and cultural basis of daily life and is valued to different degrees and in different ways by humans, whose different ways of ascribing values influence their behaviour, decisions and actions towards the environment.

Accepting these ontological statements opens up the possibility of considering the need to involve less privileged actors to control actions to approach LaDC which might entail the agency[12] of local land users. This implies a need to share and negotiate different locally-grounded constructions regarding the attachment of values to LaDC practices, which in turns influences human decisions about whether to adopt these practices or not. People may view and value aspects of the environment differently depending on their circumstances, and these differing perspectives lead to different approaches to management.

Epistemological Stances

This research mainly uses elements of logical positivist and social constructivism approaches in its attempts to make claims about the nature-society relationship by understanding land management in LaDC and their its implications for farmers' decisions and natural resource management by adopting mainly elements of logical positivist and social constructivism approaches.

In order to investigate the values attached by humans to the environment, different theories have been developed from the logical positivist and postmodernist positions (Van Deth and Scarbrough, 1995). The term "value" is used in economic approaches based on a logical positivist view in which they are measured and represented in monetary or mathematical units, making claims to universal truths. However, values also have cognitive aspects related to individuals' motivations

[12] Agency refers to the capability of people to doing things; this is why agency implies power. An agent is one who exerts power or produces an effect (Giddens, 1984).

and needs (*Ibid*) which may be exposed through postmodernist approaches.

The structuralist and logical positivist approaches see farmers' behaviour and decisions as structurally determined. Studying objective elements of a social structure allows an understanding of the structures and mechanisms that stand behind, construct and transform reality.[13] Structures (e.g. political settings, national and community organisation, markets) can both constrain and enable farmers' actions. Structuralist approaches limit the possibilities for capturing the complex reasons involved in the attachment of values; particularly those related to social issues. Therefore the research approach includes some postmodernist elements, specifically tools which could help to understand land users' values. The deconstruction of farmers' accounts offers the possibility of revealing such values, how they are formed and their influence on natural resource management. From these accounts it may be possible to give evidence of and understand how people see themselves in their social systems and how they see policy affecting their decisions regarding natural resource use, enabling an explanation of contextualised systems of decision-making around land degradation control, resource allocation and farmers' strategies. Farmers' social constructions of their reality are exposed by the accounts (e.g. Farmers' perceptions about land degradation and their effects on their livelihoods)

As Jones (2002b) points out, the deconstruction of a set of concepts and beliefs[14] allows the possibility of having a shared point of reference to physical objects and properties. Thus, people's accounts about reality are taken for granted "reality" which stands for a social object constructivism[15] (Demeritt, 1998). In this sense a study of multiple values of LaDC which integrates analysis of farmers' perceptions and actions regarding NRM may explain how farmers reshape their environment.
The identification of key variables that could reveal the source of variation is central to exploring land users' different responses to LaDC. Studying the biophysical attributes of land and how they may explain variations on nature and

---

[13] Structure is referred as rules and resources, implicated in the reproduction of social systems.
[14] Little (1991) argues that in a shared common world there is a distinction between concepts defining and references to objects and beliefs, which may be explored through people's accounts.
[15] Social object constructivism is also labelled "weak" or "mild" social constructivism (Blaikie, 2001; Jones, 2002a)

the attachment of values may help to understand farmers' decisions about LaDC technologies and natural resources allocation. These structural insights into features of the natural environment are important and constitute part of the research, which, however, adopts a holistic and systemic conception of the ecosystem, of which human activity is part.

The study attempts to learn from people's knowledge and experience and is a way of showing respect by acknowledging their ability to manage the natural resource base. It provides evidence that integrating and negotiating local constructions in the effort to control land degradation and the implications of this for achieving sustainable land management are valuable. Thus scientific knowledge is questioned by giving voice to local people living in the environment in question and the development context in global-scale narratives is investigated using local empirical evidence.

Through the epistemological stances proposed for this research it is possible to identify objective facts about nature and the environment, leading to explanations of how far and in what ways societies are affecting or being affected by them and contributing to an evaluation of society-nature relations (Castree, 2001). The expected outcome of the epistemological approach is that it will be possible to make claims of contextualised and provisional truth about values associated with LaDC actions (nature-society relations) derived from social constructions, including my construction of farmers' reality.

Finally, an eclectic epistemological stance allows the retention of elements of a rational approach to seek evidence, predict the outcomes of actions and build up composite and negotiated knowledge about the environment and how people relate to it. The epistemological choice entails the use of different conceptual approaches to land management, farmers' decision-making processes regarding the adoption of technology, values, trade-offs and sustainable land management. These concepts are core to the development of a conceptual research framework from which to study the LaDC.

2.4. Capital assets and farming rural livelihoods: The sustainable livelihoods framework

The sustainable livelihoods framework is an approach employed in rural development research to improve understanding of rural poor livelihoods (see Figure 2.1). It focuses on households' livelihood strategies for shaping their own socioeconomic conditions depending on their access to, use of and combination of assets and according to immediate and longer-term needs (Lestrelin and Giordano, 2007). Assets are combined, substituted or traded through livelihood strategies to produce varied livelihood outcomes. Households endeavour to convert their assets into positive livelihood outcomes (Serrat, 2008, DFID, 1999). Factors such as vulnerability, institutions, structures and processes affect levels of access to assets and influence the choices made and outcomes achieved. The sustainable livelihoods framework captures the dynamic and the transformative interactions between people's resources and strategies.

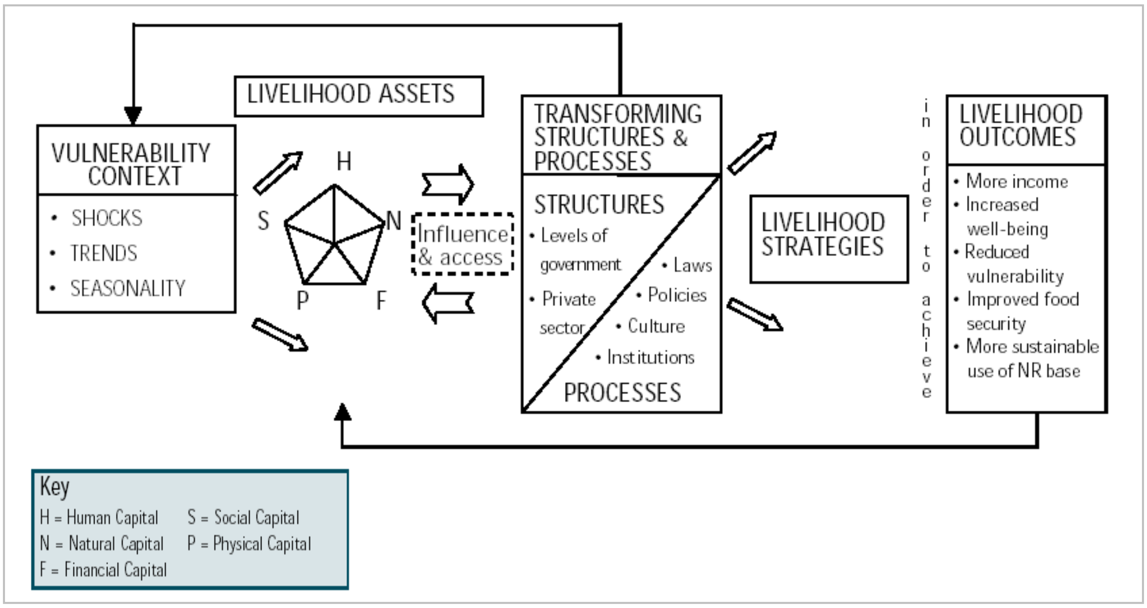


Figure 2.1 Sustainable Livelihoods framework

Source: (DFID, 1999)

People's strategies for managing their livelihood assets are varied. For instance, poor households living in marginal environments often have limited assets from which to develop strategies for achieving an improved livelihood outcome. As a result they have to nurture and combine what assets they do have in innovative ways to ensure their survival (Jewsbury, 2001b, Aguilar et al., 2000). Aguilar et al. (2000) find that in mountain communities in Mexico the creativity and capacity of farmers for finding solutions to problems result from the deterioration of biodiversity and natural resources. The strategies people adopt and the ways they invest in asset-building are driven partially by their own preferences and priorities and local policies (Rigby and Woodhouse, 2000) .

Table 2.1 Strengths and weakness of the sustainable livelihoods framework

Sustainable Livelihoods Framework	
Strength	Weakness
• Seeks to understand changing combinations of modes of livelihood in a dynamic and historical context • Explicitly advocates a creative tension between different levels of analysis • Calls for investigation of the relationships between different activities that constitute livelihoods and draws attention to social relations	• Underplays elements of the vulnerability context such as macroeconomic trends and conflict • Assumes that capital assets can be expanded in generalized and incremental fashion • Does not pay enough attention to inequalities of power • Underplays the fact that enhancing the livelihoods of one group can undermine those of another

Source: Serrat (2008)

Land management is an inherent part of the farming systems of households in hillside areas (Nyssen *et al.*, 2009). This research considers that LaDC technologies are part of the agricultural production process and hence part of farmers' strategies for managing their resources. Therefore the adoption of technologies relies on and competes for available assets; it also contributes to improving livelihood outcomes through measures such as improving soil fertility and productivity or reducing soil loss. Hence the sustainable livelihoods framework provides a structure from which to examine technologies that contribute to controlling land degradation in the highland context.

The diversity of pathways to secure sustainability are central in the sustainable livelihoods framework. The pathways can enchance or reduce household's assets base which impinge on household's strategies to improve their livelihoods . Specifically, this research mainly focused on the capital assets component of the framework to study land management decisions, particularly in adoption of

LaDC practices. The capital assets component is central in enabling the implementation LaDC technologies and understading their outcomes to households' livelihoods.

Capital assets are the materials or resources on which livelihoods are based and LaDC are dependent. Each household possesses or has access to a varying degree of assets, which change over time. Five main types of asset are commonly defined: natural, physical, human, social and financial capital (Carney, 1999, Ellis, 2000). Natural capital includes access to and quality of natural resources such as land, water, forest products, wildlife, wild foods and fibres, biodiversity and livestock. Physical capital corresponds to infrastructure (transport, roads, vehicles, buildings, water supply energy and communications), tools and technology (in this case, tools and equipment for agricultural production and adoption of practices). Human capital relates to labour availability, education, knowledge and skills and capacity to work. Social capital is associated with networks and connections, relationships of support, formal and informal groups, shared values, common rules and customs and collective representation. Finally, financial capital entails wages, savings, access to formal and informal credit and remittances.

Capital assets are often displayed in an 'asset pentagon' which lies at the core of the livelihoods framework. Presenting it visually in this way enables understanding the important inter-relationships between the various assets and how they relate to building livelihoods (DFID, 1999). Garcia (2002) compares the asset bases of farming households before and after their adoption of soil conservation practices, taking into consideration that asset endowments are constantly changing and therefore the pentagons may be constantly shifting. The shapes of the pentagons show schematically the variation in people's access to assets in Figure 2.2.

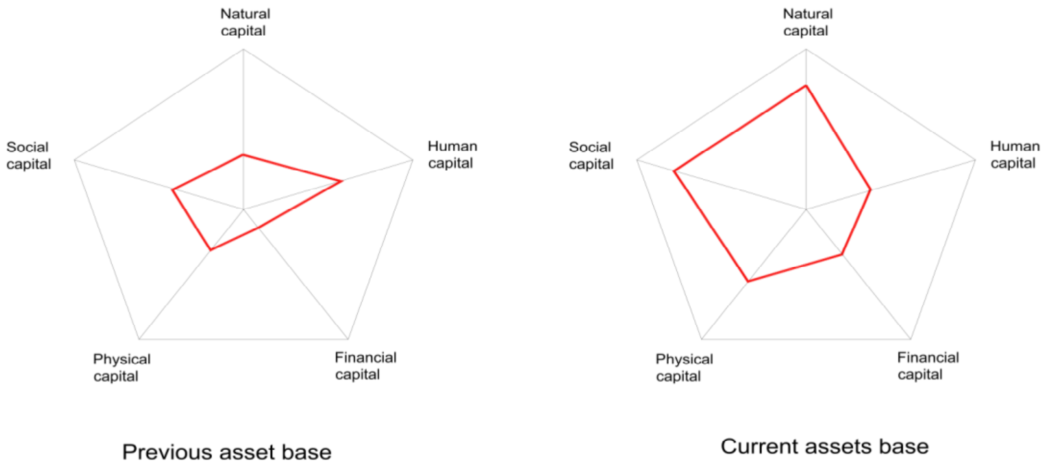


Figure 2.2 Farmers' assets base pentagons

Source: Garcia (2002)

Land degradation affects farming livelihoods by undermining households' natural assets, particularly land. Therefore farmers may develop strategies and adoption technologies to reduce the impact of land degradation on their livelihoods and improve their assets (Hengsdijk *et al.*, 2005).

> *The asset profile of the land-user is known to strongly influence the ability of poor people, who lack assets, to engage with land management. Aside from finance, labour supply, land constraints and knowledge most often limit the ability of poor land managers to practice sustainable land management and remediation.* (DFID, 2004)

In this research the livelihoods approach focuses on the capital assets (e.g. land, labour, money) allocated and traded-off by farmers in the management of their land, especially agricultural land. It concentrates on how proposed responses to land degradation through the adoption of LaDC technologies are contributing to achieving livelihood outcomes such as improvements in the quality of the natural resource base, in order to appreciate the implications of LaDC in farming livelihoods in hillside environments. The capital asset types are used as a framework in which different values related to the adoption of LaDC technologies are categorised, as explained later in the chapter. The objective of this research is to better understand decision-making process of land management at the household level. Thus, this research purposively focuses mainly on the capital assets, excluding or delimiting other components of the sustainable livelihood framework which require another level and type of analysis (e.g. insitutitions,laws, levels of government, markets). However, the thesis takes into consideration current community institutional arragements and local norms such as labour exchanged norms or access to specialised skills, involved in adoption of LaDC technologies.

2.5. Decision-making processes in the adoption of LaDC

Farmers' livelihood strategies require multiple and intricate decisions regarding the allocation of resources, especially in poor households living in marginal environments with limited assets. An area of research gaining importance is the study of households' decision-making process regarding land (Knowler, 2004). Land users' decisions about LaDC are complex, particularly in hillside farming systems developed in challenging environmental, social, political and economic contexts (e.g. eroded soils, low soil fertility, limited access to labour, money and credit, migration). It is important to understand how farmers' make decisions about their resource management, especially land management decisions that encourage control of land degradation to recognise their implications to tackling this problem. There are diverse approaches to analysing their decision-making structures, including economic, psychological and behavioural models.

This thesis approaches the decision-making process with the view that it involves an element of need and an element of choice. The need is related to demanded or expected outcomes from the decision to be made. This is associated with the rational aspect of fulfilling immediate household needs based on the availability of assets. The element of choice[16] is strongly influenced by personal experience, perception, preference and other incentives. This is strongly affected by non-rational and subjective factors such as farmers' feelings, values and goals(Öhlmér *et al.*, 1998, Posthumus, 2005). Bishop et al. (2009) claim that perceptions can be as important as facts in the decision-making process.

[16] A deliberate and voluntaristic aspect (Etzioni, 1967).

Furthermore, decisions about land management are made in a social context; therefore individual decisions are also influenced by interactions with other land users' decisions.

Kessler (2006a) points out that farmers' ability to implement conservation technologies depends mainly on the availability of assets,[17] the biophysical attributes of the land and obvious socioeconomic factors; however, farmers' willingness is largely affected by personal and behavioural factors. This research sees farmers considering their abilities and needs when deciding whether to adopt LaDC technologies; their personal perceptions, preferences and incentives define their selection of specific practices. The links between the direct, obvious reasons and the non-rational or intrinsic reasons behind choosing a particular LaDC provide a holistic perspective on land users' decision-making processes.

2.6. Adoption of LaDC technologies

In agricultural households the land users' perceptions and experience are central to planning their implementation of technologies for tackling ongoing land degradation (Okoba and Sterk, 2006). Land users perceive and articulate differences in their units of production to determine their land management strategies. Evidence shows that farmers do not usually consider land degradation a problem but its consequences, such as declining yields or low soil fertility, may be a major concern (Kiome and Stocking, 1995). Land degradation may be implicated in a number of livelihood 'problems' due to its impacts on land users' resource such as the availability of food, shortage of labour, migration among others. Historic and socioeconomic evidence indicates that farmers often respond actively to land degradation by modifying their farming systems or practices and investing in improving the land (Stiles, 1995, Reij et al., 1996). Their recognition of the consequences of land degradation on their units of production and their perceptions of benefits of a technology are needed to initiate their adoption of LaDC technologies (Knowler, 2004, Amsalu, 2006, Amsalu and De Graaff, 2007). A technology is conceptualised as a way of solving practical problems: therefore the adoption of a technology means that the farmer is responding to a perceived

[17] Differences in access to assets influence the structure and complexity of farmers' decision-making (Sambodo, 2007).

problematic situation.[18]

> *Any technology or practice used by farmers represents a particular way to solve one or several problems. Each technology or practice responds to farmers' concerns in specific ways, which may be regarded as the traits or characteristics that define the technology or practice.* (Bellon, 2001)

This thesis employs this definition of technology and considers that technology adoption depends on the users' standpoint. There is a variety of applied conservation measures at the local level, but they are not adequately recognised, evaluated or shared by researchers, policy makers or any relevant external stakeholders (Schwilch *et al.*, 2009). As part of the agricultural activities, LaDC technologies are specific choices on how to produce crops and manage land (Giampietro, 1997, Sambodo, 2007). This thesis analyses LaDC technology types according to farmers' opinions of which are the practices that contribute to tackling the degradation of their agricultural land. The LaDC measures are largely associated with their local/indigenous knowledge and based on personal experience of managing their natural assets and socio-cultural values (Amsalu and De Graaff, 2007, Oba et al., 2008).

Empirical research into the adoption of technologies in this study focuses on the identification of influential factors such as education, age, sex, soil type, distance from the home and perception of erosion (see Chapter 5), which affect land users' options to carry out conservation practices in different ways. The emphasis is on predicting the probability of adoption, integrating a range of influential factors in analysis of farming decisions. This type of analysis provides a framework with which to understand the livelihood conditions and factors that influence farmer's abilities to take up LaDC technologies, and particularly explain the rational element of need.

Most farmers in hillside areas claim to adopt technologies only when and where needed. Farmers' perceptions of land degradation impact on their interest in tackling the problem. The process of adopting technology is usually developed

[18] Technology is defined as "the specific methods, materials, and devices used to solve practical problems" (American Heritage, 2005) or as the usage and knowledge of tools, techniques, systems or methods of organisation in order to solve a problem.

over several stages (Sambodo, 2007). Responses do not necessarily involve the rapid or complete implementation of technologies: there may be partial implementation as a long-term activity or farmers may not manage technologies in all their fields in the same way. Their adaptability to political, economic and environmental uncertainties, and flexibility to change allow partial adoption of technologies (Barrera-Bassols and Zinck, 2003). According to Sattler and Nagel (2010, p.70), conservation measures are selected and adopted by farmers based on main factors such as:

- *Characteristics of the conservation measures themselves:*
- *Personal attitudes and preferences of individual farmers;*
- *Farmers' conditions such as financial situation of the farm, the specific climatic and regional conditions, the general legal restrictions and policy settings;*

Farmers' decisive factors vary according to the biophysical attributes of the land and the type of technology in question (Sambodo, 2007). Farmers' LaDC aims are that the measures do not decrease yields or impair the quality of the crops, avoid labour clashes, improve farmers' image in society, challenge their knowledge and therefore add to the farmer's satisfaction with his or her work (Sattler and Nagel, 2010)

The adoption of a technology cannot be fully explained by a model and easily measurable economic and social factors (Kessler, 2006b). LaDC users integrate local customs, traditions and inherited and acquired knowledge, as well as values and needs, which are the hidden drivers behind the adoption of technologies. In adopting LaDC technology farmers assess their options against a set of values or criteria which may not be clearly specified. The land users' intrinsic structures that contribute to define adoption of a technology provide the criteria for evaluating alternatives. Farmers' attachment of values affects and is affected by their decisions made. Therefore it is important to understand the values that support sustainable or viable conservation practices.

2.7. Values: types and measurement

The term "value" is conceptualised and applied in diverse disciplines such as economy, mathematics, psychology, philosophy and the social sciences, among others. It is broadly defined as the material or monetary worth of something; a principle or standard of behaviour considered desirable (Dictionary, 2011). In economic studies, values related to natural resource management (including social, cultural and aesthetical values) are represented by monetary units to show their market price (Turner et al., 1994, Bateman and Willis, 1999). Diverse categorisations have been developed to assess the values of natural resources. Multiple categorisation is to be expected because values measured according to one classification for a specific objective (e.g. economic) may not be suitable for other purposes, as the way in which a value is conceptualised and measured might be differently classified to meet another objective (McNeely, 1988). Table 2.2 presents categorisations of values used by various authors and the categorisation proposed for this research.

The table shows that values are usually categorised according to whether they are direct or indirect or to their use or non-use functions. They are differentiated by their consumptive, productive or market utilities and their option, existence and intrinsic use values (which involve social, aesthetic, cultural and personal values). The objective of these classifications is to measure values in monetary terms. Although these typologies provide useful frameworks for classifying values in relation to their use, function or scale, one factor constraining their use in this research is their complexity and uncertainty around being able to locate values according to each type[19].

[19] For this research the complexity and uncertainty are related to the problem that although some classification proposed similar types of values, there is not a consensus in its definitions and values are located in different categories (particularly, those differentiated by direct or indirect functions).

Table 2.2 Categorisations of values

McNeely (1988)	Direct values • Consumptive use value • Productive	Indirect values • Non-use value • Option value
Bateman and Willis (1999)	Use values • Instrumental utilitarian i. Market priced ii. Non-market • Option • Ecological functions	Non-use value • Bequest value • Existence value
Pearce and Turner (1990)	Instrumental value: economic (expressed via human values) Intrinsic value (non-preference related) Functions and potential of ecosystems – rich intrinsic values +value in use by others (vicarious value to the individual)	Total economic value: • Actual use value + • Option value+ • Existence value Option value=value in use by individual)+value in use by future individual (descendant)
Grimble and Laidlaw (2002)	Use values • Direct value • Consumptive value • Non-consumptive value • Indirect value	Non-use value • Option 20 value • Existence value
This research Based on: Bebbington(1999) and; Ellis(2000)	Natural value Physical value Human value Social value Financial value	

This research referred to "value" as a representation of goals, similar to needs that motivate action, principles affecting behaviour (Maybery *et al.*, 2004a, Roccas *et al.*, 2002). It focuses on farmers' goals, which motivate or influence them to manage their assets in particular ways through their livelihood strategies.

The typology employed in this thesis is based on the capital assets framework, an important element of the sustainable rural livelihood framework (Bebbington, 1999, Carney, 1999, Ellis, 2000). As mentioned, the capital assets framework proposes that farmers' livelihoods are constructed of dynamic combinations of the five main capital assets: natural, human, social, financial and physical. LaDC adoption entails the use, transformation and trade-off of assets and therefore the

[20]For this research the complexity and uncertainty are related to the problem that although some classification proposed similar types of values, there is no consensus to their definitions, and values are placed in different categories, particularly those differentiated by direct or indirect functions.

typology designed allows locating the multiple values of LaDC technologies according to specific assets. Values are also differentiated as short- or long-term, since farmers' LaDC strategies may be developed to achieve diverse objectives at different times. Hence the proposed typology for this research helps to furnish a description of current conditions and sufficient information from which to determine the likely impacts of specific technologies on farmers' livelihoods. It also allows linking multiple values of LaDC to livelihoods in which the perception of farmers can be framed, which is particularly important in providing a framework for the analysis of farmers' values, goals and objectives linked to technology adoption because farmers' decision-making process is complex and the structure was not clear to the researcher at this stage of the research.

2.8. The multiple values concept

Values are conditioned by peoples' preferences, interests, desires, likes and dislikes (McAllister, 1982, Mallawaarachni, 2001). In terms of individual behaviour, values play an important role "because they are cognitive representations of individual needs and desires, on the one hand, and of societal demands on the other. That is, they are translations of individuals' needs into socially accepted forms that can be presented and defended publicly" (Grube et al., 1994). Maybery et al.(2004b) argue that values and attitudes may be formulated through direct experience with the environment. Importantly, they suggest that changes in individuals' values lead to widespread changes in their attitudes and behaviours.

Of relevance to this research is the fact that LaDC technologies, which farmers consider part of their agricultural production systems and resource management, comprise not only a specific value but also a combination of multiple values. The values fulfil some of the individual needs in farmers' livelihoods. The connotation "multiple" is used in this study to show the diverse goals or needs inherent in land resources. Land resources provide different functions: productive functions (e.g. to produce food, fodder, fuel), cultural functions (e.g. to preserve or transform landscapes, maintain historical and aesthetic values in the landscape) and ecological functions (to ensure the maintenance of ecosystem functions and global life support functions) (Herweg *et al.*, 1998), which are taken into consideration in the adoption of LaDC in rural households' livelihoods. The multiple values concept is linked to the multifunctional perspective of the agricultural system used by the OECD. The multifunctionality concept "is based on the assumption that every economic action fulfils several functions besides its main function" (Wiggering *et al.*, 2006). According to Groot et al (2009), agriculture is understood as the co-production of social, cultural and natural capital in the multifunctional approach. For instance, Musali (2008) points out that land managed by households cannot be assessed by area alone or by its fertility. He states that the value attached to land goes beyond its productive function and may be controlled by other contextual variables. Multifuntionality and multiple values are linked concepts. The first one refers to the different functions that land provides to land users. The second denotes the values attached to land functions and also to land management by land users. For instance, farmers may attach values in different ways to the multiple functions of land and to the elements involved in the land management such as adoption of LaDC (e.g. labour, access to land, manageability).

The values that farmers attach to these practices may influence their perspectives on and attitudes to controlling land degradation and conserving resources. For instance, Posey (1999) points out the direct and indirect values of intercropping technologies for farming households. These technologies decrease competition for plant nutrients and soil moisture; they contribute to fixing nitrogen to soil; a scatter of seeds among other species means that minority species may be less vulnerable to diseases and pests; mixed cropping leads to lower labour requirements by producing quick vegetation cover that will smother weeds; soil and water resources are protected under plant cover; mixing crops provides a wider variety of food over an extended harvesting period; and mixed cropping decreases the risk of crop loss in adverse conditions, as at least some of a mixture of crops are likely to survive, see also Innis (1997).

Kamar (2001) illustrates the diverse values related to community-based soil and water conservation practices followed by Kenyan women, who prefer to construct terraces that act like a cut-off drain to hold or take runoff water off the field. The water can be directed to a dam or river or be allowed to infiltrate the soil, thus increasing water availability for crops. This leads to crop yield increases and raising of fodder. The women expressed that a value that contributes to their adoption of particular technologies is their satisfaction related to the need for conserving land. Full participation and cooperation among women's groups is considered an important factor in the success of their practices, because female participation in households' conservation activities increased.

Farmers' decision-making is affected by and affects values linked to practice adoption (Öhlmér *et al.*, 1998). Land users identify some characteristics of technologies as advantageous (benefits) or disadvantageous (costs) (Bellon, 2001). Land managers and decision makers are increasingly called upon to make resource decisions that address multiple and often competing values and preferences in agricultural production (Marianov *et al.*, 2004). Multiple values do not necessarily conflict, and can be mutually reinforcing.

The reasons for focussing this study on multiple values is the increasing interest in this area of research in showing and acknowledging local responses to land degradation. In addition, an appreciation of multiple values might contribute to understanding farmers' decisions about managing their resource base and their strategies for coping with adverse situations. It allows exploration of the diversity, differences and intricacy of resource management in demanding environments such as hillside communities. The multiple values approach captures the complexity, scope and significance of this wide range of inter-relationships and interactions between the agricultural sector and the environmental, economic and social domains, helping to describe and understand the multiple and often combined values of LaDC.

2.9. Trade-offs

In the context of farming systems, decision-making on land management addresses multiple objectives and a large number of alternatives in which transformations and the trade-off of assets and values are essential. Farmers face multiple trade-offs when making day-to-day decisions about the allocation of resources on their units of production (Tittonell *et al.*, 2007). According to Gichuki *et al.* (2009), trade-offs arise due to differences in human preferences for goods and services, and the achievement of one objective is generally at the expense of another. Farmers may exchange one asset or objective for another when adopting of LaDC technologies, according to immediate or longer-term needs. Thus adoption entails trade-offs between positive and negative results, which are perceived differently depending on farmers' preferences and the availability of assets (Bellon, 2001). This strategy may help to cope with farmers' vulnerability and improves their living conditions (Ellis, 2000).

Giampietro (1997) points out that trade-offs are expected in the technologies' implementation rather than what he calls 'absolute improvements', particularly when assessing their effect on different scales. Erenstein (1999) highlights trade-offs as part of the 'production-conservation duality' in farming systems. Carter points out the complexity of decisions involving trade-offs:

> [The decisions] *usually involve tradeoffs between multiple values, and one option rarely emerges as clearly superior to others. Far from the ideal world of black and white options, the real world of … choices often seems a landscape distinguished by remarkable variation in shades of grey* (Cartner, 1988: 287 quoted in CIPA, 2001).

This account explains how perceptions of trade-offs may be not explicit or easy for the land user or other stakeholders to define (Weber *et al.*, 2001). One or two objectives may appear to be preferred within a trade-off decision: however, other objectives may be inconspicuous but also relevant in choosing that particular option. According to Lu and van Ittersum (2003), trade-offs for a specific objective in agriculture can sometimes result in a great improvement for most other values.

Trade-off decisions are inherent in farming systems including LaDC practices, particularly those developed in highland environments due to constraints regarding conditions, as trade-offs are reinforced by limited access to assets. Farmers make choices and agree on what trade-offs are desired or feasible (Wolf and Allen, 1995). They evaluate their options, which depend on associated values related to ethics and cultural identity (Giampietro, 1997). For instance, Blaikie and Brookfield (1987b) highlight how farmers evaluate their options and usually adopt a technology that is within their means, even if it is a less desirable or effective one. They argue that farmers may be willing to experience a temporary loss, even of long duration, in order to reduce risk and satisfy their needs. Posthumus (2005) points out that farmers make internal trade-off analyses weighing personal advantages and disadvantages against conservation decisions.

Shively (1999) shows that contour hedgerow technologies are effective and low-cost methods of erosion control for annual crop cultivation on steeply sloping fields in the Philippines. Hedgerows are constructed as a permanent vegetative barrier. Their construction requires less labour than terracing, and in combination with manure, hedgerows can enhance soil fertility and reduce the use of commercial fertiliser. However, the adoption of hedgerows does not guarantee better crop production and unambiguously increases the opportunity cost of adoption. The area occupied by hedgerows incurs the loss of 25-33 per cent of cultivated area on steeply sloping land (Shively, 1999). Whether crop yields on the remaining area can eventually compensate for the area occupied by hedgerows, and if not, what motivate farmers to adopt this practice are important questions.

Farmers have to decide how much benefit from one value they are willing to give up in order to improve achievement via another (Erenstein, 1999). Making decisions about trade-offs is one of farmers' most important and difficult agricultural challenges, particularly when they have to make trade-offs between competing options influenced by surrounding environmental and socioeconomic factors. For instance, the assessment of soil and water conservation practices in Ethiopia revealed important trade-offs which may partially explain their low rate of adoption (Hengsdijk *et al.*, 2005). According to Giampietro (1997), it is necessary to stop looking for optimal solutions and start learning how to discuss trade-offs. Therefore explicit recognition of the implications of trade-offs is relevant in promoting the development of a mechanism to support households affected by negative allocation of resources (Wolf and Allen, 1995).

Trade-offs involving resource management need further exploration. Gichuki et al (2009:6) highlight the poor understanding and integration of trade-offs and synergies in the case of water and environmental policy formulation and implementation. A similar scenario is observed in land management discourses and political arenas.

Several approaches have been developed to assess and analyse trade-offs in local natural resource management involving economic, social and ecological factors. Among the main approaches are cost-benefit analysis, cost-effectiveness analysis, multi-criteria analysis, environmental impact assessment and trade-off analysis (Brown et al., 2002, Antle et al., 2003). For this research, the trade-off approach was chosen as a useful tool with which to investigate the transformations in and dynamics of multiple values which may drive and explain farmers' decisions. As the trade-off issue becomes a personal value question, land users may have very different value structures (Keeney and Raiffa, 1993). Therefore an analysis of trade-offs informs farmers' negotiations in their decision-making involving the multiple values of the LaDC technologies they adopt. The analysis of trade-offs allows this research to delve into the negotiations entailed in farmer's natural resource management, which in turns helps to appreciate the relationship between society and nature.

> *The art of selecting trade-offs is identified as the appropriate focus of alternative agriculture because complex and multi-level systems such as food production systems resist simple optimization approaches. The strength of this approach is explicit identification of trade-offs associated with resource allocation in material systems.* (Wolf and Allen, 1995)

The trade-off analysis with focus on multiple values shows the complexities of decisions taken by farming households in NRM and leads to an understanding of the implications of LaDC for the sustainability of resources. This may help in appreciating their role in sustainable rural development in hillside communities and in formulating better policies to achieve sustainability. However, as Wolf and Allen (1995) also point out:

> *Trade-offs mean denying sustainability at a particular scale in order to achieve it at other levels, even according to a given criterion. There is no such thing as a system that is sustainable at all levels.(Ibid)*

This thesis finds that trade-offs in farming livelihoods involve choices that may not be sustainable on all levels and on all terms.[21] What may encourage sustainable land management strategies in a particular situation could encourage degradation in another. Hence the identification of trade-offs among the multiple values of LaDC is of foremost importance in understanding the rationales behind farmers' decisions and their implications for NRM, and is essential when sustainable choices at the local level have to be identified in order to integrate competing options.

2.10. Sustainable land management

Farmers' rural livelihood strategies aim to generate livelihood outcomes such as more sustainable use of NRM, and in particular sustainable land management which allows them to maintain agriculture as a livelihood. Sustainable land management is defined as:

> *...the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions (UN Earth Summit, 1992).*

Sustainable land management concentrates on the functions of the environment for the benefit of society. It encompasses policies, technologies and activities, and in particular agriculture aimed at enhancing production and maintaining the quality and environmental functions of the natural asset base (Dumanski, 1997).

In a local context, sustainable land management integrates ecological, socioeconomic and political principles (Hurni, 2000). In farming systems any improvement or deterioration of a land resource is performed by farmer in the field. Local land management options inform farmers' contributions to addressing the sustainability of land. Therefore it is important to understand their decisions and attitudes regarding their adoption of practices to control or reverse

[21] The concept of sustainability is not standardised: it varies from local to national to global level. Stakeholders' perceptions, spatial considerations (differences in physical and biological conditions), and temporal scales and perspectives all vary (Herweg, et al., 1998).

degradation, or at least to alleviate adverse effects. This requires an appreciation of their technological choices (local and promoted) and the identification of influential drivers affecting their approaches to LaDC. At the local level, controlling land degradation may reduce vulnerability and increase food security as a result of the improved natural asset base.

Trade-offs are increasingly gaining recognition is discourses between sustainable land management with other global concerns and with local livelihoods (Scholes and von Maltitz, 2007). Hence trade-offs of environmental, social and economic values intertwined with land management in farmers' livelihoods need to be identified in order to link land users' concerns with perspectives on other levels. There is a need to identify trade-offs made by land users which could encourage land management in the direction of sustainability and encouraging sustainable development. Sustainable development is defined as:

> *the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry, and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable.*[22] *(FAO, 1995)*

Three dimensions of sustainability are expressed in the definition of sustainable development: Environmental, Social and Economic (Kassie and Zikhali, 2009). A better understanding of land management, in this case of adoption of LaDC and its values and trade-offs involved may contribute to encourage paths for sustainable development as technology implementations may contribute to the three dimensions. Environmentally, LaDC technologies help to improve soil quality and water availability, encourage conservation of soil, wildlife and plants (e.g. hedges). Economically, enhanced land management aims to increase yields, secure food production, and in some cases increase plots' area and land economic value (at different short and long terms). Socially, technologies

[22] The definition was adopted in 1989 by FAO, according to the "Sustainability issues in agricultural and rural development policies" Trainer's Manual, Vol. 1 (FAO, 1995

adopted by land users are already accepted by member of the community, implementation of technologies helps to develop social networks and are based on local norms and agreements of labour exchange, farming activities and customs. This research analyses land management by farmers in the Highlands which can contribute to find path ways to support the three dimensions of sustainable development, particularly the environmental and social ones.

2.11. Research framework

The research framework was developed in accordance with the epistemological approach, integrating the relevant concepts discussed in order to appreciate the structures and dynamics of farmers' LaDC approaches. In order to meet the research aim and objectives (see Chapter 1), the framework developed for this thesis is based on a bottom-up approach which can document the local-level decisions that induce different farmers' households to develop diverse strategies to face land degradation and improve their livelihoods. The research framework is presented in Figure 2.3, below.

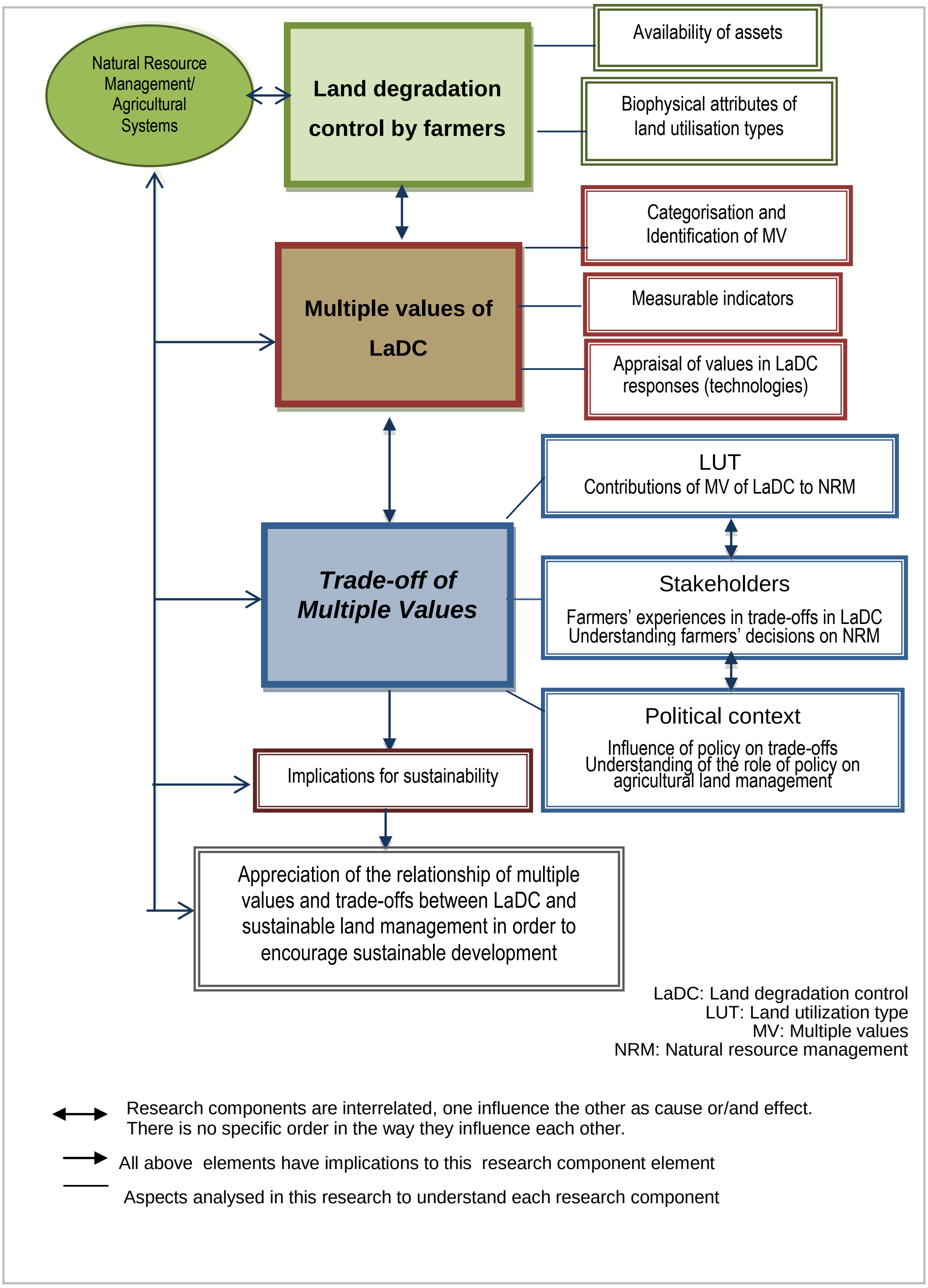


Figure 2.3 Research framework

The research framework comprises three core parts:

i) The characterisation of LaDC, considering the availability of assets and the biophysical attributes of land

As represented in Figure 2.3, it is anticipated that farmers' responses to controlling land degradation are part of their agricultural systems, natural resource management and livelihood strategies. So LaDC responses may be inherited local management practices or current responses to existing livelihood conditions. The design and adoption of LaDC measures depend primarily upon the availability of assets and the biophysical attributes of specific land utilization types (LUT). The availability of assets and the land attributes are important in characterising household livelihoods and explaining the rationale of LaDC technologies and identifying influential drivers affecting their adoption. A detailed characterisation of farmers' assets, in particular the attributes of the land, and documentation of the LaDC measures they use provide a basis from which to explore farmers' rationale for their adoption.

ii) The categorisation, identification and measurement of multiple values of LaDC

This research claims that values area attached to farmers' adoption of LaDC technologies with the aim of fulfilling diverse households' needs (multifunctionality). The appreciation of the multiple values of LaDC should entail an understanding of the agricultural system and related management of natural resources as well as of the socio-economic context in which they are developed. The framework concentrates on the identification of indicators to assess these multiple values from a farmer's perspective to show what they value in LaDC technologies, and how. Local variations in social conditions such as gender, age, wealth and differential access to resources are considered in the exploration of farmers' multiple values experiences.

iii) An understanding of multiple values through an analysis of trade-offs in LaDC

The process of adopting LaDC technologies involves a series of value trade-offs. The research analyses such trade-offs, taking into consideration differences in LUT, land users' experience and the political and historical implications of trading values (see Chapter 7). It examines farmers' attitudes to different LUT. This may specifically contribute to the theoretical and conceptual discussion of land management in different scenarios. The focus on LUT is central to the analysis of land management in Mexican hillside agriculture. Especially, LUT such as *solar* (home garden) and *milpa* (unit of maize production) are studied in different chapters of this thesis due to their historical and current importance to rural subsistence farming systems. The trade-off approach investigates how different experiences may reveal past and current transformations or substitutions of values. This contributes to tracking trade-offs as farmers' strategies for improving their livelihoods and coping with vulnerability in different settings. The political and socio-economic aspects also affect farmers' livelihoods and LaDC decisions. It is important to take the influence of local and national policy in farmers' trade-off decision-making process into account. This will provide evidence of past multiple values associated with LaDC, and improve understanding of current values.

The three parts of the framework are designed to highlight the links between LaDC, natural resource management, farmers' decision-making processes and political interventions that may reveal the implications of multiple values of LaDC for sustainability. The parts are integrated and complement the analysis of farmers' management of LaDC practices from different standpoints.

The framework is applied to hillside farming in the Mexican Highlands, where farmers' livelihoods are characterised by their ecological fragility, high vulnerability, minimal accessibility and poverty (Conway, 1997). Trade-offs are central to this thesis, as their continuous transformation of resources and available assets is a vital strategy in farmers' livelihoods to enable them to survive.

Chapter 3. Methodology

3.1. Introduction

This chapter gives an overview of the methods chosen and the instruments designed to gain an understanding of LaDC in the highland study area. It presents the research strategy and case study approach used in this research as well as a characterisation of the selected study area and methods of data collection and analysis.

3.2. Overall design

This research aims to appreciate farmers' land management in hillside communities affected by land degradation, and particularly farmers' responses to land degradation and the implications for rural livelihoods (Blaikie and Brookfield, 1987a, Becerra, 1998b). The research seeks better to understand farmers' decision-making processes regarding their adoption of LaDC technologies and their appraisal of embedded multiple values and trade-offs. A case study approach consistent with the epistemological stance taken encourages the combination of the qualitative and quantitative methods needed for the study of farmers' responses at the field level, as explained in the following section.

3.3. Case study approach

The case study approach was selected as the basis of the methodological design. The flexible and adaptive nature of this approach allows a variety of data collection techniques, epistemological orientations and disciplinary perspectives to be accommodated (Winegardner, 2002). According to Tellis (1997), a case study is the ideal method when a holistic and in-depth investigation is needed, and thus this method suits the objectives and circumstances of this research(Guijt, 1998) . Yin defines the case study research method as follows:

> *An empirical inquiry that investigates a contemporary phenomenon; when boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used (Yin, 1994, p.23).*

This qualitative research method is widely used by social scientists to examine contemporary phenomena such as the result of the application of ideas and extension methods (Creswell, 1998). It enables the representation of a situation from actual experience (Jewsbury, 2001a). Because it takes place in a natural setting and aims for a holistic interpretation of the event or situation under study, the environmental or social change to be monitored and the uncertain interaction between people and the environment may be encompassed in the research. Hence, this study of LaDC and its implications for the sustainability of natural resource management in rural hillside communities is ideal for qualitative research. It deals with a contemporary phenomenon that is influenced by socio-economic and environmental factors. Farmers do not separate their perceptions of and values regarding LaDC from the environmental and social surroundings in which their livelihoods are set. These vital perceptions and understandings of the phenomenon are best captured qualitatively.

The case studies are multi-perspective analyses (Tellis, 1997), which require consideration of the perspectives of different groups of actors and the interaction between them. This research emphasises these actors – the land users – who are important in hillside areas and are usually ignored in the policy arena.

Case studies typically examine the interplay of a wide range of variables in order to provide as complete an understanding of an event or situation as possible (Soy, 1997) This type of in-depth understanding is arrived at through a process that requires detailed contextual analysis of the event being researched; the conditions underlying it are developed, as are the relationships between the stakeholders involved in it.[23] This entails interpreting data such as cultural norms, community values and people's attitudes and motives. In this research the interpretation of this type of data is necessary in order to understand the holistic

[23] The research object in a case study is often a programme, an entity, or individuals, although it can be a group, institutions, innovation or a programme (Robson, 1993; Shatish, 2004). Each object is likely to be intricately connected to political, social, historical and personal issues, providing wide-ranging possibilities for questions and adding complexity to the case study (Soy, 1997).

nature of farmers' decision-making processes when responding to land degradation. The use of a case study extends and underpins the understanding of a complex issue (Soy, 1997), and is relevant to this research.

According to Stake (1995), selection of the type of case study depends on the purpose of the inquiry: an instrumental case study provides an insight into an issue; an intrinsic case study gains deeper understanding of the case; and a collective case study investigates a number of cases in order to inquire into a particular phenomenon. An intrinsic case study is chosen here as the research seeks better understanding of a particular phenomenon, in this case LaDC technologies, values and trade-offs.

There are several disadvantages in using a case study. One of the weaknesses of a case study is that its intensive nature may focus on a restricted sample whose results are not widely applicable in real life (replication may not be possible) and may be highly subjective. This leads to questions about the representativeness and validity of the findings (Stake, 1994). The issue of generalisation regularly appears in the literature; it attracts frequent criticism which Yin (1984, 1994) in particular refutes with a well-constructed explanation of the differences between analytic and statistical generalisation.[24] The generalisation of the result of the case study is made for the theory and not the population. Triangulation of data is achieved by using multiple sources of data (Robson, 1993), and the case study approach enables such triangulation.[25] Therefore in this research the case study should allow the establishment of relationships between the variables. In adopting a case study approach this research builds on the expertise of local land users. The choice of a case study places the research within the current context and confirms the importance of appreciating the farmers' responses to LaDC in the study area.

[24] "In analytic generalisation, previously developed theory is used as a template against which to compare the empirical results of the case study" (Yin, 1984).

[25] Stake (1995) states that the practice of ensuring accuracy is called triangulation. Snow and Anderson (cited in Feagin et al., 1991) assert that triangulation can occur within data, investigators, theories and even methodologies.

3.4. Research study area: San Pablo Tlalchichilpa community (SPT)

3.4.1. Study area location

The San Pablo Tlalchichilpa (SPT) community is the area selected for the case study. It is located in the municipality of San Felipe del Progreso,[26] along the north-western boundary of the Toluca-Ixtlahuaca Valley, and extends westwards into Mexico's Central Highlands (INEGI, 1991) (see Figure 3.1.). It has a population of 2847 people of the *Mazahua* indigenous group (INEGI, 2005). The community is divided into five sectors: San Pablo Tlalchichilpa, Barrio La Era, Barrio Dolores, Barrio San Francisco and Barrio Santa Cruz (Nava-Bernal, 2003).

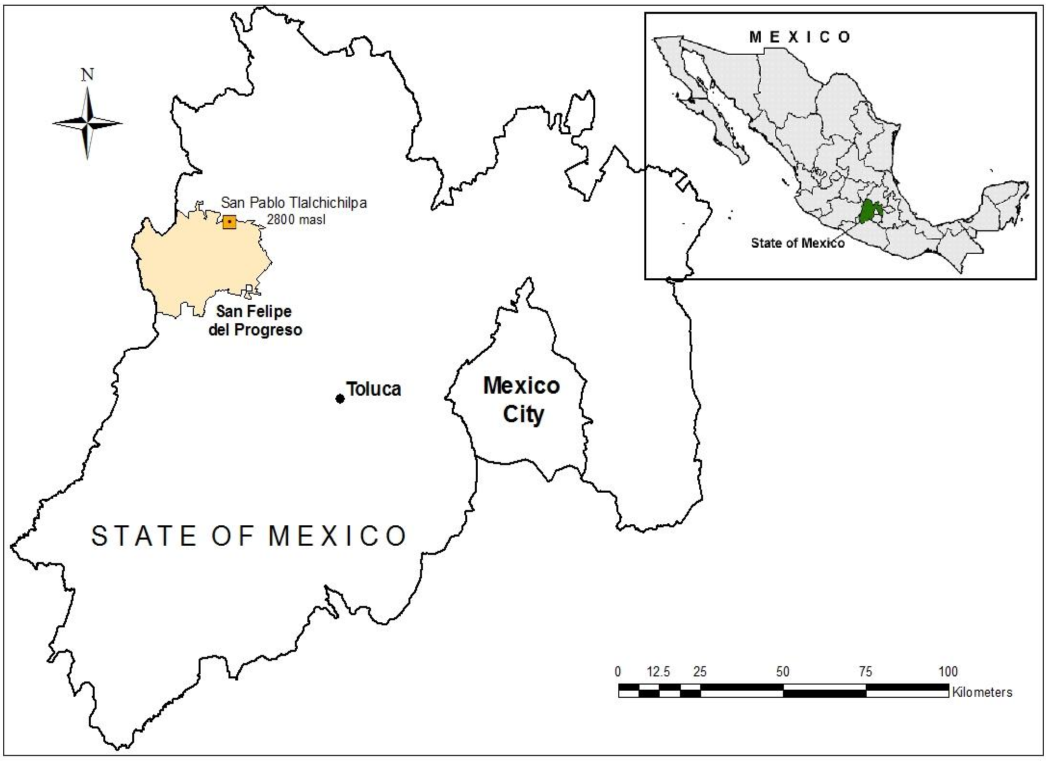


Figure 3.1 Study area location

Source: Adapted from Gobierno del Estado de México, Dirección de Protección Civil, 1998

[26] The community of San Pablo is located in the state called 'Estado de Mexico' (State of Mexico), which is the most populated state in Mexico (country) with 14 million inhabitants (13 per cent national total) (INEGI, 2005).

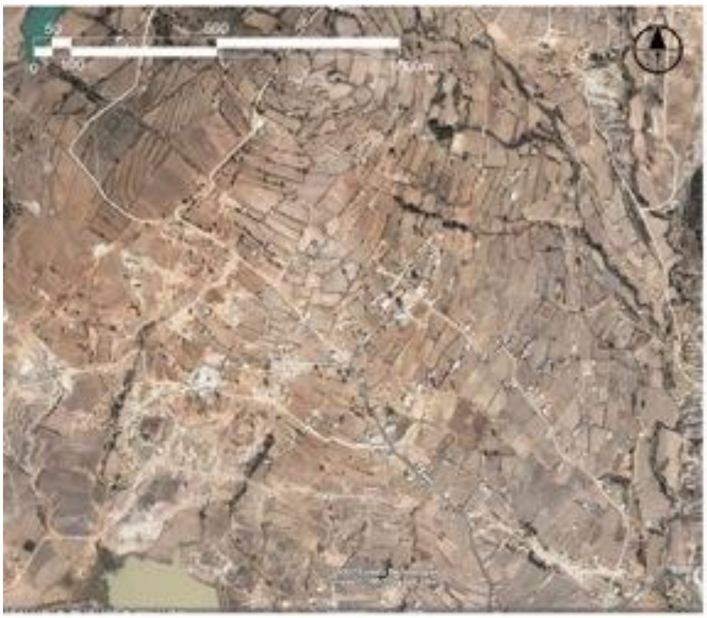
The study area presents a mixed topography of valleys and hills presented in Figure 3.2. The altitude ranges from 2760 to 2870m above sea level. Erodible andosols and lithosols are predominant in the area. The mean annual rainfall in this temperate sub-humid climate is 800 mm and the rain falls in the summer from June to September. This highlights that rain-fed subsistence agriculture systems developed in SPT are carried out in a water-restricted zone (unreliable rainfall for crop production and also limited water availability for household consumption) which may influence land management decisions.

Figure 3.2 Landscape of study area of San Pablo Tlalchichilpa

Source: Google Earth (accessed 2008)

The two main sectors analysed in this case study- La Era and Centro- are shown in Figure 3.3.

La Era sector , San Pablo Tlachichilpa, State of Mexico



Centro sector, San Pablo Tlachichilpa, State of Mexico

Figure 3.3 Landscape of the La Era and Centro sectors of San Pablo Tlalchichilpa

Source: Google Earth (accessed 2008)

3.4.2. Land degradation in SPT

Fragile soils and steep slopes make SPT vulnerable to land degradation. Soil erodibility combined with the rapid down-cutting of local rivers on steep slopes (15 to 35 percent) has caused the widespread occurrence of gullies and sheet erosion in the community. The soil erosion has been intensified by deforestation in previous decades. The degradation is visually observable in the landscape, which is dissected by gully erosion (see Figure.3.4.)

Figure.3.4 Land degradation in a sector of the study area

Some units of productions located nearby gullies are been affected by them, especially decreasing area for cultivation. However, LaDC is not generally designed to reduce erosion in big gullies since this would require high labour and capital which farmers are not able to afford. In the study area there have been community level organisations to tackle land degradation in communal lands. In 1999, farmers participated in the construction of gabions within gullies that are next to units of productions, practiced promoted and supported by Secretariat of Environment and Natural Resources SEMARNAT (Garcia, 2002). [27] Likewise,

[27] “The gabion technology has been widely used to control soil erosion in landscapes dissected by gullies in Mexico. In this case, SEMARNAT provided 90 000 pesos ($9500) to buy all the material needed to build the gabions and to pay farmers’ labour to construct them” Garcia (2002, p.37).

approximately 20 farmers from La Era of SPT were hired to dig ditches in forest areas and communal areas of the sector prone to gully erosion in 2004/5 (see chapter 7). However, this research does not intend to analyse community level organisation in the adoption of LaDC technologies in communal area as it is beyond the scope of this thesis. It focuses on practices carried out to control land degradation in agricultural unit of productions at the household level decisions. This allow a better understanding of land users' responses to tackle land degradation by allocating their own resources and provide in-dept detail to explore land users' attitudes, perceptions and rationale of technology adoption and their implications to their livelihoods.

Farmers notice the persistence of soil erosion in their fields (mainly sheet and rill erosion), however they consider it has decreased. The estimation of soil loss in units of production dedicated to maize crops in sloping areas of central Mexico is around 130 ton/ha/year (Maass, 1992). This figure agrees with the estimations calculated by Garcia (2002) of 127 ton/ha per year of sediments trapped by a stone wall constructed in a *milpa* by farmers in SPT. In general, actions to control land degradation in SPT have been individualistic decisions, each land user design and adopt technologies according to each fields' specific needs and resource availability. The technologies implemented to control land degradation are fully describe in Chapter 5.

3.4.3. General characteristics of SPT

Small-scale rain-fed agriculture mostly using household labour is the main economic activity in this hillside area (Chávez, 2007). SPT has a mean arable surface of 2.70 $\pm$ 1.99 ha/family, with a range of 0.5 ha to 10.00 ha per household (Arriaga-Jordan et al., 2005 ;author's field data). Currently, land is private, *ejido* or communal property and the majority of farmers have official land titles. Farmers (mainly men) usually inherited land from their parents or relatives In SPT women rarely inherit land; however, during the official certification of land, few land titles were given to women (see Chapter 4 and 7).

The principal crops are maize, beans and oats. Farmers cited early frosts and severe drought as the most common threats to their crops. Unreliable rainfall, declining soil fertility and severe soil erosion have all contributed to poor agricultural production, and hence LaDC practices have become important in this community (Walton *et al.*, 1998). Water management become an important issue when farmers' crop production is affected by drought. Thus, land management decisions will focus on implementing practices which help to increase soil moisture or water availability to crops. Another important factor farmers mentioned is the considerable damage to crops by intense rain and strong winds (Garcia, 2002).

Farmers in this community manage different types of land from which they obtain goods and services. As noted by (Chavez, 2000), *solar* (home garden), *milpa* (maize plots), *bosque* (forest), *pradera* (grassland) and *limites* (edges) are the LUT managed in SPT. *Milpa* and *solar* are the main agricultural LUT in the area and it is here that the responses to land degradation are occurring.

Economically, San Felipe del Progreso is one of the poorest municipalities in the State of Mexico (Blanquel and Hernández, 1999, Cotler and Ortega-Larrocea, 2006). Hence, San Pablo is characterised by poverty and marginality. About 95 per cent of the farmers surveyed for this research stated that they have the basic tools to carry out agricultural activities, but only 37.6 per cent of farmers have their own draft animals for ploughing. Although the community has regular means of transportation to San Felipe, the nearest big town, people still lack opportunities in higher education, paid employment, credit and government support.[28] The biophysical and socio-economic conditions make SPT a suitable research area in which to explore farmers LaDC approach in a hillside environment. The rationale for the selection of SPT is summarised in Table 3.1.

[28] The survey carried out in this research shows that 99 per cent of families have electricity in their houses, 94 per cent have access to gas and around 80 per cent to water (once a week) and have plastic water containers. In addition, 86 per cent of households own at least one television and 97 per cent have a radio. Less common services include a telephone connection, which is limited to 8 per cent of families and private means of transportation (car or trucks) in 11.8 per cent of families.

Table 3.1 Selection Rationale for the San Pablo Tlalchichilpa community

- The location is representative of traditional subsistence agriculture in Central Mexico, with maize the staple crop; farmers' land holdings range from less than 1 to 10 hectares and agricultural activities and natural resource management rely on family labour and social networks (Nava-Bernal, 2003).
- In San Felipe del Progreso the people of the community of San Pablo Tlalchichilpa have an innovative attitude to practising agriculture and use their land in diverse ways (Chavez et al., 1998, Chávez Mejia, 2000).
- The study area is linked to previous research on biodiversity and local soil conservation practices carried out in the People, Land Management and Environmental Change (PLEC) project in San Felipe del Progreso, which has been one of the demonstration sites of the PLEC project (Chavez et al., 1998, Chávez, 1998, Chavez, 2000). There are existing networks between researchers and farmers in the community.
- The hillside is affected by land degradation processes. Evidence of soil erosion, particularly in agricultural areas, has been observed by farmers and researchers in the community (Walton, 1998). Farming households in San Pablo Tlalchichilpa have worked with past research projects and show an increasing interest in participating.
- Local and promoted soil conservation techniques have been adopted by farmers. San Pablo is chosen as an example of how small farmers in the Central Highlands of Mexico control soil erosion through local soil conservation technologies, thereby improving the natural asset base and production (Garcia and Ruiz, 2001, Garcia, 2002, Chávez, 2007)
- There are also logistical reasons for choosing this community, such as the accessibility of the area from Toluca city, the research base 180 km from the community, and familiarity with the study area.

3.5. Research strategies

The study aims to better understand the land management and conservation actions of farmers in SPT and the implications for their livelihoods. This requires detailed primary and secondary data to analyse and evaluate LaDC from the farmers' perspective. To meet these data needs, a fieldwork stage was planned. Fieldwork activities engaged mixed methods of data collection at various stages of the research in order to provide a holistic approach. The fieldwork covered a time period of twelve months, ten of which involved working in the community.

This allowed observation of the full agricultural cycle and related land management and resource allocation adopted by land users. Fieldwork was divided into three phases: May to August, September to October and November to April. The initial phase consisted of selecting the research area (see section 3.4), exploratory visits to the study area, first contact with key farmers, familiarisation with other farmers in the community and designing a sampling plan. Interviews with state/local government institutions relevant to the study area were first carried out. A general household survey collecting data on socio-demographics, general land management and the adoption of technologies was conducted at the end of this phase. The middle phase, conducted in the UK, concentrated on a preliminary review, analysis and evaluation of the data. This period away from the community allowed useful insights into the research subject and time to redefine the research objectives and design the next fieldwork stage for an in-depth analysis. The third phase focused on exploring and appraising the multiple values attached to LaDC technologies and identifying the trade-offs made by land users. This last phase entailed a closer involvement with farmers to gather detailed information. Finally, further interviews were conducted with external actors and groups of actors working in the area.

3.6. Methods of data collection

Adopting a case study approach determines many of the data collection methods in order to involve a variety of sources and techniques in the research process. Both qualitative and quantitative methods of data collection were chosen due to the eclectic nature of the research. A combination of methods facilitates the triangulation of evidence and increases the reliability of the data-gathering process. This research builds mainly on participatory methods of collecting primary data, which contributed to a better understanding of how farmers manage their assets and LaDC practices and the interaction between all elements involved in land management. Using participatory methods helps to integrate people in the research process. The participation of farmers as partners in research and development helps to ensure the adoption of qualitative methods and can contribute to empowering local people (Thrupp, 1997). These methods legitimise land users' knowledge and expertise about the environment and specifically about land management. .

3.6.1. Research survey

In order to gain a general appreciation of the conditions of the case selected, a household survey was conducted which sought to characterise farming households and the land management practices adopted in the area (especially LaDC technologies). The survey was divided into two sections: the first concentrated on obtaining data about household demographics and socio-economic characteristics, farming and farm resources (i.e. land attributes, farm area, farming assets) through closed questions and the adoption of LaDC technologies in units of production. These data were collected via a questionnaire to generate mainly quantitative data for later analyses.

The second section of the survey used semi-structured, open questions about farmers' perceptions of land degradation, soil erosion, changes in soil fertility, their participation in the local market and their experience and knowledge of management practices. This section gathered qualitative data to obtain an initial overview of the multiple values and trade-offs linked to LaDC practices. It helped to identify how people are involved in LaDC. Interviews were conducted with the heads of the households (male or female) (see Appendix III.1)

3.6.2. Sampling design

The preliminary arrangements for the sampling design took into account the agricultural and ecological contexts of the study area and logistical factors[29] in carrying out the data collection. The study area includes 333 households and is divided into five sectors with clear political boundaries, each with its own political representative, called the *Delegado*.[30] The size of the sample proposed at this stage of the research was 30 per cent of the households in the community (approximately 100 households). The sample size takes into account the

[29] Logistical reasons mainly related to access to the community and funding.
[30] People distinguish their specific sector, especially since part of the population of SPT was converted to the Protestant religion. Protestant members claim that they were given the worst land in the area, which contained more gullies and steep slopes than other sectors in the community. Centro sector is nearer to San Felipe del Progresso city and has better access to communication and transport services than La Era. Centro is the Catholic part of the study area.

research objectives, the availability of time (farmers and researcher) and resources and access to the area. In recent decades the community has been informally divided into those of the Catholic and those of the Protestant faith. This has undermined the traditional social networks between *Mazahua* farming households. Nowadays the social networks are church- related. Such a marked social differentiation encourages exploration of how Protestant and Catholic philosophies have impacted on land management, especially on choosing specific LaDC technologies in this study. Therefore religion is a relevant issue in sample selection for the case study. The survey targets only households which manage both *milpa* and *solar* LUT, since one of the objectives of the research is to examine trade-offs between the two major land use types. Finally, only three sectors – La Era, Centro and Dolores – are selected as they have social and biophysical differences such as religion, economic activities, soil attributes, social network which could reflect changes in land management.

A survey of 101 households randomly selected from the upstream and downstream parts of the area[31] was carried out. The survey covered 55 households in the La Era sector, which manage 190 units of land (a total area of 93.36 ha); 40 households in the Centro sector managing 88 units of land (38.25 ha) and 6 households in the Dolores sector with 13 units of land (7.6 ha). Due to the small size of the sample in the Dolores sector and the similarity of its conditions to those in Centro the two have been merged and labelled Centro. Households in the La Era sector depend more on agriculture for their livelihoods than those in Centro, therefore there are a greater number of cases in the survey sample. This sample size allows general appreciation and characterisation of the household demographics (number of family members, age, sex) and socio-economic conditions (education, religion, language, occupation, access to remittances, livestock, land ownership) to be acquired. It describes the general land management, the biophysical attributes of *solar* and *milpa* LUT (plot area, soil type, location), crop production, farming systems employed, LaDC technologies (type and number of practices adopted in each field) and

[31] The household surveys were carried out with the help of research assistants. The researcher conducted the pilot interviews informally. After testing the pilot survey, training was given to the assistants to carry out the interviews. The researcher was responsible for conducting the surveys in 70 per cent of the cases. The researcher verified the quality of the data-gathering process by randomly visiting a few households targeted by the assistants.

informants' perceptions of erosion. Factors that influence these multiple values such as wealth, religion and the locations where LUT occur can be recognised or probed from this sample.

The random sampling provided a basis from which to select a sub-sample of cases for more in-depth understanding of LaDC technology assessment by farmers and implicit trade-offs. The attachment of values to LaDC technologies is an issue determined by the individual needs and preferences of the actors implicated in land management. Investigating multiple values of LaDC necessitated collecting data about the values ascribed by the household members in charge of controlling land degradation. Therefore a sub-sample would permit in-depth analysis to highlight common and innovative land management in the area and emphasise the differences between the management of *solar* and *milpa* LUT, the main agricultural production areas. The level of analysis and sampling design proposed for this research are presented in Figure 3.5.

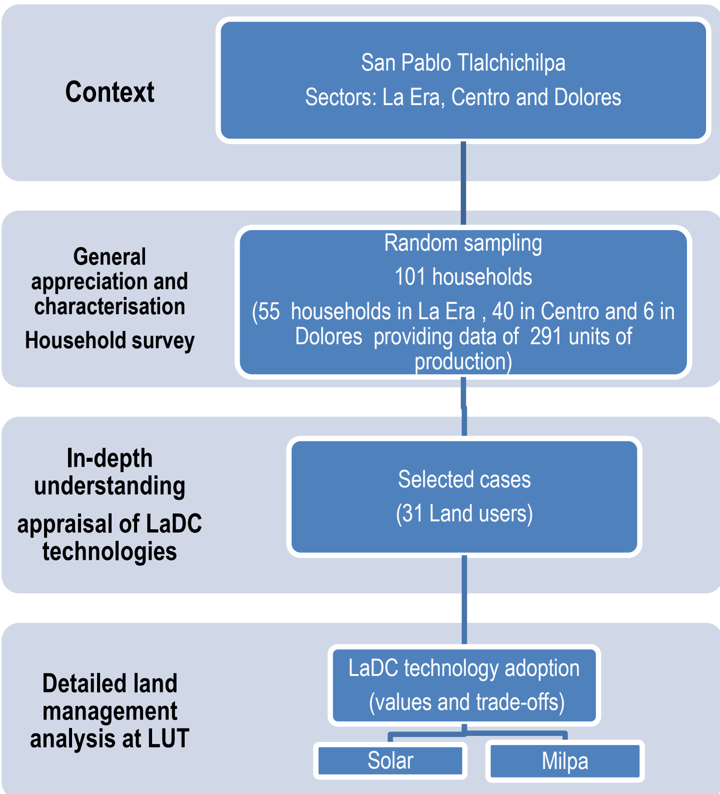


Figure 3.5 Sampling design

Source: the author

3.6.3. Interviews

Different interview methods were used in the fieldwork, depending on the stage in the research, the level of detail to be generated and the precise objective of the interview. A structured interview approach was the basis of the first part of the household survey. The second part was in the form of a semi-structured interview. In this research, the semi-structured interview was the major instrument used to gather information about individual cases. It entailed asking questions and listening to and recording the answers. Note-taking was kept to a minimum during the interviews as the farmers could be suspicious of or discouraged or distracted by it. Semi-structured interviews are convenient when approaching key informants such as expert farmers (Brookfield *et al.*, 2002), community leaders, members of local government and other relevant stakeholders. Key informants are people who, as a result of their knowledge, previous experience or social status in a community, have access to valuable information such as insights about the functioning of society and its problems and needs. The guide allowed for specific issues to be brought up and allowed the option of introducing other opinions or answers; this was particularly important when interviewing the expert farmers, whose time availability was limited. In addition to this, the data collection included an in-depth interview approach in the form of an informal conversation and standardized open-ended questions.[32] The in-depth interviews were crucial to the exploratory phases of the fieldwork which aimed to understand the farmers' views, terminology and perceptions of LaDC. Moreover, they provided rich data for the analysis of multiple values in LADC.

Focus group interviews with small groups of farmers with relatively homogeneous backgrounds and experience were set up progressively throughout the last fieldwork phase. Focus groups were selected as a method of examining the

[32] According to Mikkelsen (1995) and the World Bank (2004), an informal conversation interview relies on the spontaneous generation of questions following the natural flow of an interaction. It is flexible and provides insights into information not originally considered. The semi-structured interview involves the preparation of a guide with a predetermined set of questions or issues to be explored. It makes interviewing more systematic and comprehensive by delimiting the issues to be taken up in the interview. Gaps in the data collected can be anticipated and closed. An open-ended interview consists of a set of open-ended questions carefully worded and arranged in advance. It is useful for collecting the same information from each interviewee at different points in time or when there are time constraints to the data collection and analysis.

farmers' knowledge about land attributes, their adoption of LaDC practices and the multiple values they attached to them. This approach facilitated guided discussion, cross-checking and participant interaction. Contrasting views, disputes and networks among land users were detected in the focus group discussions. One of the challenges experienced when using this method was eliciting the full participation of some of the farmers. The focus groups were generally held at the expert farmers' houses and in school buildings. Some people refused to participate as they did not want to attend the place selected. In such cases individual interviews were arranged. Focus group interviews allowed discussion of the preliminary statistic results with the farmers to triangulate and validate the findings.

3.6.4. Participatory observation

Gathering information through observation was an important part of the field research. Several visits to the study area were made at different points in the agricultural cycle. At the initial stage this method facilitates understanding of the general social and natural settings of the case study. Likewise, issues about the implementation of LaDC practices emerged from direct and participant observation and were introduced in later interviews and discussions with farmers. This method generated a detailed description of the physical structures of the technologies used, social differences among farmers and their behaviour and attitudes regarding land management and land degradation in the study area.

Understanding the multiple values associated with LaDC practices required spending considerable time in the area and being active in the community. The researcher dedicated time to participant observation of the activities developed by diverse groups of farmers, school activities, harvest meals and the adoption of agricultural practices, especially, LaDC technologies. This allowed the researcher to identify with and integrate herself into the community. It was a useful tool for triangulation of the information gathered in the survey, and it allowed corroboration and clarification of occasional inconsistencies in the data.

3.6.5. Transect walks and mapping

Transect walks at the early stages of the fieldwork, particularly when taken with expert farmers, provided a quick entry into the local environment, the *Mazahua* language, identification of soil types and slopes and observation of land degradation processes. They also helped with the identification, in the local language, of the different types of local soils and vegetation managed by the land users. This method offered the possibility of combining semi-structured interviews and discussions about particular issues of interest. Transect walks allowed visits to individual units of production and created opportunities to meet other farmers and community members, such as migrant children, and to become acquainted with the diverse land management technologies in the different sectors of the community.

The use of maps with local land users helped to identify areas of the community according to farmers' views, locate the households selected in the sampling design and plan the transect walks. During the different stages of the fieldwork, topographic maps and aerial photo images were used and discussed with participant households. These symbolic representations of information stimulated discussion and provided a means of cross-checking. The use of images by farmers revealed their specific local knowledge of the physical space (the location of LaDC practices) and available resources in the community such as the location of pumice deposits. The farmers showed an interest in identifying and locating their units of production and points of interest. They also participated in drawing maps of the community, characterising sectors of the study area and highlighting particular features of the landscape relevant to them. This helped the researcher to understand people's perceptions of their environment.

The use of historical timelines clarified changes to land management, crops, farming practices, LaDC and livelihoods over time, as these provide an overview of past events of significance to farmers. This information, central to the understanding of adaptive strategies, showed how land users adapt LaDC practices in response to pressures on the environment or the emergence of new opportunities over time. These collection techniques are important for tracking the origin of practices and distinguishing trade-offs in relation to past experiences. The collection of historical data was based on open-ended interviews with individuals concentrating on changes in their livelihoods and natural resource management during periods of policy change that affected the agricultural sector in Mexico.

The fieldwork included the collection of biophysical data on farmer's units of production to create a customary description of LaDC practices and allow triangulation of the information given by farmers. Slope profiles, plot sizes and areas in which LaDC technologies were applied and their main characteristics (e.g. type of vegetation planted as hedges or stone wall height) were recorded.

3.6.6. Secondary data use

Secondary data consisted of information and statistics on the study area and the research already available; they included reports by local, national or international agencies on the local socio-cultural, political and ecological conditions (e.g. census, land reforms, local policy programmes, maps, photos). Since the beginning of the 1990s the research site has kept close links with the Institute of Agriculture and Rural Sciences (ICAR, formerly CICA). Postgraduate research in different disciplines has been carried out in the community. The secondary data also included collected oral traditions, local stories that can be related to the attachment of values to LaDC and that helps to explain farmers' management of the environment. The use of different sources of data contributed to increasing the validity and credibility of the research findings.

3.7. Multiple values appraisal

Matrix ranking was selected as the method by which to appraise the multiple values attached to LaDC practices. The use of a matrix suggests a participatory data collection process and encourages participants to make and evaluate their choices, either individually or in groups. Usually ranking can be displayed best through simple scoring. The study's typology of multiple values in relation to some components of LaDC technologies was used as a framework to identify and develop measurable indicators in order to assess the multiple values of

LaDC. A matrix template was designed according to the asset base typology (natural, human, physical, financial and social) before going into the field. The matrix was modified based on the preliminary findings from the initial stage of the fieldwork. The final matrix assessed technologies according to a set of five indicators per capital asset type[33]. The researcher and key informants discussed the indicators during the informal interviews. Farmers assigned scores from 0 to 4 to each of the indicators[34] (see *Appendix* III.2). The revised matrix was tested in the field. The participants were selected from the general survey. A total of 31 land users (21 from La Era and 10 from Centro) took part in this exercise, which was mainly held in the form of focus groups. The matrix ranking assessed LaDC technologies by adoption criteria; farmers were randomly selected to appraise both adopted and non-adopted technologies. The detailed methodology is presented in Chapter 6. During the scoring the farmers explained the rationale behind for their technology adoption and their personal perceptions regarding LaDC. The use of a matrix was intended to determine not a specific, generalisable measure but rather the differences between and perceptions of the land users. The scores are used as indicative elements in the decision-making process. The matrix of multiple values could thus inform discussion on farmers' personal views regarding land degradation and control technologies, social issues involved in adoption of practices, and potential trade-offs faced by them in agricultural hillside communities.

3.8. Identification of trade-offs

Trade-offs were approached from a qualitative perspective. Therefore trade-off information was collected mainly in the interviews with individuals and focus groups and by reviewing data previously gathered at the different fieldwork stages. Of most relevance were the preliminary observations and results from the matrix ranking, which indirectly indicate the trade-offs involved in the adoption of practices. During the interviews, farmers' perceptions of the values associated

[33] Indicators are a set of variables, conditions, and/or perceptions that both farmers and scientists expect to change with the adoption of a certain technology or practice. Bellon (2001)

[34] Participants assessed each indicator and gave it one of the following scores: 0 = severe constraint/very negative, 1 = slight constraint/negative, 2 = no value, 3 = slight value/benefit, 4 = good value/very good.

with practices were found to affect their trade-off options, especially in the face of environmental (climate variability), social (a decrease in *Mazahua* customs and an increase in external inputs through migration and access to education) and policy changes.

The trade-off analysis was initially prearranged by LUT (*solar* and *milpa*), past and current farmers' experiences (changes in LaDC technology adoption) and participation in programmes promoted by rural development polices. Land users responsible for the implementation of LaDC practices described their choices for LaDC technology adoption. Further description of the trade-off methodology is in Chapter 7.

3.9. Research ethics

Primary data collection involves the consideration of ethical research concerns such as conditions for participation, consent and privacy. A time to inform farmers about the nature of the study and the researcher's presence in the area was allocated. Initially, the expert farmers introduced the researcher to a few households to facilitate access to other contacts. All informants were told of their right to decide whether, when and to what extent they participated in this study. In the research area most farmers were keen to contribute to the study due to past positive experience of research projects; only two people were reluctant to participate. All informants' consent to be interviewed, recorded and have their photographs taken was requested in advance. Their consent was given verbally, particularly in the case of the farmers, who are suspicious of signing any written document. The capture of multiple values and farmers' perceptions about their own and others' land management, social customs, traditions and religion was contradictory or personal in some cases. Although informants' names are registered, their identity is protected by using pseudonyms and codes. It is worth mentioning that some farmers in La Era gave consent to use their names due to their continuous interaction with the researcher and external actors. Particular expert farmers are proud of their contribution to previous written documents; however, anonymity was maintained in all cases. In addition, the researcher asked the farmers' permission to walk through and measure their units of production.

3.10. Methods of data analysis

Data management is the initial step in developing the analytical stage of the research. Data organisation and entry are time-consuming, but detailed and comprehensive data can be obtained by combining collection methods. This research involved both qualitative and quantitative methods of analysis, and the data were managed according to the methods selected to meet the specific research objective.

3.10.1. Qualitative analysis

In the qualitative methods, data gathered through observation, transect walks and interviews were recorded in the field notes. The digital recordings of interviews in Spanish were transcribed onto a computer. Later, the data were codified, selected for analysis and translated into English. The qualitative analysis involved the deconstruction of farmers' accounts of their land management and conservation, their experience in agricultural activities and accounts of their personal life. It included the deconstruction of other informants' perceptions, texts and narratives about the research area and land degradation in the highlands.

3.10.2. Quantitative analysis

Data from the structured interviews, in particular the first section of the household survey, were entered into a database using Excel software. Data from the open-ended questions in the second part of the survey were codified and entered into this database. The data set was reviewed for inconsistencies and missing information. The demographic and farm data were completed with information and databases from other research on this study area (Nava-Bernal, 2003, Chávez, 2007). The complete database contained information covering 101 households and 291 units of production. Household data included the demographic and socio-economic characteristics of the household members and detailed characteristics of the units of production. Data management and analysis were carried out using Excel and SPSS (v12 to 16) spreadsheet software. The aggregation and selection of data subsets was carried out using filters. Excel is efficient for organising and filtering data; SPSS is useful for running specific statistical tests. The files of each programme are compatible with the other.

Statistical tests form the basis of quantitative analysis. This research employed descriptive statistics and parametric and nonparametric tests. Each test was selected according to the nature of the data involved. The initial quantitative analysis of the survey data concentrated on generating descriptive statistics and exploring relationships between variables. Correlation tests and regression models were run to identify associations between technologies adopted by farmers in the area (see Chapter 5).

In particular, quantitative analysis of farmers' adoption of conservation practices has commonly employed statistical models such as logistic, logit or probit regressions (Lapar and Pandey, 1999, Amsalu and De Graaff, 2007). In this research, influential factors in the adoption of LaDC technologies at the unit of production level are analysed using logistic regression model,[35] since the adoption data is presented as a categorical variable and the independent variables are a mix of continuous and categorical data (see Chapter 5).Table 3.2 shows the preliminary socio-economic variables used in the logistic regression and the rationale for choosing these in relation to the analysis of land management practice.

The logistic regression requires a series of statistical tests to avoid problems, which could affect the estimation of the probabilities of adoption of technologies, such as heteroscedasticity and multi-colinearity. The results of the logistic regression provided data with which to perform a cluster analysis non-parametric test in order to group LaDC technologies according to their influential factors. Matrix ranking and scoring of LaDC technology data were used to create separate databases in both spreadsheet programmes. Ordinal data were mainly subjected to Kruskal-Wallis and Mann-Witney non-parametric tests for differences in ranking by specific criteria, as explained in Chapter 6.

[35] "Logistic regression is used to predict a categorical (usually dichotomous) variable from a set of predictor variables. With a categorical dependent variable, discriminant function analysis is usually employed if all of the predictors are continuous and nicely distributed; logit analysis is usually employed if all of the predictors are categorical; and logistic regression is often chosen if the predictor variables are a mix of continuous and categorical variables and/or if they are not nicely distributed (logistic regression makes no assumptions about the distributions of the predictor variables)" (Wuensch, 2009, p.1).

Table 3.2 Socio-economic variables used in the logistic regression model

Characteristics	Aspects to explore	Units
Education	Access to knowledge and external inputs	Categorical variable
Language Religion	Cultural influence, transference of traditional knowledge and access to social capital	Categorical variable
Age groups in HH	Indication of family needs to be satisfied according to age	Categorical variable
Family size Labour index	Age/gender members Access to and quality of available labour for land management and LaDC	No. of family members Labour index
Household head (gender and age)	Characteristics of decision makers in households	Categorical variable
Occupation Migration & subsides	External economic and cultural inputs	Categorical variable
Livestock	Access to manure and financial security	Livestock heads
Land tenure	Access to and size of units of production	Categorical variable
Perception of erosion	Perception of erosion	Categorical variable
Productivity	Production of land	Ton/ha
Maize diversity management	Diversity of crops	No. of maize types cultivated

Non-parametric and parametric tests to compare differences in frequencies, means and proportions of the different types of data were performed during the quantitative analysis process. In specific cases categorical data were treated with a parametric test as a means of exploring specific hypotheses. Where such tests were performed, this is noted.

The dynamics in technology adoption in agricultural communities are so complex that no model can perfectly explain decisions of land users (Tripp, 1996). Hence, the use of qualitative methods complements and enhances the analysis of LaDC carried out by farmers in the hillside community of SPT.

The research analytical framework developed in the case study approach is summarised in Table 3.3. It outlines the research strategies in relation to the research objectives, fieldwork activities, methods and sources of information.

Table 3.3 Research methodological framework and strategies

Objective	Activities	Methods	Source information
	Methodological Research Framework		
Identify the principal types of LaDC in the case study area, identify the multiple values associated with these as perceived by local communities and relate them to Natural resource management (NRM) **LaDC Practices**	Characterisation of social & biophysical context Characterisation of LUT Characterisation of LaDC technologies Identification of Multiple values of LaDC	Secondary data collection Direct observation Household survey Transect walk Household survey, semi-structured and open-ended interviews	Research institutions (Research Centre of Agricultural Sciences, Faculty of Geography, State of Mexico), local government institutions (INEGI, SEMARNAT, University of Chapingo) Farmers' households Expert farmers
Measure multiple values of LaDC and develop indicators to analyse the values that drive farmers' decisions about adopting technologies **Multiple values**	Establishment of measurable indicators Measurement of values of LaDC Linking values with farmers' decision-making process	Participant observation Focus groups Construction of maps Transect walk Matrix ranking Seasonal calendar	Farmers in charge of LaDC mainly Household Heads (HH) Groups of households Expert farmers
Analyse trade-offs among multiple values of LaDC in order to understand farmers' decision-making on natural resource management and strategies associated with LaDC for coping with risk and vulnerability **Trade-offs**	Identification of trade-offs Characterisation of past and current trends and shocks Revision of reforms in land policy	Seasonal calendar Key informant interviews (semi-structured and informal conversation) Historical timelines Focus groups Secondary data revision	Expert farmers Different groups of households
Show how farmers' decisions about LaDC and related management practices affect the sustainability of natural resource management **Implications for sustainability**	Showing evidence of farmers' natural resource management and their contribution to sustainability	Semi- structured interviews with key informants Review of secondary data	Local governmental and research institutions Expert farmers and local leaders

The research analytical framework developed in the case study approach is summarised in Table 3.4.

Table 3.4 Research analytical framework

Use of Analytical Techniques				
Analytical techniques	Household data	LaDC practices data	Multiple values data	Trade-offs data
Descriptive statistics: Mode, median, mean, variance and standard deviation	X	X		
Analytical statistics: Nonparametric: chi-square, cluster analysis, Kruskal-Wallis and Mann-Witney		X	X	
Parametric: T-test, correlation and logistic regression		X	X	
Qualitative analysis: Text deconstruction, people's account deconstruction, narrative analysis, conversation analysis		X	X	X
Specific techniques: Conservation technology summary		X		

3.11. Conclusions

The methodological framework used a broad range of methods to collect and analyse data. This created challenges in the gathering and organisation of data, as it involved time-consuming activities and specific skills, particularly since most of the data and information were derived from the fieldwork. The combination of qualitative and quantitative approaches produced rich and detailed data about the case study (study area context, farming household attributes, land management and adoption of LaDC practices). Managing such a comprehensive amount of information was a major challenge as it increased the complexity of the data input, selection and analysis. The researcher had to seek advice from many people, and this inevitably delayed especially the analysis and interpretation of the data sets.

The presence of the researcher in the study area may have affected participants' responses, causing them to over- or understate their performance, particularly in the initial collection stage and therefore the research design encouraged the triangulation and validation of information using various research techniques and sources to query some of the data and identify inconsistencies in the data. The experience of integrating quantitative and qualitative analyses proved to be very challenging. However, through providing diverse items of information from multiple sources, an integrated strategy of qualitative and quantitative techniques of research was found not only to be helpful in verifying conclusions but also enriched the whole research process.

Chapter 4. Exploring the Settings for Land Management in the Highlands of Central Mexico

4.1. Introduction

This chapter illustrates historical and current conditions relevant to LaDC in the case study area. Historical changes regarding land degradation and its control are described in the Mexican context. Later, the study area, the SPT community, is presented in detail, identifying current factors influencing today's land management and particularly LaDC practices carried out by farmers.

4.2. Historical changes in Mexico affecting land management in the Highlands

The historical legacy of land degradation is important in order to understand the contemporary phenomenon and how land users respond to the outcome of land degradation processes. In steep environments such as the Mexican Highlands, land degradation has presented a problem equally for the indigenous population, Spanish conquistadores and *mestizo* societies but in different ways and contexts. Throughout history perceptions of and responses to land degradation have been fused, have continued and have evolved, integrating Spanish and indigenous contrasting cultural sources. Nowadays the rural parts of the Central Mexican Highlands are characterised by small-scale subsistence agriculture, soil erosion and deforestation. This environment challenges farmers to develop strategies that will enable them to secure their livelihoods. Farming households carry out local agricultural practices that determine their present land management (Chavez, 2002).

In this study, exploring the origin of current practices adopted in the area is crucial to understanding the legacy of indigenous, Spanish and *mestizo*[36] land management. The identification of these legacies helps in the understanding of land management in specific political, cultural and socioeconomic contexts and the identification of the influences leading to specific farm practices (Beshah, 2003a).

The approach here is similar to that of Zimmerer (1993), who examines the past context of land management in specific historical periods in Bolivia. Zimmerer (1993) explains that four main factors determine the adoption of land use practices in farming areas: the human population, the political economy, technology and the culture. Similar conditions apply in the Mexican context, as both Bolivia and Mexico were colonised by Spain.

This historical analysis is designed to track the introduction and evolution of technologies and to identify the driving forces influencing their adoption in hillside environments. Following Zimmerer's approach, the factors included in this analysis are political and economic context; culture and religion; human assets (particularly in terms of labour); land use and tenure; and the technologies adopted. The analysis includes the following periods: pre-Hispanic (PHP) (before 1519), colonial (CP) (1519-1810), independence (IP) (1810-1910), revolution and post-revolution (RPRP) (1910-1939), agricultural modernisation (AMP) (1940-1979), the lost decade (1980-1990) and the commercial opening (COP) (1990-2006), all of which have been significant in Mexico's history due to their impact on people's livelihoods. Table 4.1 highlights the factors linked to changes in land management practices in each historical period.

[36] Generated from the combination of different cultures

Table 4.1 Political and socioeconomic contexts of historical periods in Mexico linked to land management changes

Period	Political /Economic context	Cultural/Religious	Human Assets	Land utilisation	Technology
PHP Before 1519	• Aztec's empire focused on production tribute rather than land. • Intensification of agricultural production to pay tribute to the Aztecs, to feed increasing population	• Privileged use of *Maguey* and forest for indigenous religious purposes • *Maguey - pulque*	• Specialisation of labour skills • Good availability of labour for agricultural practices • Communal labour to increase production	• *MILPA* -agricultural areas maize production • *SOLAR* -home gardens to produce condiments, medicines, crops, fuel, etc. • Land tenure *Calpullis*	• *Metepantlis* –terraces with *maguey* including some practices such as infilling gullies, reincorporation of sediments, ditches, holes, earth bunds, boundary vegetation, stone wall • Intercropping • Fallow • Weeding • Manure and *canuela* (mulching) • *Chinampas* (low valleys)
CP 1519	• Spanish colonisation – Extensification period • Spaniards hold more privileges and power • Indiscriminate exploitation of natural resources	• Indigenous people converted to Catholicism • *Mestizaje* – races, cultural symbols and beliefs • Increased use of *Maguey* by other indigenous groups	• Demographic collapse due to epidemics and diseases • Poor availability of labour • Indigenous slaves of Spanish Crown • Reordering of labour	• Expropriation of land by Spanish • Reallocation of land tenure • Abandoning of hillside agriculture • *Mercedes de tierra* land tenure	• Construction and maintenance of agricultural practices diminished • Abandoning of indigenous technologies such as terraces in hillside • Introduction of "new" technologies, livestock and crops from the "old world" • Manure of horses and cattle • Loss of indigenous knowledge about land management
IP 1810	• Indigenous farmers pay for lease of land with work and production • Similar political and economic conditions for poor people • Split from Spanish Crown	• *Mestizaje* with other ethnic groups. • Catholic religion spread throughout country	• Peons instead of slaves • Low labour availability at household level (reordering of labour) • High labour to produce in *haciendas*	• *Milp*as leased to farmers' households • At household level *solar*'s management continues	• Pre-war technologies adopted • Indigenous technologies have been followed at household level (particularly those less labour intensive) in the marginal lands
RPRP 1910	• Revolution against Diaz's Dictatorship • Fight for land ownership • Extreme poverty in hillsides	• *Mestizaje* • Constitution of 1917	• Seasonal labour availability to carry out subsistence agriculture	• Partial abandonment of land	• Similar scenarios as before

Source: compiled by author from multiple sources used in section 4.2

Table 4.1 Political and socioeconomic context of historical periods in Mexico linked to land management changes (continuation)

Period	Political /Economic context	Cultural/Religious	Human Assets	Land	Technology
RPRP 1921	• Need to increase food production • Emphasis on agricultural modernisation • Extreme poverty in hillside areas • 1940-1960 intensive production of cereals	• Mexican culture more defined • Influence of USA • *Mestizaje* with other cultures and customs	• Poor labour availability in hillside (male labour) • Women participate in Land management activities. • Interest to increase experts on farming systems by government (capacity building in the USA)	• Creation of *ejido* • Distribution of land (*milpas*) • *Solar* land use • Reallocation of land	• Indigenous technologies not appropriate for production needs • Partial adoption of technologies in recent distributed land in hillsides
AMP 1940	• Green Revolution Recognition of Soil erosion problem by researchers • Creation of Laws and Institutions to respond to an increasing and alarming Soil erosion rate • Access to market for maize smallholder producers	• Migration: Interaction of Rural indigenous culture with urban population • **SPT Migration**	• Seasonal Migration to cities • Part-time labour availability for production • Women/children participation in land management • Increasing population (more family members per family)	• *Solar* management is intensified • Increasing production very slow in highlands • Redistribution of land (*ejido*)	• Use of fertilisers and American Technologies by rich farmers • Furrow design according to new techniques from USA • Use of tractors and heavy machinery by wealthy farmers • At the household level partial adoption of "local" technologies especially in *solar* (poor farmers) • *Milpas* poor land management
Lost decade 1980	• Economic Crisis • Lack of investment in agricultural areas • Subsides • Access to market for maize smallholder producers	• Education available in Spanish language (primary) • Returning migrants (new urban customs)	• Part-time labour and women participation in agriculture • Migration of young male labour • Children have access to education	• Investments in *milpa*, improving their management • *Solar* intensive management. • Increased use of fertiliser in both LUT	• Use of chemical fertilisers at household level • Promoted technologies by government such as terraces (failure) • Conservation of local indigenous knowledge by research institutions
COP 1990	• Mexico's international commercial agreements • International pressure • Lack of interest in agricultural sector • High prices of fertilisers • Lack of markets • Land degradation • Direct support programmes	• *Mestizaje* and loss of local knowledge as native tongues are used less. • Migration affecting the inheritance of LK • Migration- more investments in household's goods.	• Low availability of labour • Increased migration of women (locally) • Availability of Old people and child labour for land conservation • Seasonal labour: availability of men for land preparation and harvesting.	• *Solar* and *milpa* management more defined • Private land tenure, possibility to sell *ejido* • *Milpas* are cropped to secure land tenure. • More monoculture	• Local technologies • Promoted practices by government. • More investment in private property with higher market value. • Less investment in land conservation • Less intercropping and shorter fallow • More adoption of technologies in *solar* • Dependence on fertilisers

Source: compiled by author from multiple sources used in section 4.2

4.2.1. The Pre-Hispanic period (before 1519)

Farming in the Aztec Empire focused on agricultural intensification. Hillside agriculture was needed to produce enough crops to pay the tribute the Aztecs demanded.[37] The staple grown on sloping ground was maize, intercropped mainly with beans and squash. Farmers also grew varieties of amaranth, *chia* (*Salvia hispanica*), tomato and chillies (Clawson and Hoy, 1979, Whitmore and Turner, 1992).

Two of the most important intensive cultivation techniques employed by indigenous groups in Central Mexico to feed their considerable populations were terracing in steeply sloping areas (called *metepantlis* in Nahuatl)[38] and *chinampas*[39] (farming in valleys). Blanco Macias (1969) and Smith and Price (1994) claim that, while terrace agriculture was not as productive as the *chinampas* system, it was the most widespread form of intensive agriculture in the mountain region during the Aztec empire. Aztec élites promoted terracing in order to bolster their wealth and power[40] (Katz, 1958, Franco-Carrasco, 1969, Smith, 1986).

> *The good farmer, the [good] field worker [is] active agile, diligent, industrious … He is bound to the soil; he works-works the soil, stirs the new soil anew, prepares the soil, he weeds, breaks up the clods, hoes, level the soil, makes furrows, makes separate farrows, breaks up the soil. He sets the landmarks, the separate landmarks; he sets the boundaries, the separate boundaries… (Bernardino de Sahagun, a Franciscan missionary, quoted in Zuria and Gates, 2006 p56)*

[37] Williams (1972) suggests that the need for fuel, tributes and religious activities in this society might have been reasons which influenced the rate of deforestation and the erosion of upper slopes during the pre-Hispanic period. He highlights that the continuous required offerings to the gods demanded great quantities of firewood.
[38] Agricultural terraces "consisted of level earthed shelves held in place by stone retaining walls, protected by earthen embankments hedged with one or two rows of *maguey* and other plants, like *nopal* [*Opuntia*] and fruit trees" (Zuria and Gates, 2006).
[39] *Chinampa* or floating gardens are "a narrow artificial island (a raised field) constructed from *sediments* and biotic material dredged from the shallow lakes and anchored trees" (ibid). *Chinampas* and m*etepantlis* agricultural terraces are example of pre-conquest soil conservation (Blanco Macias, 1969).
[40] Agricultural system served to feed large communities. Elites competed for control of the land and the wealth that came from its cultivation (Whitmore and Turner 1992).

Bernardino de Sahagun gives us an insight into indigenous land management, providing evidence of the construction of boundaries in this period. *Maguey* (called *melt* in *Nahuatl*) as boundary vegetation in agricultural areas was an important element because of its various religious and cultural uses by indigenous societies.

Terraces with maguey were common in agriculturally marginal hillside environments (Evans, 1990). However, steep fields suffered intensive erosion, particularly during the fallow cycle (Williams, 1972, O'Hara et al., 1993). Other land conservation practices were involved in the construction and maintenance of the terraces such as the digging of small drainage ditches, holes and channels to divert water and stone walls (see Table 4.2). These practices were needed to increase plant water availability and the capture of sediments (Zuria and Gates, 2006, Whitmore and Turner, 1992). Conservation practices were part of the indigenous agricultural systems. Vestiges of these practices show the responses to land degradation in pre-Hispanic Mexico (Franco-Carrasco, 1969, Barrera-Bassols et al., 2006). Labour availability was crucial to hillside agriculture: the Aztecs had access to much human labour and specialised skills to crop the milpa (Katz, 1958, Wikipedia, 2007), a type of land utilisation practiced since pre-Hispanic times.

In the pre-Hispanic period land was held by c*alpullis* (clans). Each managed a communal landownership system cultivated by its members. People had free access to a piece of land to cultivate and owned the crops they produced. They could pass the land to their children, but could not sell or lease it, and if the land was not cultivated for a certain length of time the household lost all claim to it (Katz, 1958). Households constructed their houses and home gardens on their land. They intensively produced food crops, ornaments and medicinal plants such as avocado, *maguey*, *nopal* (*Opuntia*), *tejocote* (*Crataegus pubescens*), *capulin* (*Prunus salicifolia)* and fuel (Evans, 1990, Whitmore and Turner, 1992, Zuria and Gates, 2006). The home garden has been identified as *solar* land utilisation type.[41] *Solars* were intensively managed due to their proximity to the house and the land rights, which could be passed on to relatives. For instance, farmers collected topsoil from plots with better land belonging to relatives or from uncultivated woodland. They added soil nutrients by burning *maguey* leaves on the land and incorporating the ashes into the soil (Williams, 1972). They showed an interest in improving the soil conditions of the land they worked. *Solar* management was dependent on households' labour availability, in contrast to the communal terraces for which the Aztec élites supplied labour and investment.

During the pre-Hispanic period, labour availability, land tenure and land utilisation types were significant drivers influencing land management and conservation in indigenous communities. The technological legacy of this period is preserved in current subsistence agricultural systems in the highlands.

4.2.2. The Colonial period (1542-1810)

The Spaniards conquered the Mexican highlands in 1542. Spanish *conquistadores* reapportioned indigenous land and labour. Agricultural methods changed through the introduction of European technologies, crops and livestock from the Old World (González Jácome, 2004) . New ways of cultivating the land using ploughs, iron tools and draft animals (e.g. cows and horses) and new crops including wheat, barley and rice were imposed on the indigenous communities.

Colonial rule installed a productive model based on the extensification of agricultural production across most parts of Latin America. The Spaniards discontinued the agricultural systems used on sloping areas as they required much labour and investment. Hillsides and terraces became marginal and were abandoned due to demographic collapse caused by epidemic diseases which reduced the availability of labour[42] (Williams, 1972, Zimmerer, 1993, Zuria and

[41] *Milpa* is the general term used to refer to maize cropping areas. However, *solar* is used here to distinguish the *milpa* located next to the house.

[42] Cook and Borah (1963) suggested that the population of 25 million indigenous people in 1518 was reduced to 700000 in 1623. Therefore the Aztec terraces were not maintained and suffered greatly from erosion due to a decrease in labour and land reforms.

Gates, 2006). The colonial system[43] allowed Spaniards to acquire land titles and they started to construct the first *haciendas*,[44] forcing indigenous people into slavery (Endfield, 1998, Endfield and O'Hara, 1999). Charlton (2003) notes that the *haciendas* controlled land and labour and functioned as economic and political systems. *Hacendados* provided credit and leased plots of land to the indigenous people working for them (Alexander, 2003), on which they cultivated their own crops and followed their own cropping traditions (Whitmore and Turner, 1992, Zuria and Gates, 2006). However, the indigenous farmers lacked the resources to continue with terraced systems and did not have access to Spanish technology such as ploughs or the availability of manure. They may have followed practices that were less labour-intensive such as constructing ditches, holes and particularly planting boundary vegetation using *maguey* in their *solars* to protect the soil.[45] The adoption of *maguey* as boundary vegetation became popular due to the increase in demand for *pulque,* an alcoholic drink made from it, and it became a symbol of indigenous customs.

Indigenous farmers continued to cultivate maize as a staple, intercropping it with beans and chillies. Households were used to cooking food such as *tortillas* or *tamales* made from maize, a custom still present in today's Mexican cuisine (Romero Frizzy, 1991). In their *solars* farmers mixed native and Spanish plants and this became a place where cultural inputs were integrated (González Jácome, 2004) and for local experimentation (Arriaga-Jordan et al., 2005). Local indigenous knowledge remained at the household level, hidden behind Spanish technological development. Many indigenous practices and technologies continued and became part of the new landscape, with the Spanish occupying the valleys and indigenous people controlling the hillsides (Whitmore and Turner, 1992). Changes in the organisation of land and labour, the introduction of

[43] *Mercedes de Tierra* (royal land grants given to the Conquistadores that had to be worked for at least six years before they could be sold) and *encomienda* (grants for the control of indigenous people given in custody to Spaniards) were institutionalised by the Spanish Crown in the "New Spain". The *encomienda* (indigenous people) had to work to pay tribute in kind to the Spanish Crown for their evangelization, education and security

[44] *Haciendas* are agricultural estates operated by one owner called *hacendado* (Alexander, 2003).

[45] Spanish missionaries claimed that they carried out soil conservation practices in Puebla and Estado de Mexico, which are still preserved in the Highland region. However, Franco Carrasco (1969) argues that the native population in Mexico adopted various soil conservation practices which were later attributed to Spanish missionaries.

external elements to the local culture and the overexploitation of resources by Spanish conquistadores generated the environmental degradation of local landscapes and changes in land management practices (Williams, 1972, Zuria and Gates, 2006), the signs of which can be seen today.

4.2.3. Independence period (1810-1910)

The war for Mexican independence from the Spanish crown started in 1810.[46] Agricultural production was still undertaken in *haciendas,* which functioned as they did before the war, increasing the productivity and wealth of the upper classes. Soil conservation in independent Mexico during the nineteenth century is not well recorded. However, Zuria and Gates (2006) state that farming households on sloping areas may have continued with the pre-war land management system. According to Barrera-Bassols (2006); *mestizos* followed Catholic religious practices, rituals of Mesoamerican culture and sacred rites. The socio-cultural development of Mexico was now based on a blend of Indigenous, *mestizo* and Spanish traditions and languages. The combination of contrasting cultures shaped new cultivation systems adapted to local natural conditions and the creation of a Mexican ethnicity (González Jácome, 2004) .

4.2.4. Mexican Revolution and Post–Revolution period (1910-1940)

In the early twentieth century, increasing foreign investment and new agricultural technologies arrived in Mexico. Inequality in the distribution of land among Mexican social groups was evident; most fertile land and irrigation systems were held by the upper classes. Smallholder farmers (mainly descendants from indigenous and *mestizo* groups) survived in the highlands and participated in the Revolution of 1910. "*Tierra y Libertad*" (land and liberty) was one of the most popular mottos of the time and reflected the need for land by poor farmers.

The creation of the Mexican Constitution of 1917 was one of the biggest political

[46] The stage for the upheaval and dissatisfaction that gave rise to Mexican independence was set by political and economic changes in Europe and its American colonies of the late 18th and 19th centuries. Basically, the *Peninsulares* (Spanish-born population living in Mexico) and *Criollos* (Spanish descendants born in Spanish colonies) wanted to take control of land and resources and stop paying tribute to the Crown.

changes during this period. Article 27 was the foundation of Mexican land reform. It allowed the expropriation of land from *haciendas* and its division and distribution of land among poor farmers (ibid). This reform promoted communal land management called *ejido,*[47] whose land could not be subdivided, rented or sold, and each farmer had access to a piece of land. If the land was not cultivated, it could be reclaimed by the *ejido* and reallocated to others (Nuijten, 2003, Romo-Santos, 2005). The *ejido* land tenure system was similar to that of pre-Hispanic times and the land management to that before the revolution. Legislative and institutional instruments were developed to generate changes in later years. After the Revolution the allocation of *ejidos* was carried out and the Mexican government promoted intensive monoculture using imported technology. Marginal sloping lands were not targeted due to their low productivity and poor contribution to the national economy. Agricultural modernisation contrasted with small farming systems.[48]

Land reapportioned to farmers was usually not adequate for agricultural activities. Smallholders lacked the economic, physical and human capital to carry out either the traditional or the intensive practices promoted by governmental programmes. Barrera-Bassols, et al.(2006) claim that farmers managed their land through what they call the adoption of “soft water and soil conservation practices” including the management of sediment transport and deposition. The inheritance of indigenous and *mestizo* knowledge of land management may have survived as a result of people’s ability to follow traditional practices on their *solars.* Inherited practices appeared more appropriate to their production needs (Zuria and Gates, 2006). There was a clear incompatibility between the demands of the new technologies and the resources of local land management.

The creation of the *ejido* system had a great impact on land management in the context of extreme poverty. *Ejido* was valuable natural capital which required continuous cultivation in order to keep the land rights. Hence women increased

[47] The *ejido* was a land tenure system in which farmers (members of *ejidos*) hold the land in usufruct as it is owned by the *ejido* and not by individuals. The government used this restriction to mandate farm practices and control *ejidos’* internal political structure (Haenn, 2006).

[48] Technological developments were often not accessible to the poor who prevailed in the Mexican Highlands.

their participation in agricultural activities in the *solars* and other *milpas*. Generally, women's expertise was in managing ornamental, medicinal and condiment plants which they grew in their *solars*, but their experience helped them to participate more in land management practices which up to then had mainly been carried out by men. In some cases women competed with men to determine who was best at working in the *milpa.* Social recognition became an indirect driver to women's involvement in land activities. However, poverty and population growth in the rural Mexican context increased male migration to urban areas and their labour became seasonal and less available (Chávez, 2007). Thus time spent on soil conservation practices was reduced.

At the end of this period of land redistribution as *ejido*, the growing international market for cereals, the incompatibility of new technologies with local land management and production costs generated a new context for local communities. Agricultural activities were now determined by the availability of household farming assets with which to work the land under the *ejido* system without access to technological advances.

4.2.5. Agrarian modernization (1940-1980)

The early 1940s were characterised by the decentralisation of land[49] and access to credit and technical assistance by farming households. However, only 20 per cent of the land was used for rain fed agriculture, the rest being forest and grasslands. National and international investment in further agricultural modernisation increased to encourage rural development through the Green Revolution[50] (Romo-Santos, 2005). As a result of transforming the national production system, Mexico was able to be food self-sufficient between 1956 and 1971 (Ganzel, 2007).

[49] President Cardenas granted around 18 million hectares of land to a million farmers. Later Mexican presidents decreased the distribution of *ejido* land and encouraged irrigation agriculture on private property to promote cereal production.

[50] The Mexican federal government implemented programmes to fund agricultural science researchers to study in the USA, especially in land management and conservation (Blanco Macias, 1969). In addition, international organisations such as the World Bank, the International Centre for Maize and Wheat Improvement (CIMMYT), Banco Interamericano de Desarrollo (the International Development Agency) and German development agency were investing considerable amounts of money in Mexico to introduce the Green Revolution.

However, agricultural technological development brought with it soil erosion and inappropriate use of fertilisers, especially as the land cultivated was inadequate for agriculture (ibid). During this period soil erosion was recognised by researchers as an alarming and increasing problem that affected the national economy. In the mid-1940s the Mexican government established a Soil Conservation Department and passed the Soil and Water Conservation Law (Blanco-Macias, 1969, CONAFOR, 2007, Romo-Santos, 2005). Official action regarding soil erosion was inadequate as the problem was underestimated[51] and support for conservation was limited. A contradiction between conservation policy and necessary development action was recognised (Franco-Carrasco, 1969). Farmers reported increasing soil degradation after the introduction of the Green Revolution maize package in the 1970s (Barrera-Bassols *et al.*, 2006).

The distribution of *ejidos* and agricultural modernisation generated two contrasting agricultural systems. The first, *latifundium,* was characterised by large areas of land with access to irrigation, fertilisers, markets and credits. The second, *minifundium* involved small-holder farmers on *ejido* land who depended on rain fed subsistence farming and suffered from lack of access to credit and technology and poor education (CONAZA, 1993). In the mid-1960s CONASUPO (National Company of Popular Subsistence) was created to promote economic and social development and regulate and secure markets to farmers.

Between 1940 and 1980 poverty and population growth grew considerably in Mexico's Central Highlands. In rural areas maize production was not enough to cover basic needs as family size increased. The migration of male household heads became a common livelihood strategy for farming households. The participation of women and children in agricultural activities grew, especially in the *solar,* as it was the nearest and safest field.[52] Thus the *solar* was better managed than other *milpas*. Women carried out planting, weeding, harvesting

[51] Ortiz Villanueva (1969) remarked that research institutions developed programmes on soil conservation. Unfortunately, lack of money constrained the application of these programmes. In addition, soil conservation technologies from US conservation systems were adopted; the practices were expensive, labour intensive and failed to address the problem.

[52] Distant fields were not managed by women or children due to risk of assault and because it was not considered culturally appropriate.

and sometimes ploughing activities. Their participation varied according to religion, ethnicity and LUT.

Traditional conservation technologies carried out by farmers on steep areas were considered undeveloped practices (Clawson and Hoy, 1979). Using *maguey* was still a crucial practice in the rural landscape due to its soil retention function, for protecting land from animals and for delimiting the *ejido* when used as boundary vegetation. Although agrarian modernisation was promoted at the national level, farmers living on steep slopes of the Central Highlands could not access it. However, the productivity of their subsistence agriculture was improving very slowly but constantly during this period through traditional technologies. The rural sector faced the incompatibility of conservation policy with smallholders' farming activities, isolation from the national soil conservation service[53] and soil erosion (Oviedo, 1969).

4.2.1. Loss of food self-sufficiency (1980-90) and Commercial opening (1990- to the present)

In the early 1980s Mexico's food self-sufficiency was lost and importation of maize was needed. Subsistence farmers started being able to access fertilisers due to agricultural subsides, remittances and markets (the political and economic context in agricultural households is discussed in Chapter 7). In poor rural areas farmers were keen to adopt the use of fertilisers due to their immediate results in increasing production. However, extension activities and farmers' technical knowledge on the use of chemical fertilisers were lacking. Soil erosion increased due to changes in land use. During this decade governmental initiatives were developed to target soil conservation through the first soil and water conservation manual (CONAFOR, 2007). The government promoted soil conservation technologies such as terracing but failed to address the root causes of the problem. Pressure from international organisations brought land degradation into the Mexican political arena. Moreover, research institutions recognised the need

[53] The legislation and programmes regarding soil and water conservation programmes were unknown among governmental institutions. There was no regulation or monitoring of their application. The Soil and Water conservation Department was dismantled, with constant administrative changes.

to restore and conserve traditional knowledge and practices. In the Highlands, local communities still followed indigenous practices in their fields and began to use fertiliser on some of them.

Farmers employ both promoted and traditional technology. Practices to tackle land degradation in rural agricultural areas are commonly based on local management traditions. One of the most notable examples is hedgerows, which have been an important element of the landscape since pre-Hispanic times. Hedges still provide a variety of services and products to local farmers.54 Intercropping, fallow and the incorporation of organic matter are technologies used since pre-Hispanic times. Most current agricultural conservation is practised by small groups of people, often individual families. It tends to be developed gradually over a period of time rather than in short, intensive bursts of labour (Wilken, 1987, Smith, 1986). According to Smith (1986), decisions on adopting traditional and local land management activities including soil conservation are applied in reaction to identifying specific problems rather than in a pre-planned project approach.

During this period the research sector has emphasized and increased documentation of local practices and has encouraged the conservation of traditional agriculture and related land management practices. Governmental institutions generally employ a top-down approach to integrating indigenous or local farmers' experience in natural resource management in order to establish new land use systems (Anaya-Garduno, 2003, Hudson and Alcantara-Ayala, 2006, Sommer et al., 2007).

In the early 1990s, neoliberal policies implemented in Mexico, the creation of the North American Free Trade Agreement (NAFTA) and emphasis on industrial development had an impact on the agricultural sector (see Chapter 7). NAFTA has had negative effects on the Mexican agriculture sector as small-holder farmers cannot compete with North American producers. Policy interventions carried out during this period affected in complex and varied ways farming

[54] Zuria and Gates (2006) list the uses of hedgerows; they "divide the land into smaller fields, define land ownership; reduce the erosion rate; produce fruits, flowers, medicinal plants, fodder and wood; protect crops from cattle; provide shade; and function as habitat for game and wildlife".

livelihoods and land management. For example, liberation of maize prices, creating insecure markets (e.g. dismantling of CONASUPO), land tenure titling by Programme for Certification of Ejido Land Rights and Titling of Urban lots (PROCEDE) and in the last years the creation of Farmers Direct Support Programme (PROCAMPO) to compensate farmers for low maize market prices and generally used by farmers to purchase of chemical fertilisers (see Chapter 7). PROCAMPO has increased the use of chemical fertiliser by farming communities which is becoming a ‘secure’ way to produce maize by farmers. Likewise, in this period, policy reforms to *ejido* land tenure were made, allowing them to be converted to private property influencing land economic value and therefore, land management decisions.

All these changes in the political and economical sector have influenced land management in rural areas. Farmers started to sell their surplus through intermediaries, who paid lower prices. The incentive to invest in agriculture decreased as the value of the output decreased as land users paid high prices for fertiliser. For instance in 2005, a ton of maize was paid at £60 and price of ton of urea was £150. Also, migration and other off-farm activities increased during this decade.

In the Highlands, a monoculture of maize, inadequate use of fertiliser, shortage of young labour, migration and poverty are common problems faced by farming households. Farmers continue to invest more in their *solar* and/or private property than in *milpas*. Allocation of resources to *milpas* depends on changing political conditions, the implementation of rural policies and access to assets. Farmers are barely coping with this challenging context, which drives their decisions about managing their land. The historical context, legacy of land management practices and the influential drivers of their adoption are presented in Table 4.2.

The implementation of past technologies responded to specific drivers related to natural, political and socioeconomic systems. As observed, changes in land management have marked the characteristics of current strategies adopted by farming households. Today’s practices are a combination of indigenous, Spanish and *mestizo* traditions and foreign technologies.

Table 4.2 Land management technologies and influential drivers to their adoption

PERIOD	Pre-Hispanic Before 1519	Colonial 1519-1810	Independence 1810 - 1910	Revolution and Post-Revolution 1910-1939	Agrarian Modernization 1940	Lost Decade 1980	Commercial opening 1990-2006
Technologies	• Terraces-*maguey* • Infilling gullies • Capture sediments • Boundary vegetation • Stone wall • Ash incorporation • Intercropping • weeding • Fallow • *Chinampas* • *Coa* (hoe) based cultivation system	Indigenous technologies at HH level: • Boundary vegetation (*maguey*) • Intercropping • Capture sediments • Reduced construction and maintenance of their technologies Spanish technologies: • Manure • New crops (cereal) • Plough cultivation system	• Indigenous technologies followed at HH level e.g. *maguey* • Pre-war technologies e.g. Manure, Plough cultivation	• Partial adoption of indigenous technologies at HH level (slow process) • Similar scenarios in highlands as previous periods • New technologies (USA) • Chemical Fertilisers • Less manure • Use of tractors • Monoculture	At HH level • *Maguey*- hedges • Stone walls • Intercropping • Fallow • Ash incorporation • Plough *(hoe)* • Wealthy people (lowlands) • Chemical Fertilisers • Monoculture • Use of heavy machinery • Terraces	At HH level • Local technologies adopted in stages • *Solar* management intensified • Infilling gullies • Incorporation sediments • Boundary vegetation • Capture of sediments • Shorter fallow Promoted technologies: • Gabions • Terraces	At HH level • Adoption of local technologies in stages • Monoculture • Fertilisers • Hedge • stonewalls • Manure • Fallow • Plough (animals/tractor) Promoted technologies: • Gabion • Terraces • Intercropping • Change of crops
DRIVER	• High availability of labour • Intensification • Land tenure *Calpullis* • Political/economic Aztec power • LUT - *Solar* & *Milpa*	• Low availability of labour • Extensification • Livestock • European technology/crops • Land tenure • LUT - *Solar* & *Milpa* • *Mestizaje*	• Low labour availability • Land tenure lease of land (*haciendas*) • LUT • *Solar* HH better land management	• Poverty • Similar availability of labour • Changes in land distribution • *Ejido* land tenure • Agrarian modernisation cost • Use of fertilisers • New varieties • Markets • Incompatibility of new technologies with local management • Land reallocation	• Land tenure • Markets/costs prod. • Exportation cereals • More labour for production • Migration • LUT • Increasing population • Women participation • Cultural factors	• Economic Crisis • Cost subsides • fertilisers • Land Tenure • LUT • Seasonal migration • Part-time labour • Increasing population • Cultural factors	• Low labour availability • Migration young people • Production costs • markets • land tenure • Subsides • International pressure • Cultural factors

Source: compiled by the author from multiple sources used in section 4.2

4.3. The Mazahua community of San Pablo Tlalchichilpa

SPT, the chosen case study area (see Chapter 3), has experienced different periods of rural exploitation. It was settled by the *Mazahua,* one of the biggest indigenous groups in the State of Mexico, and later upheld by Spanish colonisation. The Spanish introduced plant and animal species and generated new practices of cultivating and ploughing including the incorporation of cattle manure in the soil, among others (Arriaga-Jordan et al., 2005). Although Spanish has been the mother tongue in the country since colonisation, the *Mazahua* people have managed to preserve their own *Mazahua* language.

Influences of the Mexican Revolution in SPT are not well-documented. However, the consequences of the revolution were far-reaching in affecting land tenure, agrarian commercialisation and agricultural techniques, and today SPT hosts a mix of indigenous, Spanish and *mestizo* societies that has shaped the development of farmers' livelihoods. Maize crops, agave hedgerows, strong social capital, the division of agricultural tasks, attachment to land and patriarchal traditions are some of the characteristics preserved in today's *Mazahua* society (Soustelle, 1993, Nava-Bernal, 2003, Chávez, 2007).

Since the 1980s the agricultural crisis and the constrained economic situation in the country have led to an increase in migration and changes in labour availability, affecting SPT farmers' households. Therefore a characterisation of households living in this community is essential to understanding their land management practices and specifically LaDC technologies. Chapter 3 gave a general overview of the characteristics of the study area. This chapter focuses specifically on the differentiation of attributes in sectors of SPT and LUT, using mainly primary data collected during fieldwork. The characterisation of SPT is an examination of the chosen variables to provide a setting on which the decision-making process of land management is built.

The study area is presented as two sectors: La Era and Centro (see Chapter 3). Considering farmers' claims about the historical and physical differences between these sectors, this study reviews the differences in the physical and socioeconomic aspects of La Era and Centro. Such differences contribute to the diversity of land management decisions and particularly those focused on LaDC. In view of the significance and legacy of LUT in land management in the Mexican context, this study differentiates the attributes of two LUT *solar* and *milpa* (the main agricultural LUT in the area) according to each sector. This provides primary data at the field level.

SPT is vulnerable to land degradation processes because of its mixed topography of valleys and hills, in particular, its soil erosion on the steep slopes. Maize, beans and oats are the main crops cultivated by farmers in this community. Water availability for crop production is restricted to 800 mm rainfall per year. This increases the vulnerability of crops to climate variability. Water availability may drive farmers' decisions on land management, particularly, adoption of technologies which contribute to maintain and/or increase soil moisture and improve maize production. In general, frost and severe drought are the most common threats to these crops. Unreliable rainfall, declining soil fertility and severe soil erosion have all contributed to low agricultural production. Hence LaDC practices have become important in this community (Walton *et al.*, 1998).

4.4. Land Characteristics

4.4.1. Soil Types

Because farmers are challenged by the constraints to farming their land, an understanding of the processes and elements involved is required in order to learn how they manage their resources. Chavez (2007)explains that farmers' understanding of the soil on their land is based mainly on physical characteristics of soil such as colour and temperature. This knowledge manifests in their practices.[55] Local soil classification in the study area is comprehensive and

[55] The value of local soil classification has been validated by scientific studies, especially in the ethnopedology field (Barrera Bassols 2006).

complex, as there are different combinations of soils which reflect the diversity of the soil attributes. Table *4.3* compares both local and FAO classifications of soils and their characteristics; it details soil characteristics associated with soil fertility and management and maize diversity.

The table presents in-depth data about soil categorisation and a general overview of the farming systems in SPT. However, the focus of the research is not the detailed classification of soils but the ideas behind the decision-making processes that determine how such soils are managed. Therefore the classification of soils is generalised to focus on six major and easily-distinguished soil types recognized by farmers: *arena* (sand), *pejo* (clay), *colorada* (red), *polvillo* (dust), *tepetate* (duripan) and *negra* (black), covering the predominant soils on each unit of land and occurring in or adjacent to the lands of most of the farmers in this study. This simplification enables a focus on contrasting soil attributes in La Era and Centro sectors and LUT and increases the statistical significance in tests employed later in the analysis.[56]

.

[56] The information about soil type and its distribution is based on a survey of 55 households in the La Era sector and 46 in the Centro sector. From the household, survey 91 plots are described and 100 corresponded to *solar* and 191 to *milpa* (see Chapter 3).

Table 4.3 Local understanding of soil, management and appropriate maize varieties for cultivation

Type of soil					Soil characteristics associated with fertility				Management and maize diversity	
Mazahua name	Phonetic	Spanish Translation**	English Translation	FAO classification	Colour	Texture	Temperature and Mazahua name for hot and cold	Capacity to hold moisture Mazahua name	Soil Improvement	Management
Pejo ‘T’shapo	Peho	Barro, Barreal	Clay	Haplic Phaeozem plus pelic Vertisol	Grey	Clay	Hot (ñinsse)	low (s’ojomü)	White sand animal manure	Ploughed and cultivated when dry. Seed sown in first rains (April-May). Maize: white, blue, pink, yellow and speckled.
B’ojomu, Bójomy	Bohomu	Barro negro, tierra negra	Black clay	Eutric Planosol plus pelic Vertisol	Black	Clay	Hot (ñinsse)	low (s’ojomü)	Animal manure	Ploughed and cultivated when dry. Seed Sown in first rains (April-May). Maize: white, blue, pink, yellow and speckled
Shi jai	Shihai	Tierra parda, colorada	Reddish and brownish-grey land	Haplic Phaeozem plus Molic Andosol	Reddish and brownish-grey	Sandy	Cold and hot	good (jojomü)	Animal manure	Ploughed and cultivated when dry. Seed sown in first rains. (April-May). Maize: white, blue, pink, yellow and speckled.
Xijomu, Shijomü, Shijomy	Shihomu	Polvillo	Fine dust	Luvisol and Phaeozem	Orange and brown	Silt	Cold (ñinpa)	low (s’ojomü)	Animal manure and inorganic fertiliser	Ploughed and cultivated any time. Seed sown before rains (March). Maize: blue, pink, yellow and speckled.
Mej□mu Mbajaomu, Nbajomy	Mehomme	Barro Colorado o rojo	Red clay		Red	Clay	Cold (ñinpa)	low (s’ojomü)	White sand and animal manure	Ploughed in first rains. Seed sown in first rains (April) or until June. Maize: blue, pink, yellow and speckled.
Dyonxomú	Dionshomme	Arenal con polvilla	Sandy soil	Chromic Luvisol plus luvic Phaeozem	Brown	Sandy	Neither hot nor cold	good (jojomü)	Animal manure	Ploughed and cultivated any time. Seed sown before rains (March).Maize: white, blue, pink, yellow, speckled
Ňonshomü	Nonshomu	Arena*	White sand		White	Sandy	Cold (ñinpa)	low (s’ojomü)	Clay soil or animal manure	Ploughed and cultivated any time. Seed sown before rains (March). Maize: white, blue, pink, yellow and speckled.
T´□xiro, Mëpeña	Toshiro	Tepetate	Duripan	Combination of Haplic Phaeozem and pellic Vertisol	Grey	Clay	Hot (ñinsse)	good (jojomü)	White sand	Ploughed and cultivated any time. Seed sown before rains (March). Maize: white, blue, pink, yellow and speckled.
		Tierra blanca con grava	White land and grava		White	Sandy	Cold (ñinpa)	low (s’ojomü)	Animal manure	Ploughed in first rains. Seed sown in first rains (April) or in June. Maize: blue and pink.

Source: Chavez (2007)

Table 4.4 shows how farmers describe the soil types and the places where the soils are commonly found. Key farmers explained that different types of soil are related to the erosion process. According to them, initially there is black soil (good quality and very productive) which is eroded to expose another type of soil; this may also be affected by erosion and lost, exposing other soils below. This gives rise to the prevailing idea in SPT that there is a sequence of soils resulting from degradation, starting with the best soil (black soil) and then inevitably and inexorably leading to progressively less productive soils.

Table 4.4 Characterisation of soil types by farmers

Soil Types	Characteristics described by farmers	Location
Arenosa (SAND)	• *This soil type is like sand, with little stones. It is not prone to erosion and it keeps humidity* • *It is like soil with white sand, it is not sticky, keeps humidity.* • *It is like nabo [Brassica rapa] seeds. Very good soil if it is mixed with manure*	Capulin
Pejo (CLAY)	• *This is a sticky soil, it is prone to floods and it sticks in your shoes.* • *It is often a grey soil. It is productive if it's mixed with sand* • *The pejo soil is located under the good black soil*	llano
Colorada (RED)	• *It is a red soil when wet like chewing gum. It is hot and it dries quickly. The water cut it [eroded it] and it becomes thinner. This is a hot soil and eats lots and is salty* • *It lacks of sand and vitamins*	Near gullies
Polvillo (DUST)	• *This soil is like flour and very thin, commonly found in the areas near forests*	Monte
Tepetate (DURIPAN)	• *This soil is very hard like rock but good to produce with manure.* • *It is the kind of stone that you can break [crumbles] and be converted into Milpa. It takes around 40 years of hard work.* • *It is hard and massive is grey, greyish, black or yellow, there are different colours*	La Era
Negra (BLACK)	• *This soil is black, it is like pejo and is prone to floods and it sticks in the shoes. There are different types of black soil, one productive and the other like pejo not so much.*	Llano

Source: Field data.

According to Mr. Leode (expert farmer), *Pejo* or *Polvillo* soil is found under *Colorada*, and under this, *Tepetate*, the last before the rock. It varies depending on the area. Mr. Leode considers that the top soil layers have been lost due to intense erosion in the past. In Illustration 4.1, he indicates the soil types in a soil profile during a transect walk in La Era. In addition tectonic processes have altered the landscape in SPT by bringing to the surface or burying soil horizons. Water erosion has modified the exposure of the horizons. These processes explain the combination and complexity of soil geography.

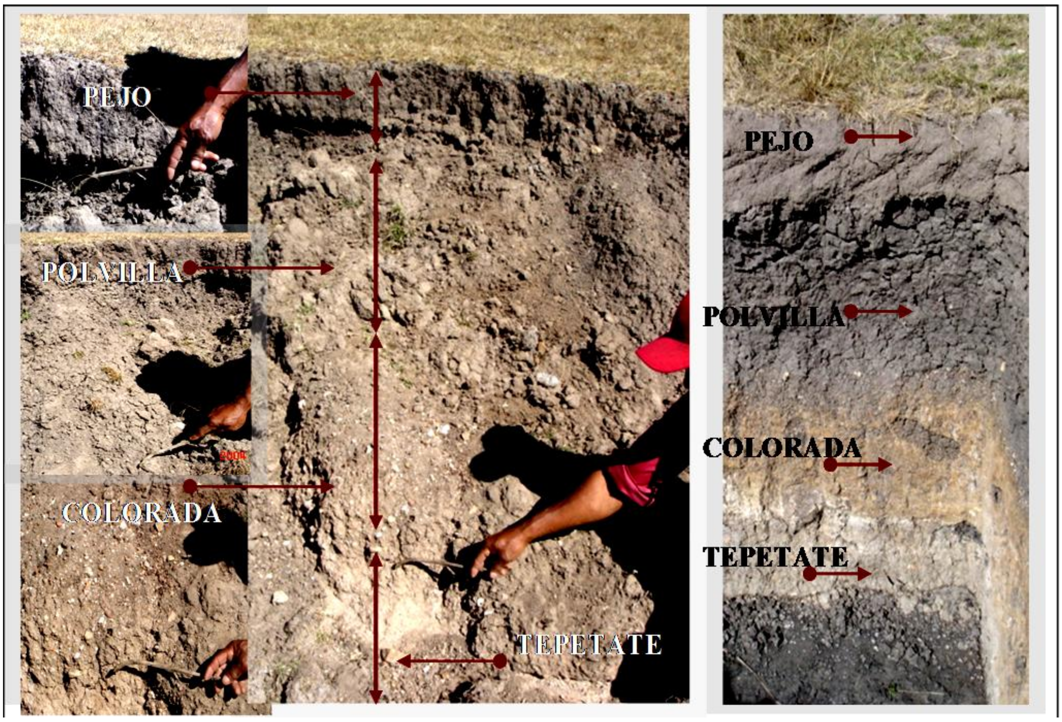


Illustration 4.1 Farmer Indicating Soil Types in La Era Sector

Source: Field data

According to classical scientific soil classification the local types of soil as categorised by farmers are more a differentiation of soil horizons. Each horizon presents specific physical and chemical features. The rationale is that farmers use the superficial horizon (no deeper than 50 centimetres) for agricultural production, and this is the one they experiment with and manage. The farmers' soil categorisation partly reflects horizons, so may not be exactly the same as local classification of distinct soil classes. In some cases the farmers' classification may describe level of soil degradation, possibly within one soil type. However, this research uses the farmers' categories as points of reference, as their land management depends on this local categorization.

4.4.2. Distribution of soil type per sector

Table 4.5 in showing the area of each soil types, gives a picture of the distribution of soils between the two sectors in SPT. Farmers living in La Era manage larger areas of land than in Centro, considering both *Solar* and *Milpa*. Proportion of area to *Polvillo* and *Tepetate* soils are statistically significant between the two sectors[57].

Table 4.5. Area extension of each soil type per sector in SPT

Soil Type	La Era		Centro		SPT area (ha.)
	(ha.)	%	(ha.)	%	
Arena	6.98	7.48	5.24	11.42	31.12
Pejo	24.60	26.35	16.67	36.33	103.95
Colorada	17.43	18.67	14.31	31.19	81.6
Polvillo	25.58	27.40	1.68	3.66	58.32
Tepetate	12.46	13.35	0.50	1.09	27.4
Negra	6.30	6.75	7.48	16.30	36.83
	93.35	100	**45.88**	100	339.22

Source: Field data

However, the area covered by different types of soils does not indicate any difference at the LUT level in which types of soil might be important attributes that determine specific land management activities. Therefore this research explores the distribution of soil types in the *solars* and *milpas* in the case study area.

4.4.3. Distribution of soil types according to LUT

Soil types in *solar*

Figure 4.1. illustrates soil types on both LUT by sector. In the case of solar LUT, there is a clear differentiation in the distribution of *Arena*, Polvillo and Tepetate soils. The statistical results indicate that the distribution of these soils (in number

[57] The test statistic **z** is called a test of homogeneity of proportions is employed to identify statistical differences between sectors as the number of cases in each is different in each one In number of plots *Arena* (Z=2.34), *Polvillo* (Z=5.09), *Tepetate*(Z=5.24) and *Colorada* (Z=1.97). There are significant statistically differences in area of *Polvillo* (z=4.238) and *Tepetate* (z=3.146) (at p<0.05)

of units and area covered) is significantly different in La Era and Centro.[58]

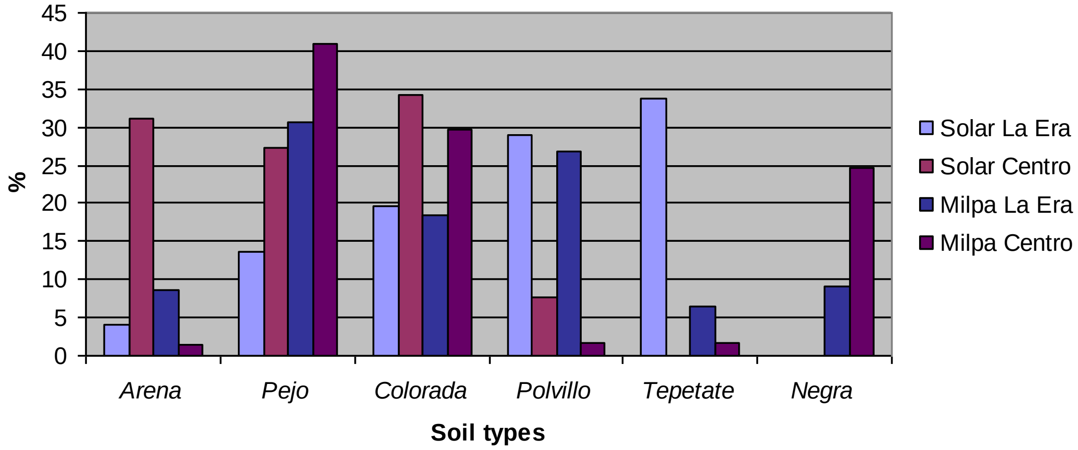


Figure 4.1 LUT soil types according to sector in SPT (per cent)

Source: Field data

The farmers claim that *Arena* is the best soil they can have. Farmers in Centro own more units of *Arena* soil, but more importantly they have a more of it in their *solar* LUT. This explains why farmers in La Era consider that those in Centro have better soils. Difference in *Polvillo* distribution is related to the location of forest areas; part of La Era, particularly the north side, limits with the line pine forest having more access to this type of soils. *Tepetate* are soils that have been degraded. According to farmers from Centro sector, *Tepetate* is considered a bad soil and not profitable to invest in. However, farmers in La Era cultivate crops on *Tepetate*. Some have constructed their homes on this soil as it is far from the centre of the community due to religion differences. Most farmers in La Era may have different units of *Tepetate* but they are small in area.

[58]According to statistical results there are significant differences $p<0.05$ between area of *solar* units in the following soil types: *Arena* (Z=2.16), *Polvillo* (Z=2.62) and *Tepetate* (z=6.91); results of test using number of plots of *solar* indicate the following significant differences: *Arena* (Z=3.71), *Polvillo* (Z=2.56) and *Tepetate* (z=5.41)

Soil types in *milpa*

As regards *milpa* LUT, statistical analysis indicates that *Polvillo* and *Tepetate*[59] soils present significant differences between sectors in number of units of production. However, *Polvillo* soil was found to be the only significant type when comparing area covered by soil types, as visually presented in Figure 4.1. The geographical distribution of *Tepetate* and *Polvillo* is common in La Era. Farmers here said that they are forced to work with such poor soils as *Tepetate* due to lack of access to better land. They have converted this type of soil into *milpas* in order to produce some crops from it. However, cultivation on *Tepetate* often covers only small areas, is highly labour intensive and offers few long-term benefits to farmers. People in Centro do not consider this valuable, hence the low use of *Tepetate* for *milpas*. *Polvillo* soils are associated with forest areas; some La Era farming households have a unit of land in forest. For farmers in Centro the distance to forest is greater, reducing their interest in using land in this zone. This empirical evidence suggests the need to explore the distribution of soil types at the LUT level as a factor relevant in LaDC practices.

4.4.4. Soil diversity

Diversification in farming households is a livelihood strategy. Greater diversity of physical attributes of land offers more options for securing household needs. Hence access to different soil types of soil may affect land management choices to a certain extent. According to the data collected, 61 per cent of households in Centro manage one soil type and 32.6 per cent, two soil types. In contrast, in La Era 22 per cent of farmers work land with one soil type, 42 per cent with two soil types, 22 per cent with three types and 14.5 per cent with four types. Restricted access to better-quality soils or their need to increase agricultural production could explain the farmers' rationale for diversifying their land types by working poor soils which is explored in the following chapter.

The average soil type diversity managed by farmers in La Era is 2.29 (one to four

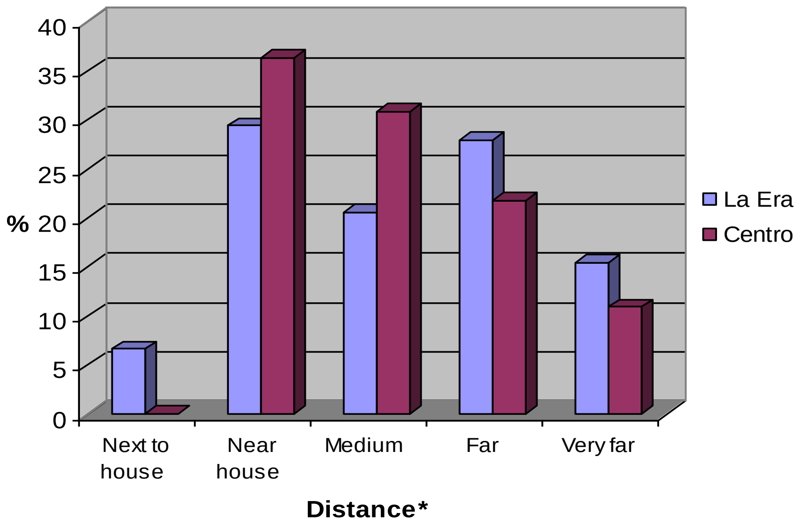
[59]Comparison of two proportion according to number of *milpa* plots: *Polvillo* (Z=4.63) and *Tepetate* (Z=2.89). Regarding to *milpas'* areas, *Polvillo* (Z=4.36) is the only with significant difference.

types) soils and in Centro is 1.47 (one to three types). According to the data on soil types in each LUT, Centro has a tendency to have *solars* on *Arena* or *Pejo,* which are regarded as more productive than the other soils. In La Era farmers have experimented with crops in the nearer units of land, increasing the diversity of the soil they work on.

4.4.5. Plot distance

Distance of unit of production to the farmer's house is an important factor influencing land management. The influence of distance is important in *milpa* LUT management. Five categories have been created to represent distance. Farmers mentioned how far each of their pieces of land is from the house according to their perception, using the categories: 1 = next to the house (0 km); 2 = near the house (0.5km); 3 = medium distance (1.0km); 4 = far away (2-4km); 5 = very far away (>5 km). However, distance is rescaled for visual purposes and better understanding of differences between sectors. The new scale is the square of distance. As illustrated in Figure 4.2, farmers in both sectors have *milpas* in the near or medium distance (0.5 to 1.5 km). Farmers in Centro have five percent less *milpas* near to their houses than farmers in La Era.[60] The research hypothesis is that the greater the distance the *milpas* from the farmer's house the less management will be needed regarding LaDC. This hypothesis is tested in the next chapters.

[60] *Milpas* held by farmers in Centro with *Pejo*, *Colorada* and *Polvilla* are near or in a medium range distance to their *solar*. In La Era farmers have *milpas* of *Pejo*, *Colorada, Arena*, Tepetate and *Polvill*o types in an average medium range. However, the black soils are located far away from their house location.



* Distances^2 is used for scale purposes

Figure 4.2 Distance of milpas from house by sector

Source: Field data

4.5. Socioeconomic characterisation

This study explores the manner in which farmers in from survey manage their land. In the case study three types of families were identified: nuclear families (52.5 per cent), extended families (23.8 per cent) and solitary (two to three members in the household) or single-mother families (23.8 per cent). Family structure plays an important role in land management decisions and is related to the household head, labour availability, migration and knowledge of agricultural tasks (see Chapter 3).

Frequencies of education, language and age groups are presented (Table 4.6). There are similar education levels between sectors. However, at intra-household level there are differences in education between family members which are statistically significant in both sectors.[61]

Spanish and *Mazahua* are spoken in SPT.[62] According to the results there is a slightly higher percentage of bilingual people in La Era and more Spanish speakers in Centro. In the last decades social discrimination and migration to urban areas have reduced the number of speakers of *Mazahua*. Spanish is systematically undermining the intergenerational transfer of traditional knowledge about agricultural practices, culture and local resource management transmitted in *Mazahua* language (Garcia and Ruiz, 2001).

Table 4.6 Education, language and age groups in SPT and per sector

Characteristics	**SPT**	**La Era %**	Centro %
Education			
No education	14.9	**17.3**	12.0
Primary incomplete	2.4	1.8	**31.0**
Primary completed	37.4	36.4	38.5
Secondary School	26.1	23.6	**29.2**
High School/College	14.6	14.2	15.1
Higher education	4.6	**6.7**	2.1
	100%	100%	100%
Language			
Speak Spanish/*Mazahua*	38.2	**43.8**	31.5
Speak Spanish/ Understand *Mazahua*	17.6	20.2	14.5
Speak only Spanish	43.7	35.4	**53.5**
Speak only *Mazahuas*	0	0.4	0.5
	100%	100%	100%
Age Groups			
8-15	28.2	24.5	32.8
16-18	7.0	6.6	7.5
19-30	16.6	19.3	13.2
31-50	21.5	17.0	27.0
51-65	17.1	22.6	10.3
> 65	9.6	9.9	9.2
	100%	100%	100%

Source: Field data

[61] Chi-square results show that there are no significant differences in education between sectors (X^2= 2.58, p=0.063). The data indicate that household heads and their partners did not go to school or have primary level education incomplete. According to farmers' opinions, usually "the younger or clever" boys used to go to the first years of primary school but they often stopped to work or migrate to contribute to the living expenses of their households. Mainly men had access to primary school, secondary school or technical college. However, most of them achieved only the first three schooling years of primary education. Nowadays each sector has its own schools for kindergarten and primary education, so boys and girls, are able to study from the age of 5. In–laws, relatives and other members of the household have a low level of education.

[62] Currently some people who are bilingual; others speak Spanish and only understand *Mazahua*; usually the youngest only speak Spanish and few old women speak only *Mazahua*.

Statistical analysis shows that there are significant language differences in the two sectors (X^2= 14.494, p=0.002). Generally households in which old people are in charge of agricultural practices and resource management do not expect remittances or use migrant labour, especially from young people, to carry out agricultural production and land husbandry. This has forced them to increase farming practices with a low demand for labour. Social networks such as family and the church are important in coping with vulnerability.

Religion

In Mexico the main religion is Catholicism (around 98 per cent of the population). Protestant churches are powerless and discriminated against in rural societies. SPT has both Catholic and Protestant churches – the latter mainly Baptist and Adventist. Catholicism is predominant in Centro (91.3 per cent) while La Era is mainly Protestant (80 per cent). In the last three decades, conflicts between *Mazahua* Catholics and Protestants have undermined important social network linkages. Current social support groups are more church-based than *Mazahua* indigenous networks. This study investigates whether such marked social differentiation may impact on land management and especially on choosing specific technologies for LaDC.

4.5.1. Labour availability

Households have an average of 4.4 members with a 2.09 standard deviation.[63] According to local culture in SPT, household members younger than eight are not usually involved in land management activities as these are not considered appropriate for their age. Thus children younger than eight are not included in either the characterisation of labour or the analysis of LaDC. Figure 4.3 illustrates the ages of family members in SPT by age group. Children and adults, and especially old people, provide the most available labour for household activities. Young people (16-18 years old) who can participate more actively in land management activities usually migrate to urban areas.

[63] The Chi square test shows that differences between sectors in family size are not statistically significant (at $P \leq 0.05$)

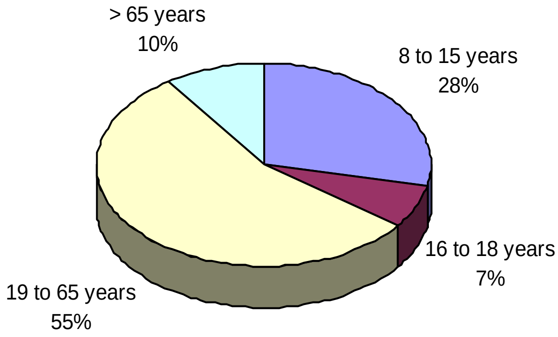


Figure 4.3. Labour availability in SPT

Source: Field data

According to the data, the age group 19-30 is the median in both sectors. In Centro, families have more access to young labour. In La Era, the 19-65 age group is the largest. This could mean more adult people's livelihoods depend on agriculture-related activities; therefore better land management could be expected.

However, age group distribution may provide limited information regarding access to labour. In rural Mexican areas, gender is an important factor that determines the roles of household members. Labour constraints are a significant factor in decisions regarding land management and conservation. Hence this study sought to capture the availability of labour that households can access for agricultural and land management-related activities. A potential labour index was created to represent the likely accessibility of labour (potential labour) per household for land management activities.[64] The weights used are

[64] The weights are decided considering farmers' opinions and observations during fieldwork. The weights given to households' members are according to age group and gender. For instance, women participate less in land management and therefore have a lower value than men; children and old people labour represent a lower value than adult males. Likewise boys (8-15 years) are full time at the school and male adults are working in farm or non farm activities. However, the labour of these groups could be accessed during certain short periods such as for preparing the land, weeding or the harvest. They may stop going to school or work for a couple of days or in holidays to carry out the work needed.

presented in Appendix IV.1. According to this index, both sectors have similar average potential labour availability at the household level (La Era = 2.62/household and Centro = 2.57/household). This represents approximately 2.5 male adults' potential labour per family. The distributions of labour per sector using the potential labour index are: La Era has 21.8 per cent of households with less than 1.5, 56.4 per cent of households with 1.75-3.0 and 21.8 per cent of households with more than 3.5. Centro presents 19.6 per cent of households with less than1.5, 58.7 per cent of households with 1.75-3.0 and 21.7 percent of households with more than 3.5. Table 4.7 presents percentages of potential labour in both sectors according to age group and gender. It shows that the La Era has the highest potential labour index among household members over 31 years old and boys of 8-15. This suggests that households in La Era could access labour from people with experience in land management practices (older people) which could be used more constantly (dependent on agriculture). In Centro the highest percentages are for males of 31-50 years, boys (8-15) and women (51-65). Centro households could access male labour from members who are prone to migration or are normally engaged in non-farm activities (in education, in the case of boys).

Table 4.7 Potential labour in SPT according to age groups and gender by sector

Sector	Centro		La Era	
Gender Age Group	Male (per cent)	Female (per cent)	Male (per cent)	Female (per cent)
8-15	17.4	3.4	10.7	4.7
16-18	7.6	1.7	3.6	2.4
19-30	8.5	4.2	4.9	7.6
31-50	21.2	8.3	12.5	12.0
51-65	6.8	14.0	11.1	10.4
>65	5.1	1.9	18.0	2.1
Total	66.5	33.5	60.8	39.2

Source: Field data

In terms of land management and LaDC practices, it was expected that the greater possibility of using male labour would mean better management and the adoption of different technologies as the participation of women in some activities is culturally restricted. The male and female potential labour indexes for both sectors are illustrated in Figure 4.4. There are visual differences in male labour between sectors; therefore this study looks for evidence to determine their influence in LaDC later in the analysis.

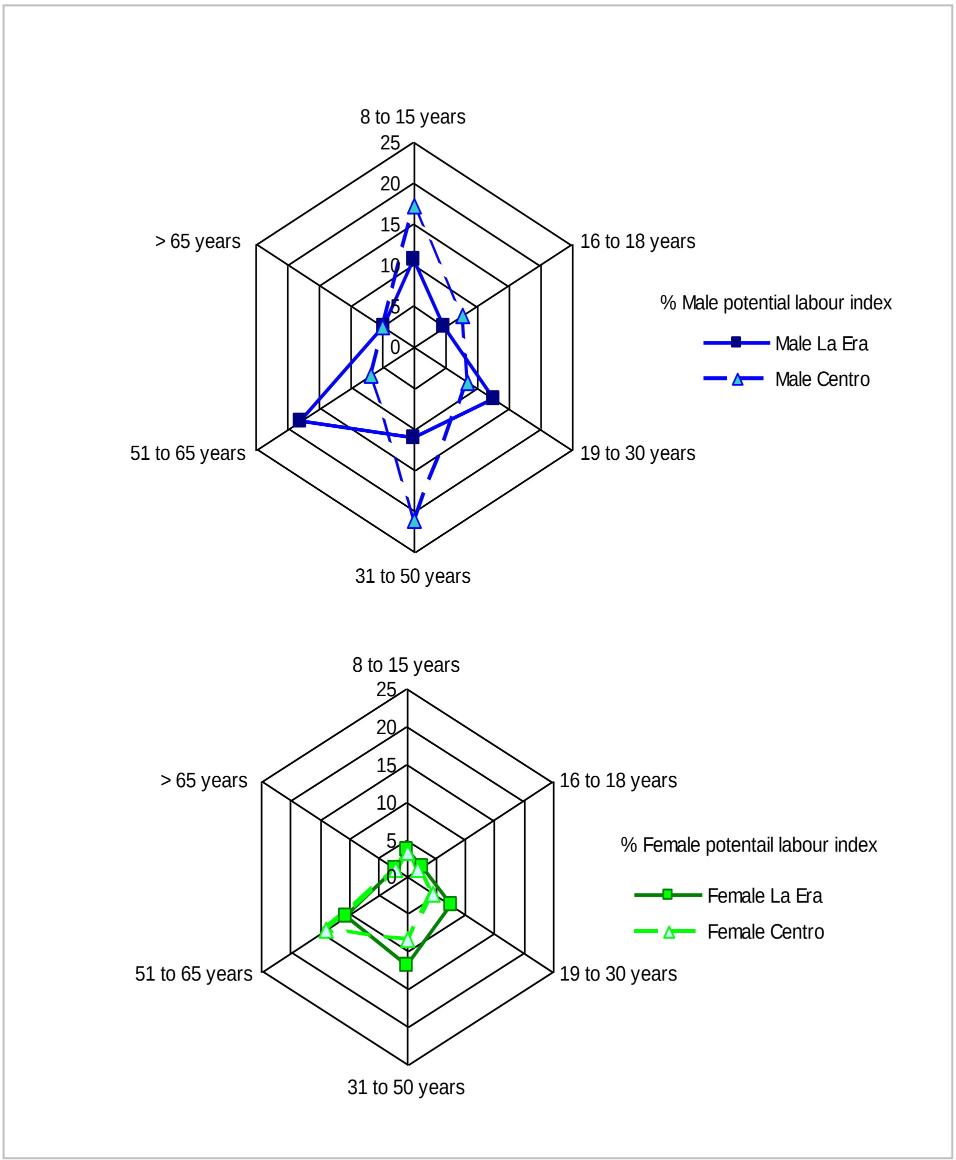


Figure 4.4 Male and female labour index by age groups per sector

Source: Field data

Household head

In rural areas of Mexico's Central Highlands men are traditionally the household heads. Migration and access to education have modified livelihood roles in each household. Nowadays it is common to find women heading their families as their husbands are migrant workers. Being in charge of the family means distributing and managing its capital, including land and crops. Cultural roles and traditions are being challenged as female household heads struggle with restricted knowledge about the land, experience, time and money, which may determine their choice of LaDC.

In the SPT community 33.7 per cent of households are female-headed and 66.3 per cent male-headed:[65] in La Era, 74.5 per cent are headed by men and 25.5 per cent by women. In this sector household heads follow a traditional pattern. In Centro males head 56.5 per cent of households and females,43.5 per cent. More women are household heads Centro than in La Era. This could be associated with men’s migration to urban areas and/or their not participating in on-farm activities. The age of the household head is relevant in the process of managing resources. Figure 4.5 presents differences in the distribution between sectors of household heads according to age group. As illustrated in the figure, 50 per cent of household heads in La Era are 51-65 years old and 19 per cent are over 65. This represents a scenario in which old people are in charge of household decisions which may be more associated with agricultural and land-related activities. Older household heads need to invest in and carry out agricultural activities as they are not able to migrate (there is no work available to them) and their livelihoods depend mainly upon their on-farm activity. Centro presents a higher percentage of younger household heads than La Era, with around 59 per cent of heads of households younger than 50. Young household heads may be interested in children’s education, access to money and migration. However 24 per cent of this sector has household heads older than 65 years old.

Therefore decisions related to LaDC may differ according to household heads’ gender and age, which may influence the decision-making process. Consequently exploring the characteristics of household heads is important in

[65] Of which 13.9 per cent of female household heads are in La Era and 19.8 per cent in Centro and 40.6 per cent of male household heads are in La Era and 25.7 per cent in Centro.

order to understand decisions regarding land management and LaDC, which are considered in the analysis in the following chapters.

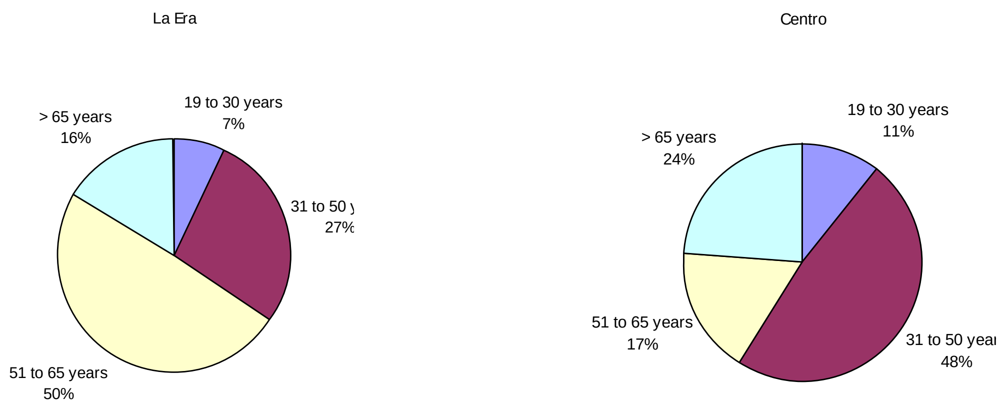


Figure 4.5 Household heads according to age groups per sector

Source: Field data

Occupation

Agriculture is the main economic activity in SPT. The majority of households depend on crop production to secure their food supply (e.g. for *tortillas* and fodder), but it does not cover all their living expenses. Therefore heads of families (usually old people, women, or illiterate members and children over 15) will look for paid work in on- and off-farm activities, and young people or people who have completed their primary education often take non-farm jobs.

Figure 4.6 shows the occupational categories of household heads in SPT. It is not distinguished by sectors as there is no significant statistical difference between occupational categories. The first category represents households dependent on agriculture-related activities (including the sale of surplus produce or livestock). The second includes households that depend on agriculture, off-farm and non-farm activities. The third category specifies heads of families who work in non-farm activities as, for example, painters, construction workers or shop workers. The main differences observed in the occupational categories are sale of livestock (not found in Centro) and household head with a constant extra income (more common in Centro)

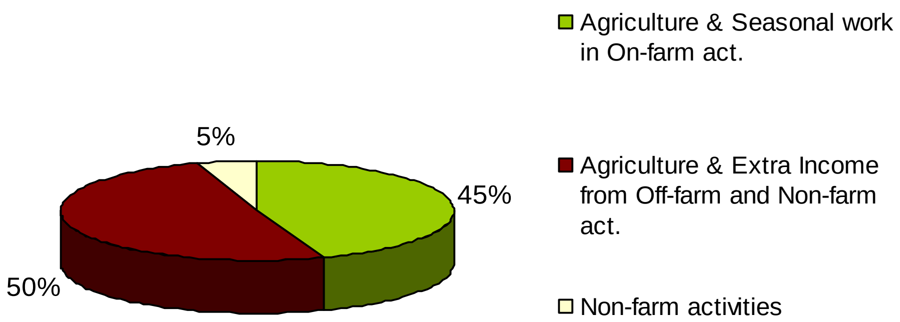


Figure 4.6 Household heads' occupations in SPT

Source: Field data

Taking into account household heads' occupation, a difference is expected in land belonging to farmers in categories 1 and 2, whose livelihoods are more dependent on agricultural production, and those in the last category.

Migration

The constrained economic situation in Mexico, the lack of policies to support farming activities and the low profitability of agriculture have all conspired to increase migration to rural areas. Arriaga-jordan *et al*. (2005) describe how the growing population, lack of land to pass on to children and subsistence agriculture have changed the rural landscape of the Central Highlands of Mexico over the last 50 years.

In SPT agricultural production has become insufficient to fulfil the consumption requirements of many households, leading to the out-migration of farm labour, mainly by men and young people, to urban centres such as Mexico City or Atlacomulco (Chavez et al., 1998, Garcia, 2002). Migration by at least one household member, male and/or female, to nearby cities to find paid work has become a common household strategy to secure a constant flow of cash, especially for younger members (15-30 years old).

The availability of labour for cultivation and land conservation practices is limited to children (older than 8 years old) and adults, and especially old people. Migration has influenced changes in agricultural systems. Arriaga-Jordan *et al.*(2005) highlight how the complex association of crops in the *milpa* system has moved on to a maize monoculture based on synthetic fertilisers and herbicides which require less labour. Migration strengthens the link between Mazahua households in SPT with wider society (ibid). This research suggests that migration modifies the roles of family members and households' decision-making processes which is tested in the next chapter.

Livestock

In the highland agricultural systems in Central Mexico and in *Mazahua* communities (Gonzalez et al., 1996a, Arriaga-Jordan et al., 2005) the animals most commonly owned by households are poultry, sheep and donkeys, cattle, and horses or mules for draught and pack purposes.[66] Manure is recognised as making an important contribution to small-scale agriculture. In general sheep and horses are the most popular sources of manure. In SPT manure is combined with chemical fertilisers. According to the survey data, 41.8 per cent of households in La Era own 7 to 15 sheep and 7.3 per cent more than 15 sheep, 69 per cent of own two or more heads of equids (e.g. horses or mules) and 35.5 per cent of have one or more heads of cattle. In Centro, 30 per cent of households have 7 to 15 sheep, 39 per cent of households own two or more heads of equids and 17 per cent own cattle (commonly one to two heads. So there is more manure availability in La Era than in Centro, which could influence farmers' decisions to apply it to the land.[67] Farmers stated that the manure obtained from their animals is not sufficient to cover all the plots they work on and therefore they prefer to use it on their *solars*, on plots of greater economical value or with private property tenure.

[66] Arriaga-Jordan et al (2005, p.840) describe that "men are the traditional owners of cattle, horses and mules: any member of the family may own any kind of livestock… Women are responsible for the *solar* and small stock and children help with these responsibilities".

[67] Poultry manure is not taken into account as the quantity and use do not significantly affect land productivity on farmers' plots. It usually is applied to ornamental plants and trees growing next to the house.

Production

Maize production varies according to LUT, therefore *solars* and *milpas* are compared by sector. Figure 4.7 shows total maize production (ton) in relation to total area (ha) hold by households according to La Era and Centro sectors.

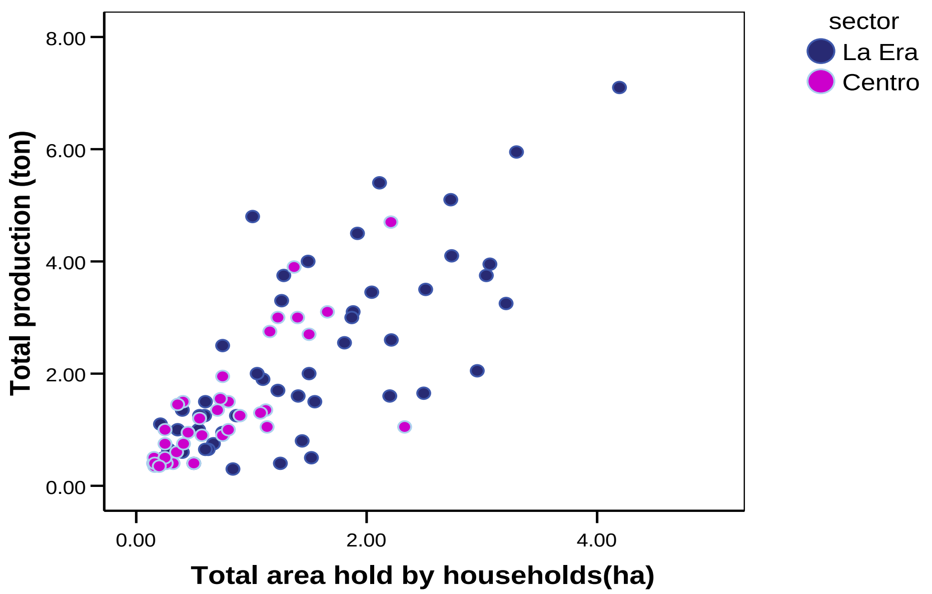


Figure 4.7 Relationship between total area held by households (ha) and total maize production

Source: Field data

Table 4.8 Maize Productivity (ton/ha) in *Solar* and *Milpa* per Sector

LUT	La Era		Centro	
	Maize production (ton/ha) mean	No. plots	Maize production (ton/ha) mean	No. plots
Solar	2.59	47	2.23	40
Milpas	1.5	127	1.96	52
Total	1.79	189	2.08	101

Source: Field data

Table 4.8 shows maize productivity between *solar* and *milpa* according to each sector. The data indicate that productivity is higher on the *solars* in both sectors.

This was expected, as *solars* have historically and culturally been subject to more intensive management than *milpas*. Farmers in La Era achieve slightly higher mean maize productivity on their *solars* than those in Centro. In addition, La Era has a higher percentage of older household heads who depend more on agricultural production and for which the *solar* may be an important unit of production. By contrast, farmers in Centro produce more on their *milpas*. Centro presents a higher mean productivity than La Era; however, this higher productivity could be related to the lower number of *milpas* per household in Centro than in La Era and the better soils in *milpas.*[68]

Currently the majority of households in SPT have access to government subsides such as PROCAMPO (to buy chemical fertilisers), Oportunidades (financial support for education, clothes and health for poor families)[69] and some have access to PET (Programme of Seasonal Work). In addition households may receive gifts or access to money through members' affiliation to political parties such as PRI and PAN.

Maize diversity

In the Central Highlands farmers cultivate various varieties of maize with different cob colours. Each colour variant has specific uses in the household and reasons for their cultivation on different units of land. Specifically, in SPT farmers generally manage five varieties of maize: *blanco* (white), *amarillo* (yellow), *negro* (black), *rosado* (pink) and *pinto* (mixed colours). Table 4.9 shows maize crop diversity per sector (considering only those pieces of land dedicated to maize production). As shown in the table, households in La Era manage more than one colour of maize in 50.5 per cent of their units of production in comparison to farmers in Centro with 32.2 per cent. This research expects that a higher maize diversity will encourage farmers to manage in different ways their unit of

[68] According to Sanchez-Tovar, et al (2004), maize consumption per capita is around 300 kg/per year. Mexico still produces 78 per cent of the maize it uses, with maize consumption 230 kg/per capita per year average (ibid). According to Dahlin et al (2005), under subsistence agriculture maize consumption is approx. 1 ton/ha per Mayan family of 5 members.

[69] In Oportunidades the payments are per family member and vary according to age, education level and occupation.

production and a greater variety of adoption of LaDC technologies.

Table 4.9 Maize colour diversity per sector

No. of maize's Colours managed by Household	Sector	
	La Era (%)	Centro(%)
1	48.5	67.8
2	32.3	24.4
3	10.2	3.3
4	8.0	4.5

Source: Field data

Land tenure

Land tenure is a factor commonly related to land management decisions. In SPT land is either private, *ejido* or communal property. In 1992, *ejido* tenure was changed to the equivalent of private property.[70] Households who hold the official title deeds to land might be encouraged to invest more in it than others who do not. If people own the land title it increases their security of land tenure and therefore their investment. It might enhance resource use, particularly soil conservation and fertility improvement practices. In SPT around 74.4 per cent of pieces of land are owned by household heads or their partners and 25.6 per cent of pieces of land are owned by their children or relatives or are rented. Generally there is a security of land titles by household heads which could encourage better and more intensive management of land. Land security could therefore influence farmers' decisions regarding LaDC practices.

Perception of erosion

One of the important factors in land users' choice of soil conservation practices is their perception of soil erosion. Where erosion s seen as a problem it may lead to greater adoption of LaDC practices on more of a farmer's units.[71] Out of 291

[70] Before the modification of Article 127 of the Mexican Constitution, *ejido* land was communal property used by a specific family who could work on it as long as they cultivated it: if not used the *ejido* was passed on to another family *Ejidos* could be inherited by children (especially male) and could not be sold.
[71] Farmers were asked if they saw soil erosion as a problem in their units of production during fieldwork.

plots, farmers considered that 40.5 per cent (118 plots) presented high erosion problems; 31.0 per cent (90) had medium erosion problems and 28.5 per cent (83) were unaffected. Farmers' perceptions were similar in both sectors. They commented that they will adopt LaDC *on pieces of land that need them, particularly on those where water cuts the soil*. This observation accords with the earlier finding that land users are more engaged with tackling the processes of erosion than they are with joining programmes of soil and land conservation (see Chapter 3). For example, constructions of gabions in gullies promoted by research and government institutions or plating of trees in agricultural fields (Garcia, 2002)

4.5.2. Households wealth proxy

Wealth is an important factor influencing decisions on rural livelihoods. Household access to and security of capital assets diversify choices related to the management of resources, especially land. For instance, poor households generally experience strong pressure on natural resources leading to degradation and impoverishment. On the other hand, rich households possess more assets and this research expects that rich households experiment more with their management if they have produced enough to feed their families. Wealth is relevant in decisions on land management as household livelihoods depend mainly on their agricultural activities. This study expects that differences in wealth may explain why farmers manage their pieces of land differently.

There are various perspectives from which to determine wealth at household level, from participatory approaches (e.g. ranking in the community) to economic calculations (e.g. monetary values of assets and incomes). Yet at the community level people construct a specific set of assets that determine household wealth. In general, there is an impression that rich people usually construct large modern houses of bricks or other materials; they may have a car or truck and a telephone.[72] In agricultural context there are other assets that may determine wealth. For instance, in SPT farmers usually consider that a family is rich if it has good land, animals and production to sell. This perception of wealth is influenced by economic activities, and social norms to some degree which may be distinct from a traditional economic measure of wealth. In this case, wealth's perceptions are shaped by the agricultural practices and social norms Therefore this research considers land, livestock ownership and production and adopts them as criteria to develop a wealth proxy which is in accord with farmers' perceptions. Taking into consideration the local view of wealth in SPT, a wealth score was created as a proxy for household wealth (see Appendix IV.2) based on three assets:1) Total land area (weighted by soil productivity); 2) Livestock (in tropical livestock units) and; 3) Total production (in tons).

These assets are essential to developing household livelihoods dependent on agricultural activities and are strongly linked to land management practices. Firstly, weighted land area gives a more real value of land. Secondly, livestock are an important asset as they represent savings or a source of income in rural communities. They have been converted to tropical livestock units (TLU)[73] in order to estimate total TLU per household. Thirdly, total production of maize per household is not capital but a production flow. It represents food security and access to cash flow when selling excess production. For instance, high production of maize will provide households with grain to be self-sufficient for a certain length of time and reduces forage expenses.

The minimum score of household wealth in SPT was 0.2 out of 15 points (the

[72]In this research, housing conditions, the economic value of land and access to services are not included for three main reasons. First, there is a lack of data about housing conditions or the economic value of land. Second, the money required to construct houses and acquire services is mainly obtained from access to remittances. Third, the market value of housing is uncertain, as there is no demand for this asset and the land tenure may not be clearly established. Therefore housing and services are not a clear indication of the quality and quantity of the natural assets possessed by farmers that impact on NRM, specifically of land. According to Morris et al. (2000) in rural localities of developing countries, housing markets are almost non-existent. Most residences are constructed using household labour and a mix of purchased and gathered goods. Consequently it is rarely possible to attach a monetary value to housing stock.

[73] According to SAGARPA (accessed in January, 2008) a head of cattle or equids is equivalent to 1.0 unit a head and one of sheep to 0.14 (SAGARPA, 2008). Poultry are not included they are temporal and morbidity changes every year.

poorest household) and the maximum was 14.3 out of 15 (the richest households). Mean scores of area (weighted), production and TLU and mean wealth proxy of households in SPT and per sectors are presented in Table 4.10, below.

Table 4.10 Mean scores of area (weighted), production and TLU and mean wealth proxy of households in SPT

Location	Wealth categories	Assets' scores (mean)			**Wealth proxy (mean)**
		Area (ha weighted)	Production (ton)	TLU	
SPT	Poor	0.7	0.6	1.1	**2.4**
	Medium	2.2	2.3	2.0	**6.5**
	Rich	4.6	4.6	3.1	**12.3**
Era	Poor	0.8	0.6	1.3	**2.7**
	Medium	2.4	2.4	2.2	**7**
	Rich	4.7	4.4	3.8	**12.9**
Centro	Poor	0.6	0.5	0.9	**2**
	Medium	1.8	2.2	1.6	**5.6**
	Rich	4.5	5.0	1.3	**10.8**

Source: Field data

At the community level, the mean wealth proxy values are: poor households (2.4), medium households (6.5) and rich households (12.3). The proxy score shows that there is different access to resources according to wealth category. The scores of assets are converted to equivalent real values of area (ha), maize production (ton) and livestock (TLU) hold by households in SPT. [74] The conversions of scores shows that at the community level poor households have access to less than 0.6 ha of land (weighted) and produce a mean of 0.7 ton; they own an equivalent of 2 TLU. Medium wealth households manage less than 1.7 ha with a production of 2.75 tons of maize and have a mean of 4 TLU. Rich households own more than 3.5 ha, produce more than 5 tons and manage 2 to 7

[74] The table presents the mean scores of the wealth proxy, the conversion is done by identifying the real values of production (ton), area (ha) and TLU of the general database which correspond to scores calculated.

TLU (there is higher variability of livestock holding within this category).

Households' mean wealth proxy in La Era and Centro sectors are slightly different. Households in La Era hold more land and TLU than those in Centro. TLU is higher in La Era in all three wealth categories: in rich families the driven asset increasing wealth proxy is TLU (equivalent to 7.8 units in La Era and 2.7 units in Centro). The main differences between sectors are found in the medium wealth households. In Centro families hold less land and fewer TLU. Land repartition and migration may have contributed to their managing smaller plots and having less time to look after livestock. The variability in wealth proxy among households here can mainly be explained by land extension and livestock. Differences in wealth could help to identify how choices related to land management are made where the availability of resources varies among households.

4.6. Socioeconomic landscape in land management decisions

The use and management of assets such as land, livestock and production at the family level are mainly decided by the household heads, whose education influences decisions about resource use. Literacy plays a role, increasing external inputs to local knowledge and driving choices of economic activities; availability of labour is another essential factor in carrying out specific uses of assets.

Linking assets such as land, livestock, production (used in the wealth ranking), the education of the household head and labour (illustrated by the potential labour index see section 4.5.1) provides a key asset base on which farmers' land management decisions are taking place.[75] Capital asset pentagons for poor, medium and rich households are constructed using tropical livestock units (TLU), total area of land (weighted) and maize production (ton) following the wealth criteria, pentagons include household head education categories (see Table 4.6)

[75] Education scores are: 0= no education, 1= primary not completed, 2= primary completed, 3= secondary, 4= high school/college and 5 = professional. Labour index see appendix IV.1.

and potential labour index (see Table 4.7). These five aspects are presented in order to display the context in which decision making occurs, particularly regarding land management practices (see Figure 4.8). The aim is to identify differences in the availability of assets that could influence land management decisions. Likewise, the pentagons help to appreciate access to education and demand for food and other needs, and highlight the vulnerability of households according to wealth differences.

As the figure shows, rich families in SPT present low levels of education as they are generally old people. Land holdings and production are high; livestock is variable. Labour varies per household but is not commonly high. Generally production area and production livestock are positively related. These families are food self-sufficient with the option of extra income from the sale of grain and animals.

The medium-wealth pentagon illustrates the diversity of access to assets in this type of family. There is a large number of families in this category. There is remarkable variability in their assets, which highlights the complexity of their decision making. The variability may be in response to movements between wealth categories: a rich family may sink to the medium category, a poor family scale up to medium or a medium household become poor (e.g. driven by changes in livestock holdings, selling off land). Both positive and negative associations among production-livestock-area are observed.

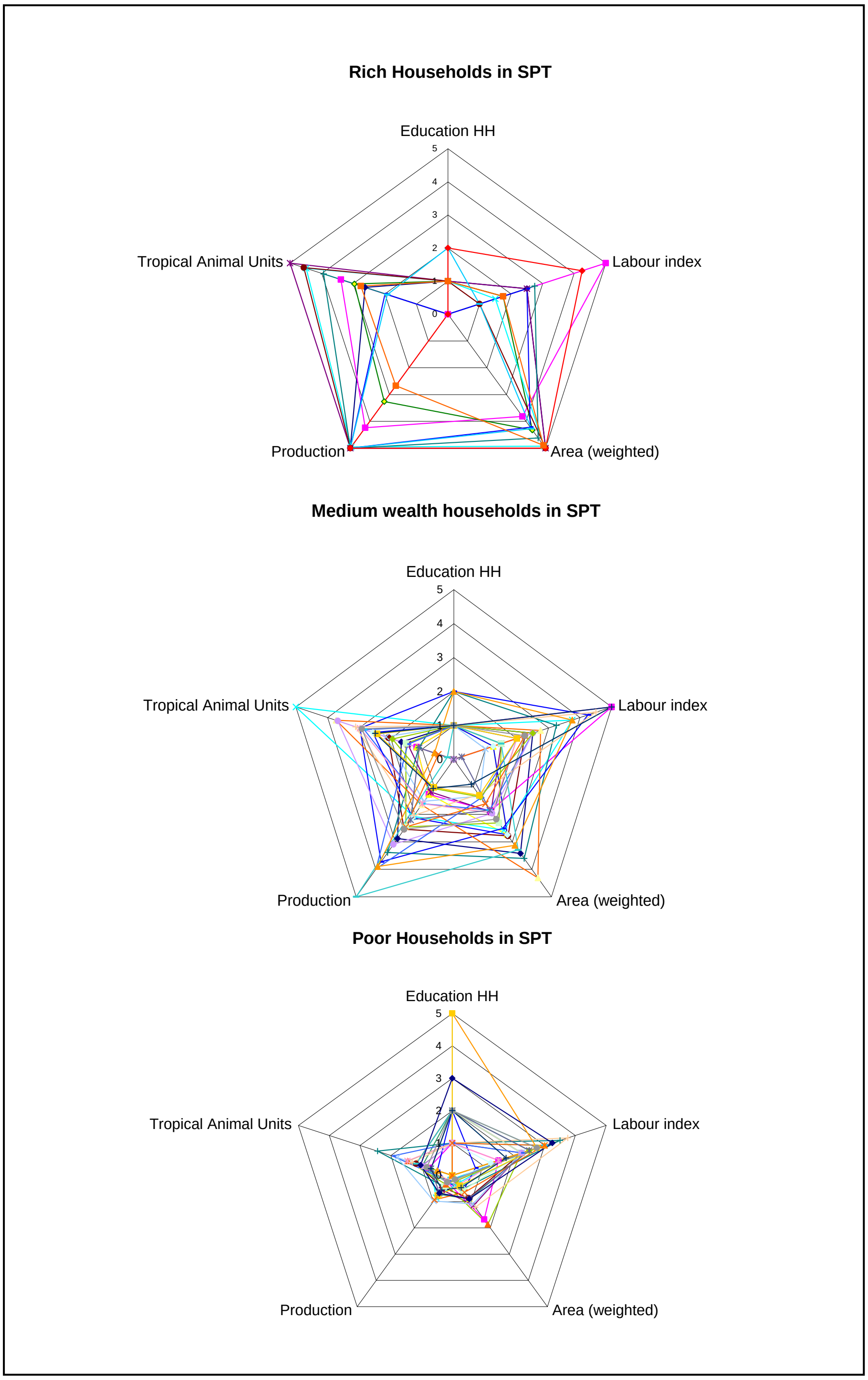


Figure 4.8 Capital pentagons according to wealth categories: Land management decision-making scenarios

Source: Field data

The poor households' pentagon shows the vulnerability of their livelihoods. Education levels are higher than in the medium or rich households, people have access to at least primary education. Labour is variable in this category. These families' livelihoods are not directly production-based due to their limited access to land and livestock. They are not food self-sufficient and depend on employment in non-farm activities and remittances. Land degradation affects the poor more than the rich. Degraded soils and declining production demand more resources from the poor. Socioeconomic and physical assets create a landscape that is driving farmers' choices to respond to land degradation.

As observed in the figure, unusual or contrasting scenarios are presented when linking education and labour of household heads to the wealth categories in the pentagons. For example, poor household heads with higher level of education than rich or medium household heads. This is due to the rationale of the wealth categories used which reflects a particular classifying typology associated with assets involved in the agricultural practices and to specific social norms of SPT. The typology may differ from traditional or more economic perceptions of wealth. This research employed this wealth proxy as it considered useful to better understand land management decision-making process.

4.7. Conclusions

The historical legacy of land use is fundamental in understanding current patterns of land use and engagement with systems of land degradation control. Through from the pre-Hispanic period of land use, to later systems of organising land distribution, the patterns of allocation of land, labour and other resources has influenced the present-day pattern of land use. The Highlands of Mexico are a valuable place to observe such legacies, environmental and social diversity, cultural complexity, biophysical challenges and decision-making process on farming livelihoods.

High prices of fertilisers, lack of markets for small producers, land degradation, subsides (becoming an instrument to obtain votes by political parties), migration, monoculture activities are characterising the current national context. This reality is shared by millions of Mexicans since it affects directly the agricultural and land management activities in the highlands. The fusion of knowledge, cultures, languages and the physical characteristics of SPT are intrinsically related to farmers' strategies to manage their natural resources, particularly their land. Data analysis at the field level is relevant to explore trade-off within households LUT. The socioeconomic and physical context is central to understand decision making on land management.

This chapter has shown how the geographical setting and historical context for land degradation are vital factors to determine how and why present land uses are constructed and how land users now face the challenge of contemporary land degradation.

Chapter 5. ‘Taking Care of the Land’: Farmers’ Responses to Land Degradation in SPT

Better a ruined than a lost land
(Proverb cited in Araya, 2002)

5.1. Introduction

As established in the previous chapter, the biophysical attributes and the socio-economic context and subsistence agriculture of SPT all combine to conspire that land is made vulnerable to degradation, especially through the processes of soil erosion. Land degradation, in turn, impacts back on farming livelihoods in a variety of ways and to various extents. As implied in the headline proverb to this chapter, ruined or degraded land can at least be restored; something well-understood by the farmers of SPT. However, responses to degradation are diverse, depending on the perceived effects, the land users’ knowledge, needs and available assets, and ethical and individual attitudes. ‘Taking care of the land’ is the aspect explored in this chapter, with a particular focus on the technological processes used by farmers to address their complex needs not only to restore land but also gain a living.

This chapter elaborates on the LaDC technologies taken up by farmers in SPT. Through the use of conservation technology summaries, the characteristics of adopted practices are described in detail. The next sections of this chapter illustrate the diversity and distribution of LaDC technologies within sectors of SPT and, particularly, differences in management between *solar* and *milpa* in LUT. Later, in order to understand the farmers’ decision-making processes, the biophysical and socio-economic factors influencing the probability of LaDC adoption are explored through a logistic regression model. Finally, technologies are grouped according to similar influential factors by using the cluster analysis.

5.2. Land degradation and 'taking care of the land'

This research focuses on the current decisions taken by farmers that directly or indirectly contribute to controlling or reducing land degradation. Nevertheless, an understanding of how farmers in this community recognize and respond to land degradation problems was needed before identifying the adopted technologies. Thus the scientific concept of land degradation[76] was introduced to farmers by the researcher during the interviews and during focus group discussions. This introduction was not to deny that farmers have an understanding of land degradation – they did and their understanding was sometimes quite sophisticated – but it was to capture their view and understanding of degradation in order to explore, in further chapters of this research, how they then used their understanding to make trade-offs (see Chapter 7).

Generally in SPT, farmers recognize the consequences of land degradation such as soil loss, decreased fertility and lower yields. They acknowledge how it affects their land. Farmers emphasise that they need to look after their land, protecting it especially from soil erosion, "water cutting land" and lack of nutrients or "vitamins" in the soil. They have responded – according to their perceptions of the problem – by adopting activities to reduce the impact of the problem or enhance better conditions (in the short or long term).

The phrase "taking care of the land" is referred to by farmers as the approach to controlling land degradation. "Taking care of the land" involves more than protecting solely the soil resources; it entails techniques to increase or maintain maize production. Practices adopted in order to "take care of the land" are embedded in agricultural activities (e.g. preparing the land for cultivation and incorporating nutrients and materials to enhance plant growth and soil quality). Practices dedicated to control soil erosion are often considered part of the agricultural activities (e.g. holes, ditches, hedgerows). The main goal of adopting

[76] Land degradation defined in its broad sense is the process that deteriorates (temporarily or permanently) the natural potential of land and its components (especially soil and vegetation), affecting productivity and future use (Stocking, 2002a; GEF, 2005)

technologies is to improve the quality of the land (*juajma*[77]) in order to obtain higher yields.

> Households link SWC [soil and water conservation] and the cropping systems with several other subsystems to fulfil their needs, rather than focusing only on SWC as outsiders often do (Beshah, 2003b, p.53)

Land degradation control is then part of a complex agricultural system developed by households in steep-slope areas through time. In this agricultural system, inherited land management techniques have shaped current practices (some can be traced back to the Pre-Columbian period), which have also been influenced by the transfer of local knowledge (intergenerational) and promoted technologies through governmental and research programmes. In addition to this context, farmers' decisions are dependant on their current perception of the problem, the availability of natural assets, socio-economic conditions and the perceived benefits of conservation. Taking into account these influential factors, the research investigates either the traditional technologies or the promoted practices adopted by farmers in SPT.

5.3. Land degradation control technologies

In the community of SPT, this research has identified seventeen technologies that farmers cite as contributing to their philosophy of "taking care of the land". Farmers regularly and consistently emphasised that technologies are focused on two main purposes: 1) fertility management – the enhancement of soil qualities such as nutrients, moisture and depth; and 2) control of soil erosion by means of mechanical or biological structures in order to reduce run-off and soil loss. However, each technology holds a more specific objective(s), which contributes to achieving the two general purposes. A special case was found for one technology, where the original main purpose was to increase the usable area of land. The seventeen technologies are presented in Table 5.1 according to their purpose (highlighting any specific objectives); their names are given in English, *Mazahua* and Spanish.

[77] *Juajma* is the Mazahua word for cultivated land, equivalent to *milpa* in Spanish.

Table 5.1 Land degradation control technologies

TECHNOLOGY'S MAIN PURPOSE	Specific objective	TECHNOLOGY NAME	MAZAHUA NAME	SPANISH TERM
Soil erosion control	Structural/ mechanical Short term	• Hole	*T'o oo*	Hoyo
		• Ditch	*Zanja*	Zanja
		• Mid-field earth bunds	*Sangradera*	Sangradera
		• Tied-ridges	*Tchit oo*	Tope
	Mechanical short term related to cultivation purpose	• Furrow design	*ñe ku/u*	Surco
	Structural/ mechanical Long term	• Stone wall	*En rro jo*	Cerca
	Biological/ Long term	• Boundary vegetation	*Kazaa ñaind nejuajma*	Besana
Fertility management	Increase soil moisture	• Arena-pumice incorporation	*A-re-ná*	Arena
	Incorporation of crops and weed residues	• Weeding	*Jeziraya/ pin yoo*	Deshierbar
		• Fodder residues mulching	*Shiyé*	Canuela
	Source of soil nutrients – From livestock – Inorganic nutrients	• Manure	*Máshara*	Estiercol/Lama
		• Fertiliser	*Abono/quimico*	Fertilizante
	Source of soil nutrients from other crops	• Intercropping	*Ra chamba*	Intercalación de cultivos
		• Crop rotation	*Ra potch pun*	Rotación de Cultivos
	Rest of land	• Fallow	*Rasoya*	Descanso de la tierra
	Reuse eroded sediments	• Sediment incorporation (Reinstating sediments)	*Ra picht pii*	Engruesar
Extension of land		• Infilling gullies	*Ra ni chi net'oo*	Relleno de Barrancas

Source: Field data, interviews and observation by the researcher

Some of the LaDC technologies mentioned by farmers are adopted each year such as short-term erosion control practices (e.g. ditch, holes, *sangradera*). However, other technologies were adopted one or more decades ago or have been adopted gradually over a long period and are usually maintained rather than being initially adopted (such as arena-pumice, infilling gullies or stone wall). Specifically, the enabling conditions presented when adopting these practices may have been different to current ones. However, farmers cited technologies previously adopted because they still obtain benefit from this type of practices which are relevant to their current livelihoods. The technologies are designed by farmers to achieve benefits and allocate assets at different periods of time (short to long term). This is central in understanding attached values and trade-offs (analysed in the following chapters), particularly those providing long term benefits which may have been excluded if farmers considered only those adopted in the year of the survey. Therefore, this research does not made differentiation regarding time of adoption of technologies as farmers did not express this distinction.

5.3.1. Conservation technology summaries

This section provides a detailed description of the technologies using conservation technology summaries. This type of summary has been employed successfully as a practical tool of analysis, originally used by Clark *et al.* (1998). It has similarities to the technology descriptions used in a major international project, the World Overview of Conservation Approaches and Technologies (2007), identifying the principal attributes of individual technologies that are successfully employed to control soil erosion and other processes of land degradation. The conservation technology summaries describe in a brief and detailed way the assets, time and methods that farmers use to control land degradation. The summaries illustrate how the technologies work, highlight the benefits and constraints generated from their adoption and capture other non-conservation benefits (related to secondary purposes), variations and relevant observations. This tool provides comprehensive descriptions of technologies which lead to a better understanding of their adoption and performance.

For the characterisation of technologies, the summaries are presented according to the technology's main purpose (see Table 5.1). Generally, one summary is constructed per technology, except in cases where practices share specific objectives (e.g. structural/mechanical short-term practices such as holes, ditches, *tope* and *sangradera*); they are included in one summary. The technologies are also later examined individually in the next sections of this chapter.

5.3.2. Fertility management – "improving soil through …"

Incorporation of Arena-pumice

Based on local knowledge and experience, farmers observe that when there is heavy rain, water cannot infiltrate the soil and erosion occurs. Soil erosion significantly affects the landscape by removing topsoil and changing the surface hydrology. Farmers also notice that arena-pumice sand helps to keep soil moist and say that *it is like a sponge which absorbs and keeps water*. Arena-pumice acts as an extra layer of topsoil (reducing run-off and protecting it from erosion), helping to reduce soil loss (see Table 5.2). The main application of arena-pumice is to increase soil moisture and improve yields. This practice has been widely adopted by farmers, particularly in the sector La Era.

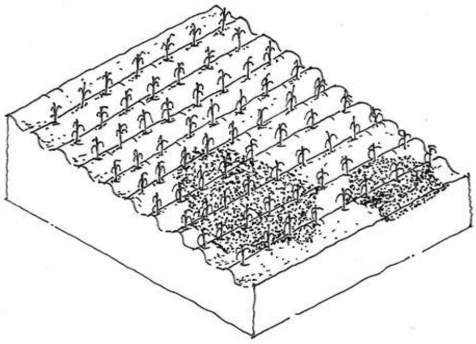
Natural arena-pumice deposits were once commonly found in the community; however, the main deposits are now located in forest areas some distance from the centre of SPT. This has affected accessibility to the deposits (in space and time), so farmers frequently mention that *there is no arena*-pumice *any more*. They perceive that it is difficult to find *arena*-pumice and that there is not as much 'sand' – the *arena*-pumice has a generally sandy texture - as in the past.

Table 5.2 Incorporation of *Arena*-pumice conservation technology summary

Local name:

Arena Blanca

Arena-pumice sand



Description:

The *arena*-pumice sand is collected from communal land (forest) and transported by animal traction in the early hours of the morning. This material is incorporated in places that show evidence of soil erosion or where farmers consider soil is thin, using wheelbarrow and spade. The incorporation is done before the crop season and so ploughing mixes it with the topsoil. The high calcium content of *arena*-pumice reduces soil acidity and helps to make other plant nutrients such as P and K more available to growing plants (Garcia and Ruiz, 2001). Farmers regard *arena*-pumice primarily for use in increasing soil moisture (highly porous material) and workability (changes soil texture to a more manageable one). The amount of *arena*-pumice used depends on farmers' needs and time availability. For instance, approximately 42 m^3/ha is incorporated by hand (equivalent to 30 journeys, for which farmers spend 3 hours per journey). This practice does not require any maintenance, but farmers can continue incorporating the material only if labour is available.

Variations:

This material could be bought and incorporated using trucks and hired labour. In this case, the amount of *arena*-pumice incorporated is 727 m^3/ha. Farmers believe that the quality of sand is similar to that from the communal land. *Arena*-pumice can also be applied in an indirect way. Farmers use *arena*-pumice as a floor for animal pens and they change it every year. The sand and manure is incorporated into the land (Chávez, 2007).

How does the technology work?

- A layer which absorbs and keeps water in the soil, which benefits crops.
- Barrier which reduces volume of run-off.
- Reduces the erosive impact of drops on the soil, and prevents soil from washing away.
- Reduces slope.
- Improvement of soil texture.
- Increased availability of plant nutrients (organic matter, phosphorus, calcium, potassium, nitrogen, magnesium (Chavez, 2007).
- Allows deep rooting.

Other costs and opportunities foregone	Non-erosion benefits/opportunities gained
▪ Excessive incorporation of *arena*-pumice reduces soil productivity, turning it into a sandy soil. ▪ Lack of organic matter reduces the soil aggregation process.	▪ Greater soil depth, capacity of soil moisture. ▪ Facilitates cultivation, as the texture is more manageable to work with a plough. ▪ Less labour to cultivate land and less use of fertiliser. ▪ Better growth of plants due to greater water storage and increase in yields. ▪ Increases land's economic value.

Other observations:
Labour to carry out this practice is exclusively male farmers, as deposits are located in isolated areas and it is usually transported at around 3-4 a.m. (for around 3 hrs per day for a month). Farmers prefer to apply this practice only on *solar* or fields near to their houses, as they are often the primary source of the household's food. Farmers point out that production is better with more *arena*-pumice on the fields.
Constraints on adoption:
The location of *arena*-pumice deposits may be some distance from the farmers' houses. Livestock and male labour are needed to carry the sand and incorporate it into the land. Lack of male labour and time required for transporting the material limits its implementation in *milpa*. Households with a lack of male labour or livestock are not able to adopt the technology even if the benefits are recognised. Also, it requires economic resources when farmers decide to buy the material and hire labour to apply it.

Weeding and Mulching

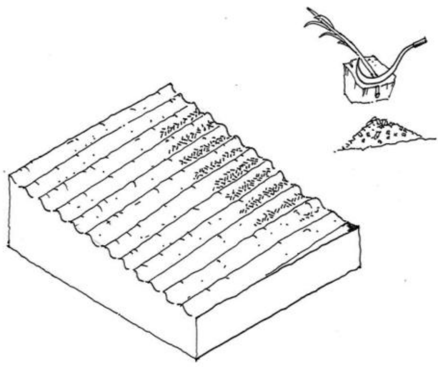
Local farmers make use of crop residues and weeds as a form of fertility-enhancing practice through keeping the biomass in the field and only lightly incorporating it into the topsoil keeping most of it on the surface. The two main ways of employing weeds and crops/fodder residues are through the agricultural processes of weeding and mulching.

According to farmers, weeding is one of the agricultural tasks needed to achieve good maize yields. The main purpose is to avoid competition between weeds and the maize plants (for nutrients and light). Farmers consider that weeds are harmful to the "*milpa*" (term referring to maize production). Nevertheless, farmers acknowledge the benefits of using weeds as green forage, green manure or human food. Specifically for this research, weeding is considered as a LaDC when weeds are cut and left as green manure to decompose in the *milpa*.
Canuela (Spanish) or *shiye* (*Mazahua*) is the term used for mulched crops/fodder residues which are incorporated into the *milpa* (see Table 5.3). This is an activity related to the management of residues (mainly from forage). However, it is when *canuela* is brought back to the *milpa* to discompose that it performs as a LaDC.

Table 5.3 Weeding and Mulching conservation technology summary

Local name:

*Canuela/ shiye/*mulching
*Deshierbe/*weeding



Description	
Weeding and mulching are technologies which contribute to improving the fertility of the soil by adding organic matter to the field in the form of cut weeds or fodder residues. **Weeding** is an activity needed to clear fields and reduce competition for nutrients and water when maize is grown. Weeding is done as frequently as possible during the week (at least for a couple of months or until the maize plants have "won" over weed growth). Moreover, it is carried out to obtain green fodder for livestock in the rainy season. Farmers cut and leave weeds (those that are not good for animal or human consumption) in the field between furrows or outside the field to degrade. **Mulching** uses the residues of fodder given to livestock. Farmers incorporate *canuela* between furrows to decompose. *Canuela* could be left at the side of each furrow to reduce soil loss around the edge of maize fields.	
How does the technology work?	
▪ When cut weeds and mulching are left in the furrows, they act as a barrier which reduces run-off, captures sediments and acts as an extra layer that protects the soil from erosion during the rainy season. ▪ A way of incorporating nutrients and organic matter to soils; according to farmers, they are like "juices of vitamins" to the soil. ▪ Retains and increases soil moisture.	
Other costs and opportunities foregone	**Non-erosion benefits or opportunities gained**
▪ Weeds can grow and compete with maize plants. ▪ Harbours pests and animals. ▪ Areas could retain too much water and damage crops. ▪ They could influence access to the land or make it more difficult to walk inside the *milpa*. ▪ Increases weeds for next year.	▪ Weeds left to the side of the field will be later used as a green manure during preparation of land. ▪ A way to manage waste. ▪ Improves crop production. ▪ Reduces the use of herbicides. ▪ Weeding provides seasonal household food as *quelites* (herbs suitable for consumption) ▪ Weeding promotes conservation of biodiversity.
Other observations:	
The majority of farmers consider weeding as an activity to look after the crops rather than land management. Mulching is associated with livestock; the residues of fodder are often carried by male farmers to the fields. In the *solar*, a woman or child could transport the *canuela* frequently. Mulching is not a widespread practice, as fodder shortage is a common problem in the community. Weeding provides households with seasonal food such as *quelites*, which are part of the rural Mexican diet and are important to conserve biodiversity. Unfortunately, herbicides have reduced the growth of these *milpa* products.	

Constraints on adoption:
Weeding is a labour-intensive activity usually carried out by women and children; therefore, its adoption is related to human or social capital. Usually, fields near the house have a better management of weeds. It is a time-consuming activity. If farmers have livestock the demand for weeds as green fodder increases and reduces the possibility of leaving weeds in the field. The use of herbicides restricts weeding activity. Farmers who use a fodder mill do not have access to *canuela*, and therefore they do not adopt this technology.

Manure and Chemical Fertiliser

Farmers value the enhancement of soil fertility and meet this in two ways: by incorporating chemical fertilisers (inorganic) or manure (organic). This research recognises that these two technologies work in different ways and provide different benefits, but for the purpose of the summary they are described together considering their specific objective (see Table 5.4).

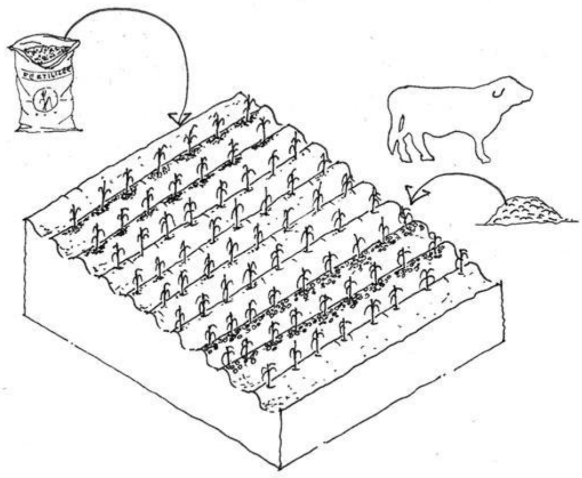
The perception of most farmers in SPT is that, "if you do not apply chemical fertiliser, the maize plant is not going to grow". They say that it is essential to invest primarily in fertiliser to secure production. Chemical fertiliser is subsidised by the Mexican government, which provides 1,120 Mexican pesos (£60 in 2005; £58 in 2011) per hectare of land cultivated[78]. It is seen as a modern technological advance.

Farmers highlight the advantages of using manure as fertiliser. They understand that its benefits last longer than inorganic fertiliser, particularly for increasing production. However, the high cost and scarcity of manure (not enough to cover all pieces of land and dependant on livestock ownership) makes it less viable than chemical fertiliser.

[78] Subsidies are not related to the quantity of fertiliser used (bags or kg); the amount is fixed per hectare of land cultivated by farmers.

Table 5.4 Manure and Fertiliser conservation technology summary

Local name:
Lama/estiércol abono químico
Fertiliser



Description

Incorporation of manure or chemical fertilisers to improve soil fertility and increase crop production. Manure is applied to fields dedicated to maize crops. Farmers collect manure from their livestock (e.g. horse, cow and sheep) over the year and store it in the open to decompose. If there is availability of manure or means to buy it, farmers incorporate it into the soil before ploughing in January or February (Arriaga-Jordan et al., 2005). Farmers carry it in a wheelbarrow or by truck (usually hired) to the field. They incorporate it into one part of the field and a different part the next year. *Mateado* is to the term for incorporating a small amount of manure at the base of each plant; this is adopted especially when manure is scarce. Preference is given to the *solar* or nearby pieces of land.
Chemical fertilisers (urea and 18:46) are bought in local markets and applied to each plant during the cropping season to increase production.

How does the technology work?

- Manure provides organic matter and nutrients to the soil, increases soil moisture, improves soil structure and aggregation and improves soil texture.
- Chemical fertiliser provides short-term nutrient benefits, increasing fertility for one agricultural period.

Other costs and opportunities foregone	Non-erosion benefits or opportunities gained
▪ Chemical fertiliser is expensive and may undermine natural soil fertility. ▪ Manure stored can harbour pests and increase health problems if located near the house (digestive infection). ▪ Space needed to keep livestock.	▪ Manure improves soil quality and workability of land in later years. ▪ Better crop production increases possibilities to sell maize and improve financial situation. ▪ Good way to manage animal waste (manure);and reduce cost of chemical fertiliser in the long term.

Other observations:

In around 90 per cent of land, chemical fertiliser is applied. There is a social belief that “without fertiliser there is no maize production”, therefore farmers are encouraged to use it, despite its disadvantages. Government subsidies are offered to buy fertiliser.
Farmers are fully aware of the benefits of using manure. They prefer cattle manure, as it lasts up to five years, and horse or sheep manure (up to three years). Provision of manure for the fields is an important contribution of their livestock.

Constraints on adoption:

Manure is adopted in around 55 per cent of plots (in this research), as its incorporation depends on livestock ownership. The main constraints in adopting this technology are access to manure in the quantity needed to cover the farmers’ land. Lack of male labour availability and means of transportation to move manure to other fields could influence its adoption.
Chemical fertiliser depends upon government subsidies and access to financial capital. Land where chemical fertiliser is not adopted is not dedicated to maize production, is distant, has high quantities of manure in the soil, is very small or is dedicated to other purposes.

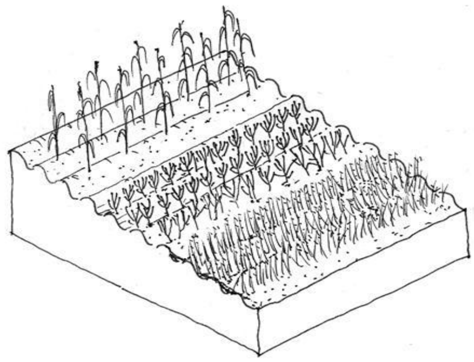
Intercropping and Crop Rotation

Serial and temporal crop mixtures such as intercropping or crop rotation are activities taken up by farmers in SPT to make available nutrients to soil through cultivation (see Table 5.5) and to diversify farmers' crops. Traditionally, farmers have mixed maize crops with beans and/or runner beans. These crops are the main ingredients in the rural Mexican diet. People state that "tortilla and beans are enough to eat"**.** This intercropping system has been the most popular in the Highlands since the pre-Hispanic time. In addition to this, pumpkins and legumes can be intercropped with maize.

After a period of continuous (at least five years) maize production on a piece of land, farmers cultivate alternative crops such as forage or cash crops for one or two years. Afterwards, they return to maize production, their main interest, and maintain this cycle for as long as possible. Farmers prefer to rotate maize with forage or cash crops as a way to save on fodder and generate an income from selling their crops in order to support their livelihoods. These two technologies work differently but for presentation purposes they are combined in the summary.

Table 5.5 Intercropping and Crop Rotation conservation technology summary

Local name:
intercalación de cultivos and
rotación de cultivos



Description

Intercropping (IC) and crop rotation (CR) are technologies which provide nutrients and biodiversity to the soil. Although different technologies, farmers recognize their benefits in improving the fertility of the land. **IC** is where maize is planted with other legumes such as beans, runner beans and pumpkins. They could be intercropped with maize or could be sown in a specific area of the maize field. **CR** is where maize is alternated with other crops such as ebo (*Vicia sativa*), avena (*Avena sativa*), green peas (*Pisum sativum*) or other available crops for one or two agricultural periods. It is claimed that rotation and intercropping improves maize yields in the following year and adds nutrients.

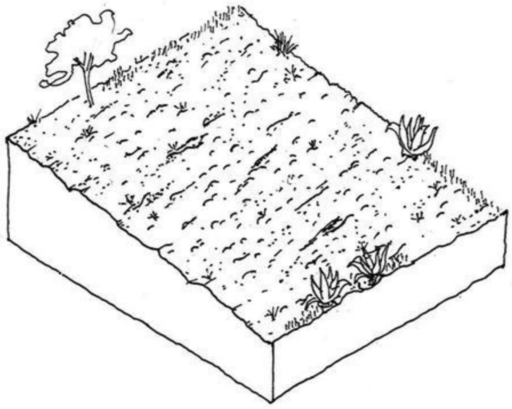
<table>
<tr><th colspan="2">How does the technology work?</th></tr>
<tr><td colspan="2">▪ Both technologies provide a source of soil nutrients (e.g. legume component enriches soil through nitrogen fixation).
▪ Nitrogen facilitates the soil aggregation process and improves soil structure.
▪ Both increase the humus content of the soil.
▪ Prevention of soil erosion, as there is good ground coverage (especially at the early stage of the maize crop when intercropped).
▪ Prevention of nitrogen loss from the soil.</td></tr>
<tr><th>Other costs and opportunities foregone</th><th>Non-erosion benefits or opportunities gained</th></tr>
<tr><td>▪ In IC, crops compete for water and light; they do not allow maize to grow properly; increase labour for weeding and harvest.
▪ In CR, there is no production of maize to eat or sell; temporal crops are susceptible to damage by pests or livestock.</td><td>▪ Income generation from selling different crops.
▪ Diversify family diet.
▪ Fodder for livestock (CR).
▪ Savings on herbicides and helps to control weeds (IC).
▪ Savings on weeding labour (e.g. money and labour) and fertiliser in CR.</td></tr>
<tr><th colspan="2">Other observations:</th></tr>
<tr><td colspan="2">IC has decreased in the last decade. One of the reasons is that it requires more labour for harvesting. Another is that farmers mentioned that runner beans and beans do not grow as well as in the early years. Therefore, they are designating a specific part of their land to plant these crops instead of intercropping with maize plants. CR is mainly done with forage to increase fodder for livestock, and in a few cases with cash crops. Some farmers prefer to change to temporary crops as a green cover to protect soil from erosion rather than leave it fallow.</td></tr>
<tr><th colspan="2">Constraints on adoption:</th></tr>
<tr><td colspan="2">In IC systems: lack of labour to sow and harvest; distance of plots is important, as in far fields people steal beans or runner beans; high cost of seeds or low availability (cash crops and forage) are limitations; dependant on access to other pieces of land for maize cultivation or to good storage for maize for consumption in that year.</td></tr>
</table>

Fallow

Typically, farmers leave land fallow to rest it from continuous harvesting (a practice traced back to Aztec times). Usually, specific pieces of land are left fallow if food production is secured to feed household members for at least one or two years. Farmers might be able to leave part of their land fallow in order to enhance soil proprieties and processes (e.g. aggregation and structuration). Nevertheless, leaving land fallow might be a strategy to cope with the lack of labour or financial capital (to pay for ploughing, harvesting labour and fertilisers) and low market prices for maize. In the main, farmers' decisions to leave land fallow are dependent on access to other pieces of land to produce maize (see Table 5.6)

Table 5.6 Fallow conservation technology summary

Local name: *Descanso de la tierra*



Description

Leaving land fallow is where fields are not worked for an agricultural period in order to allow the land to rest. This in turn will enhance soil processes and properties. It is usually adopted on pieces of land that are far from the households' houses or "tired lands". Nothing is cultivated for a period of one to three years, depending on access to other pieces of land and on "what land needs". Farmer may adopt this to improve soil fertility and reduce soil disturbance.

How does the technology work?

- When resting the land no tillage is done.
- Improves soil aggregation; helps to strengthen the structure of the soil.
- Helps retain moisture and nutrients; fertility restoration.
- Soil conservation, as land is not tilled.

Other costs and opportunities foregone	Non-erosion benefits or opportunities gained
▪ No crop production. ▪ Fields on steep slopes are easily eroded. ▪ Requires more labour to cultivate them for the next agricultural period, as land is more compacted. ▪ Greater presence of weeds.	▪ Saving in labour, fertiliser and other agricultural cost involved such as harvesting. ▪ Available field to graze livestock.

Other observations:

Leaving land fallow could be adopted in order to rest the land or to cope with a shortage of human labour and financial capital. If land is left fallow for a long period it suffers from soil erosion.

Constraints on adoption:

The main constraint is the lack of land. Farmers who hold a small area or few pieces of land are not able to adopt this technology, as their maize production may not be sufficient to cover the households' food needs. Another constraint is the need to work a hectare of land to have access to fertiliser subsides each year.

5.3.3. Improving and gaining more land through…

Infilling Gullies and Reinstating Sediment Technologies

Gullies are obvious features in the landscape of SPT. Deforestation, steep slopes and farming activities have increased their growth, affecting farmers' fields. It is common to find gullies on the edges of or within fields, reducing the area available for production. Farmers infill gullies mainly with sediment and rocks. During this process they level the field, form "provisional" terraces and construct barriers to reduce run-off. One of the most important reasons to undertake this practice is the need to increase the amount of land available due to a lack of space for agricultural activities. In addition, in certain cases, religious beliefs have been part of the reason for implementing this technology. For some farmers, converting gullies into productive land is an ethical aspect of their religious faith and internal motivation, as expressed by Mr Gonzalez:

> *Es la voluntad de Dios que al agua corte la tierra y haga barrancas, por eso mando al hombre para trabajarlas, rellenarlas y producir en ellas [It's God's will that water makes gullies on the land, but God also sent men to work the land and infill the gullies to produce on them] (quoted in Garcia, 2002).*

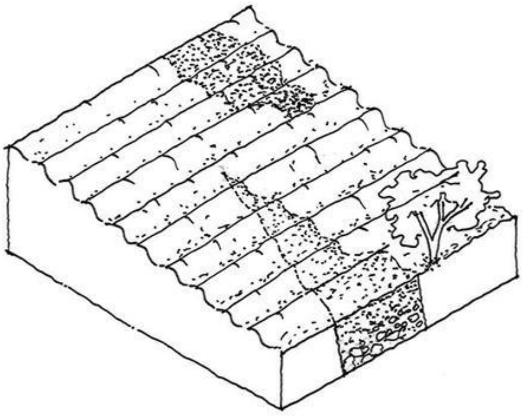
Reinstating sediments (RS) is a technology related to enhancing soil fertility. Farmers obtain sediments from the bottom of the slope, river sediments or from cleaning holes and ditches. Later, they reinstate the sediments into the field, especially where soil is "thin". This practice is illustrated with the infilling gullies summary, as it is one of the steps followed to cover the gullies, however sediments could be added to any field, even if not affected by gullies (see Table 5.7).

Table 5.7 Infilling Gullies and Reinstatement of Sediments conservation technology summary

Local name:

Relleno de barrancas

Engruesar la tierra



Description:

IG comprises two stages of implementation: 1) Construction of semi-structured piles of stones at the bottom and upper part of the gully, transverse to the slope, in order to retain sediments. 2) Reinstatement of material accumulated in sediment traps around the gully's edges to fill up the gully. Deposition of sediments and material continues until infilling is completed. Tools needed to do this work are basically spade, wheelbarrow, bags and pickaxes. Maintenance consists of reinstating sediments at least three times per year (material used to infill the gully is highly erodible). Levelling of soil is part of this process, which helps to reduce soil erosion and keeps the slope adequate for farming activities.

RS is a done especially where the soil is "thin" and less productive. The sediments could be brought from the same plot (captured through holes or ditches) or from rivers. Farmers consider the latter to be richer in "vitamins" and better for soils but requires more human labour and animals to carry it.

Variations:

Usually, the infilling is done by hand, but hiring a road machine to fill up gullies in a short time can also be done. This is feasible if financial capital is available (400 pesos per hour, and between four and eight hours are needed to infill the gullies). In RS, farmers may hire people to do this job, especially if they are women or the men are migrants. Incorporation of sediments is related to the maintenance of technologies such as holes or ditches.

How does the technology work?

- Re-uses the sediments collected in sediment traps.
- Reduces slope, which also decreases soil erosion.
- Increases both agricultural area and production.
- Changes gullied landscape to an agricultural one.

Other costs and opportunities foregone	Non-erosion benefits or opportunities gained
▪ Upslope part of the fields may have thin soil because of the extraction of material. ▪ Soil fertility could be low in the first years after infilling due to lack of organic matter in the filled areas. ▪ Susceptible to damage by erosion.	▪ The area increased depends on the gully's size. ▪ Filled area can be used to sow crops, increasing production. ▪ Lower-angle slope facilitates farming activities. ▪ Easy ploughing and land management. ▪ Long-term improvement in soil quality. ▪ Land may be sold or leased at higher price. ▪ A means of attracting subsidies for crops.

Other observations:
Usually, stones are brought from communal land by animal traction, using household or hired labour. Construction and maintenance is primarily a male occupation done by farmers. The maintenance is essential to avoid water erosion, so that water does not continue to erode the field.
Constraints on adoption:
Farmers do not have enough time to reinstate sediments, especially in the rainy season. Thus the slopes are prone to soil erosion. Infilling by hand takes around 15 years to complete, therefore the benefits are long term. In addition, lack of financial capital is a constraint to hiring a machine to IG in other fields and consequently has the benefits of these practices in the short term.

5.3.4. Controlling soil erosion and loss (long term) by…

Boundary vegetation

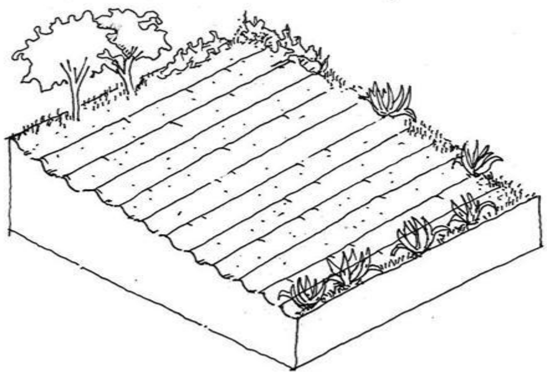
Planting boundary lines of vegetation on the sloping highlands of central Mexico has been a traditional practice by indigenous and rural groups since pre-Hispanic times[79]. In particular, *maguey* (*Agave* spp.) has been the most common species used in hedges, which has been an effective way to retain soil[80] (see Table 5.8). Maguey is a plant with diverse uses, such as making *pulque*, a traditional and popular alcoholic drink that has been a basic part of peoples' nutrition and culture in rural central Mexican areas (Nava, 1999; Guerrero, 2000; Chavez 2007). Nowadays, *maguey* has been replaced by fruit trees or grass in hedge management.

[79] *Maguey* (Agave spp.) or *Melt (in* Nahuatl) on indigenous terraces helps to prevent soil erosion, capture sediments, increase soil depth and maintain moisture on the hillsides (Whitmore and Turner, 1992).

[80] Nopal and maguey are two species that play an important role in the management of soil and water in steep slope areas in Mexico. The particular anatomy and distribution of their roots make a 'net' in the soil at a shallow depth, they hold water of rainfall, keeping soil particles together, avoiding erosion. The area on the surface reduces to the minimum transpiration, and the efficient use of water in the vegetal tissue ensures production is high.

Table 5.8 Boundary Vegetation conservation technology summary

Local name: *besana*



Description:

A live fence, acting as a barrier to sediment movement down the slope and forming a support for the accumulation of soil. Usually a line of *maguey* (*Agave* spp.) and/or fruit trees such as *ciruela* (plum) (*Prunus domestica* L.), *capulin* (cherry) (*Prunus capuli* Cav.), *durazno* (peach) (*Prunus persica* L.) or *manzanas* (apple) (*Malus domestica* Bork) are planted along field edges, especially on the downward slopes, which are prone to soil erosion. The plants are usually spaced one metre apart depending on the farmer's preference. Fruit trees can be planted in the middle of the field (following promoted technical advice from SEMARNAT in 2001. The vegetation is usually planted in fields near to the farmers' houses. Maintenance consists of irrigating the plants at least once per week and protecting them from animals. When plants are grown, farmers need to prune new growth, cut down dead trees and re-plant new ones to keep up the fence. The boundary vegetation does not require later irrigation and is not labour-intensive. Fruit trees are preferred in the *solar* and *maguey* in distant fields.

Variations:

Bush, wood trees and grass are also planted as boundary vegetation. However, the latter two are used less often because they involve extra-costs. Planting can be done in the bottom or upper parts of the field.

How does the technology work?

- A permeable barrier, trapping sediment but allowing water to pass through.
- Barrier which reduces volume of run-off.
- A vertical support against which up to 0.5 m depth of soil accumulates.
- A source of organic material from falling leaves or pruning; soil quality improved.

Other costs and opportunities foregone	Non-erosion benefits or opportunities gained
▪ Space taken up by hedges is not available for crops. ▪ Competition for water and nutrients between hedge and crops (especially with *maguey* and fruit trees). ▪ If plants grow with no attendance, they can make access to the land for ploughing difficult. ▪ Can harbour pests and other animals which damage the crops. ▪ Social implication, as farmers need to look after their trees to avoid fruit or *maguey* being stolen.	▪ Vegetation marks field boundaries, dividing pieces of land informally. ▪ Protects crops against animals. ▪ Fruit can be consumed by households (saving) or sold to generate income. ▪ A charge can be made to extract pulque from the maguey, generating income to households (selling each maguey plant). ▪ Farmers like hedges as part of the landscape. ▪ Less labour to protect the soil available for cropping season.

Other observations:
Men and women share the labour of planting and maintenance of boundary vegetation. However, men prefer to maintain the living fence because they can decide which plants or landscape they want to see. Children also participate in pruning once per year. Religious beliefs influence the use of *maguey*. In the case of fruit trees, planting is by men and the maintenance is mainly women's occupation. Maintenance consists of irrigating trees at least once per week when initially planted. Farmers like peach and apple, which contributed to the adoption of the technology. Ornamental and medicinal plants can be part of hedges mainly in the *solar* LUT, where women decide which plants to cultivate and where to plant them in order to have easy access to them (Chavez 2007).
Constraints on adoption:
Lack of time, labour or interest may limit the adoption of this practice in other fields. Moreover, hedges located far away from farmers' households are prone to be damaged by animals or are likely to be stolen by people, particularly if hedges contain fruit trees. Some farmers are not interested in the practice because trees obstruct access to the field to plough with animals. In addition, trees provide a wide shade that prevents sunlight reaching part of the plots (which may affect crop growth).

Stone walls

The stone wall has been a traditional soil conservation practice of the *Mazahua* indigenous groups since the early pre-colonial period (Blanquel and Hernández, 1999). Farmers comment:

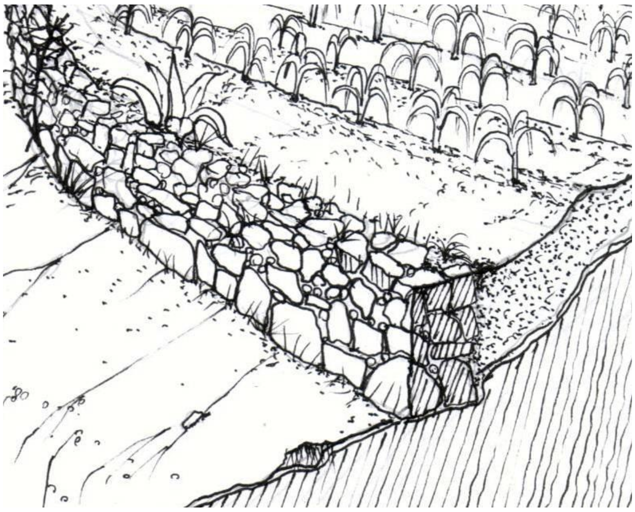
> *My father used to sell things in other towns, he walked for several days from place to place and he was picking up stones on the road, then he brought them home to make its cerca [stone wall] (Mrs Carmen).*
> *I used to go to the riverbank to pick up rocks and take them [stones] to my field to construct a cerca [stone wall] (Mr Oscar).*

One of the main objectives of building a stone wall has been to delimit land boundaries. Likewise, this practice has been regarded as an effective way to avoid soil loss (by retaining sediments in the field) and protect crops (see Table 5.9). For that reason it is still being adopted with effective results for soil conservation (Garcia, 2002)[81].

[81] Its adoption has also been documented in Ethiopian sloping environments as a common practice to conserve soil and delimit fields (Okoba and de Graaff, 2005).

Table 5.9 Stone Wall conservation technology summary

Local name: *Cerca*



Description:	
A stone wall acts as a physical barrier transverse to the slope at the bottom edge of the field. This wall retains sediments transported by erosion from the upper slopes. Stones to construct the wall are brought from communal land using animals or carrying them. Farmers choose stones of regular sizes to avoid removal. The length of the stone wall depends on the field's area. However, they are usually 1 m high and 0.6 m in width. The maintenance consists of replacing removed or damaged stones and taking out useless plants that could grow on the wall.	
Variations:	
Stone walls are usually smaller in fields far away from farmers' houses and they are constructed with small stones in a semi-organised way. It can be constructed using cement to last longer and reduce maintenance. Some stone walls are built on lateral edges but the purpose of these is more related to marking a boundary than conserving soil.	
How does the technology work?	
▪ A barrier where sediments accumulate. ▪ Barrier which reduces volume of run-off. ▪ A vertical support against which up to 1 m depth of soil accumulates. ▪ Reduces slopes. ▪ Reduces soil loss.	
Other costs and opportunities foregone	**Non-erosion benefits or opportunities gained**
▪ Space taken up by a stone wall is not available for planting. ▪ Do not offer organic matter to the soil. ▪ Good soil buried against the wall and unavailable to growing plants. ▪ Could make access to plough the land with horses more difficult. ▪ Can harbour animals, which damage the crops. ▪ Less soil depth on uphill parts.	▪ Mark field boundaries. ▪ Protect crops against livestock. ▪ Greater accumulation of sediments and more considerable soil depth downhill. ▪ Less labour to protect the soil needed for the cropping season. ▪ Can help access to fields on steep slopes. ▪ Provides a place to put stones from the fields, and to dry weeds for composting. ▪ Increases land's economic value.

Other observations:
The construction and maintenance are the responsibility of male farmers. The stone walls are observed mainly in fields near to farmers' houses to mark the boundary with other fields. If stone walls are unattended and fall down into other fields, this may generate problems with neighbours. Farmers who managed to adopt this technology are recognised as good land users. Migrant households hire labour to construct stone walls around their land to delimit their property, but more for an aesthetic reason than for conservation.
Constraints on adoption:
Stone walls have not been adopted in all fields because the time and physical and human capital are limited to transport stones. In addition, some fields have been or will be distributed among family members. Therefore, they cannot construct the wall until farmers finish the partition of the land.

5.3.5. Controlling soil erosion and loss (short term) by …

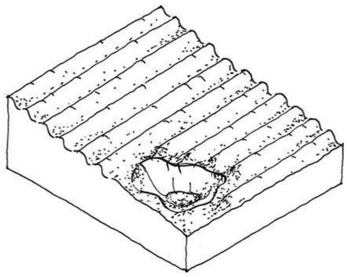
Hole, Ditch, *Tope* (tied-ridge) and *Sangradera* (mid-field Earth Bunds) Technologies

During the rainy season, farmers know that run-off will remove sediments from their land on sloping fields, which is then lost for immediate productive purposes. Therefore, farmers adopt technologies which focus on reducing run-off, capturing sediments and retaining water such as *Hoyos* (holes), *Zanjas* (ditches), *Tope* (tied-ridge) and *Sangradera* (earth bunds in the middle of the field) (see Table 5.10). These are short-term practices usually carried out each agricultural year. They help to reduce soil lost *in situ* and gain sediments from upper fields. Holes and ditches are very popular, as they require little labour. *Tope* and *Sangradera* are less commonly used. The first is focused on reducing run-off and harvesting sediments and water in the field. The second is done in order to reduce run-off and then divert water flow outside the field. Its name is derived from *sangre* (blood) and could be translated as "blood drain", referring to draining the water.

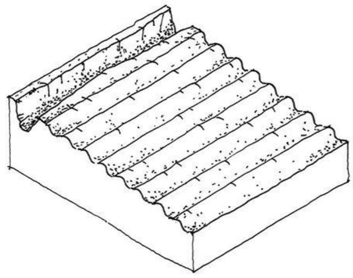
Table 5.10 Hole, Ditch, *Tope* and *Sangradera* conservation technology summary

Local name:

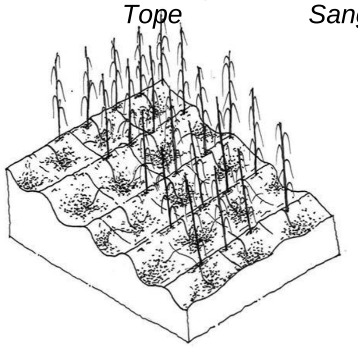
Hoyo



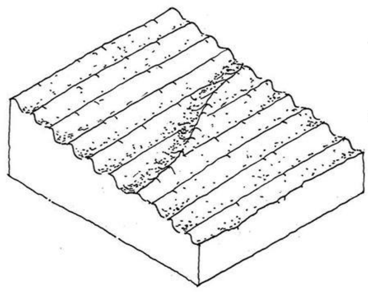
Zanja



Tope



Sangradera



Description

These technologies are physical structures designed to reduce run-off and to retain sediments transported by water erosion in the short-term. ***Hoyos*** **(Holes)** are usually located at the bottom of the field; one to four can be dug in one piece of land depending on the slope. ***Zanjas*** **(ditches)** are dug in the upper part and the length and width depend on the need to reduce run-off or capture sediments from the upper fields. They are a long narrow rectangular shape. ***Sangradera*** is a channel to divert water and sediments to holes; they are constructed in the middle of the field transverse to the slope. The design of *sangradera* requires local specific knowledge of the places where soil is prone to erosion, soil type and slope of the field. Holes, ditches and *sangradera* are to retain sediments "outside" the field. ***Tope*** is a less adopted technology which consists of small holes transverse to the slope located between furrows like "brick lines" to reduce run-off and capture sediments "in the field".

Tools required to adopt these technologies are basically spade, wheelbarrow and pickaxe. The maintenance of holes or ditches consists of cleaning (removing sediments) at least once per year. *Sangradera* and *Tope* do not need maintenance; they are constructed once every year (if the field is used for cropping). All the technologies are adopted in units of land where maize crops are produced. These technologies control soil loss while other long-term options could be adopted later.

Variations:

The design (including size, length, depth and width) of each structure will depend on the steepness of the slope, soil type and labour availability. Therefore, their adoption varies according to each household and on each piece of land. For instance, in the case of lack of labour, farmers may dig smaller structures or they could hire labour to do these jobs within one or two days.

How does the technology work?

- Structures reduce the speed and volume of run-off within fields.
- Places where sediments and water accumulate.
- Reduces soil loss on each farm.
- Greater accumulation of sediments from other fields.

Other costs and opportunities foregone	Non-erosion benefits or opportunities gained
▪ Can harbour animals and pests. ▪ If they are designed inadequately they increase erosion. ▪ *Tope* is highly labour intensive. ▪ Soil sediments may be lost if structures are not well dug or designed.	▪ Increase water availability of soil. ▪ Reduce the need to carry sediments from other fields or from rivers, therefore reduce labour demand. ▪ Soil conservation of far units of land. ▪ Cheap technology; no material needed.
Other observations:	
Construction and maintenance is done basically with male labour (adult or young people). However, women can dig ditches or holes in their field when needed. These technologies are considered part of the agricultural activities to prepare land for sowing.	
Constraints on adoption:	
Lack of labour or time undermines the adoption of these technologies. Farmers may adopt sediment traps in the upper field if they perceive a gain of sediments from the upper fields or reduced run-off. If not, they would prefer to adopt traps in the bottom or sides of their land to retain the sediments. Holes or ditches in fields located far away from the household's house are less well maintained. If maize is not cultivated, these technologies are not usually adopted.	

Furrow design

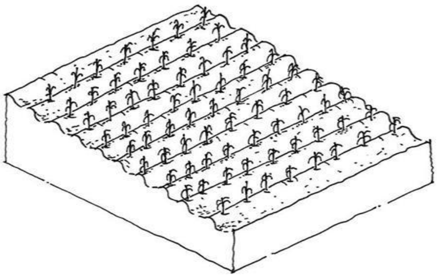
Digging furrows is an agricultural activity designed essentially to promote maize plant growth (see Table 5.11). Furrows are dug in the *primera-barbecho* (first tillage); the furrows are re-shaped in the *segunda-barbecho (*second tillage) when the maize plants have grown more. Generally, furrows are shaped using a plough pulled by draught animals, but in a few cases they are constructed by hand using a hoe. Farmers state that the form and direction of the furrows are essential to reduce soil erosion (primarily rill and gully formation). Creating furrows is a specialised activity which is carried out by *yunteros* (men who work the plough). Each *yuntero* designs the way in which the furrows are aligned. An ex-*yuntero* (whose good work is recognised by the community) states:

> *every yuntero works differently, you have to look for ways to divert the rainfall in order to prevent that "water cuts the land" [soil], then, when it rains water does not take too much soil. The first year you look where joyitas (rills) are formed and you fix that part of the plot. According to each year experience you improve your work and then you learn in each pieces of land how to avoid that water cut the land (Mr Teode).*

The specialised knowledge of this practice implies that outsiders (hired *yunteros*) decide how the technology is adopted. This practice is only adopted if maize is grown, as forage and other crops require a different method of planting.

Table 5.11 Furrow Design conservation technology summary

Local name: *echar surco*



Description

Farmers hire a *yuntero* (a man who ploughs the land) who constructs furrows in fields where maize is the main crop. It is generally done using ploughs but it can be done by hand using a hoe. A *yuntero* usually charges 200 Mexican pesos per day (around £12). According to the *yuntero*'s experience and knowledge of the land and soil type, they decide the size and shape of the furrows needed for each field. The furrows are transverse to the slope, and in very steep areas they are usually higher (by 2 cm) and smaller and narrower in less steep areas.
Experience improves knowledge on how to make the furrows. The quality of the work is revised when farmers observe where the maize plants have fallen down and where the land has been "cut" (eroded). If there is erosion, it means that the furrows were not correctly done. Consequently, the *yuntero* will pay attention to protect that area more.

How does the technology work?

- Decreases run-off.
- Increases water retention but at the same time prevents flooding.
- Helps to reduce rill or gully formation.
- Protects plants from erosion.

Other costs and opportunities foregone	**Non-erosion benefits or opportunities gained**
▪ Costs around 200 pesos per day, usually working 0.25 ha per day. ▪ Increased need for forage for draught animals. ▪ When done by hand it is time consuming and limited to small areas.	▪ Slightly reduces labour for incorporating sediments and digging holes or ditches. ▪ Reduces loss of maize plants, improving yields. ▪ Social recognition. ▪ It is a source of income (for *yunteros*).

Other observations:

Social recognition is gained when farmers pay for or carry out *primera* and *segunda*. They are regarded as good farmers that take care of their maize. Farmers who own draught animals and a plough do not hire labour or tools. They save the economic cost related to this practice. When it is done by hand, a more detailed furrow is constructed. In intercropped systems it is more difficult to define the furrows.

Constraints on adoption:

It is adopted only on pieces of land dedicated to maize crops. Farmers with limited access to cash may adopt only *primera* to avoid paying the cost of *segunda* (even though it may generate a lower yield). Lack of knowledge of how to manage a plough and design furrows is a constraint for households which own draught animals. Managing the plough and creating furrows is an activity 100 per cent dedicated to male labour. There are no women *yunteros*; managing ploughs is demanding physical work. Socially, male farmers are considered to hold more knowledge about land types and characteristics and maize production.

5.4. Associations between technologies

In the study area, farmers generally implement more than one technology in any one unit of production. The number and type of technologies adopted on a piece of land depends on the field's attributes and the household's assets and needs. Decisions about combinations of technologies are important for the overall achievement of LaDC in the field. Certain combinations could improve or undermine the practices' performance, showing positive or negative associations. The farmers' previous experiences of bringing together technologies are taken into account when determining the land management of a field. Figure 5.1 shows visually the correlation coefficients for commonly associated technologies co-existing on units of production where $r \geq 0.3$, which is statistically significant at $p \leq 0.05$.

This research employed statistical correlation analysis in order to identify possible associations between the technologies adopted in SPT. Technologies show positive correlations among themselves, with the exception of fallow, which was expected[82]. The strongest correlation between two technologies is presented for **weeding** (see p. 135 for description) **& reinstating sediments** (see p. 142 for description). Both technologies demand large amounts of human labour for their adoption but at different times of the agricultural calendar. Their objective is to improve soil fertility, which later increases production. This combination is commonly implemented by so-called “good farmers” who dedicate time to weeding activities and the transport of sediments to shallow parts of their fields. This implies social recognition and local status as farmers who take care of the land. **Holes** (see p. 148) **& weeding** and **holes & reinstating sediments** are associations of soil erosion control and fertility management, which are complementary, as there is no conflict in labour demand.

[82] In general, the results illustrate correlation coefficients significant at $p \leq 0.05$. However, 57 per cent of these significant correlations present values lower than 0.3, which does not give a clear indication of the relationships. 38 per cent show >0.3 and < 0.5 coefficients, 4 per cent >0.5 <0.7 and 1% >0.7 (see Appendix V.1).

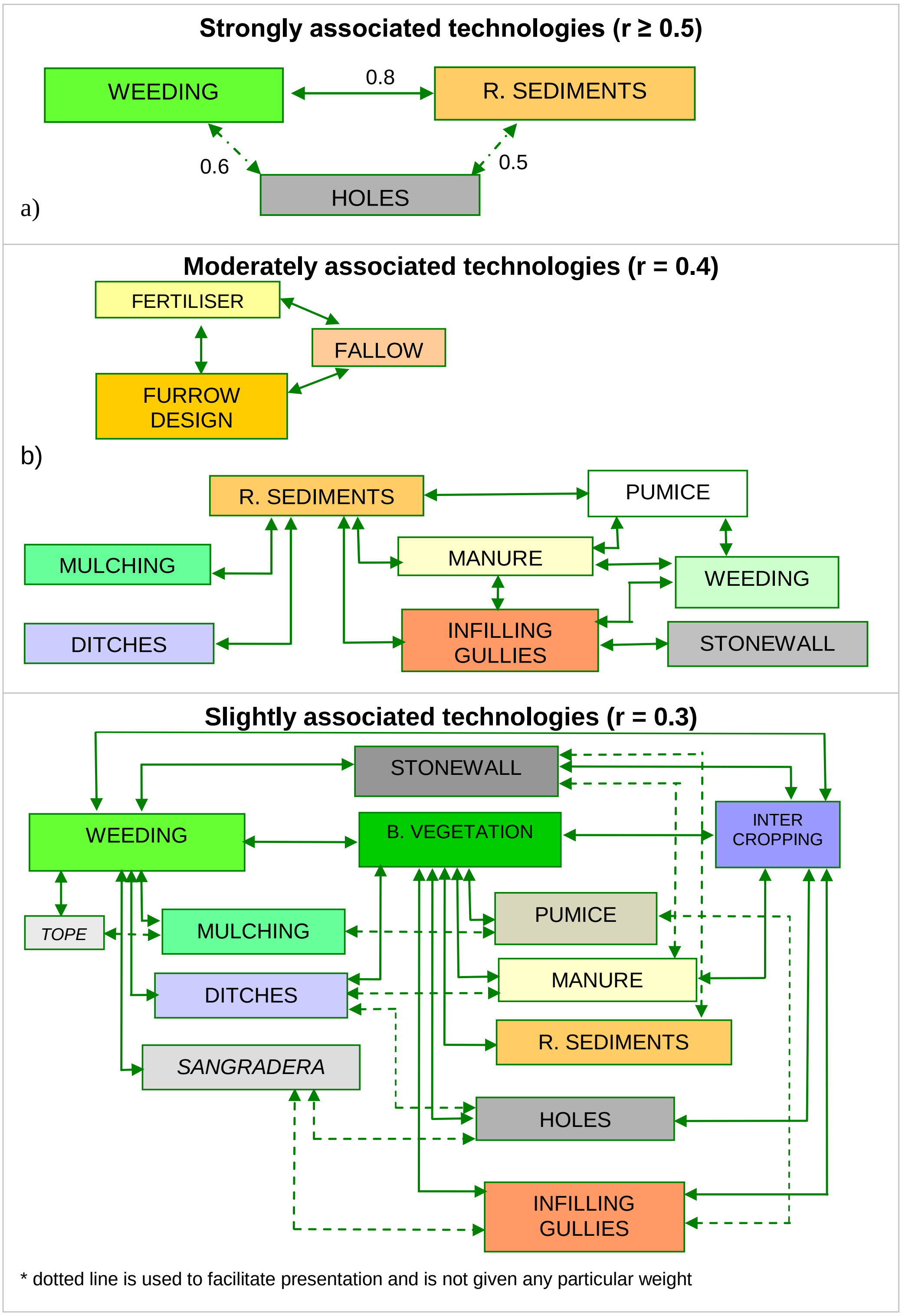


Figure 5.1 Association of technologies according to correlation coefficients

Source: Field data

***Arena*-pumice & manure** show a moderate level of association as indicated by their correlation coefficient (see p. 133 and 137 for technologies descriptions).

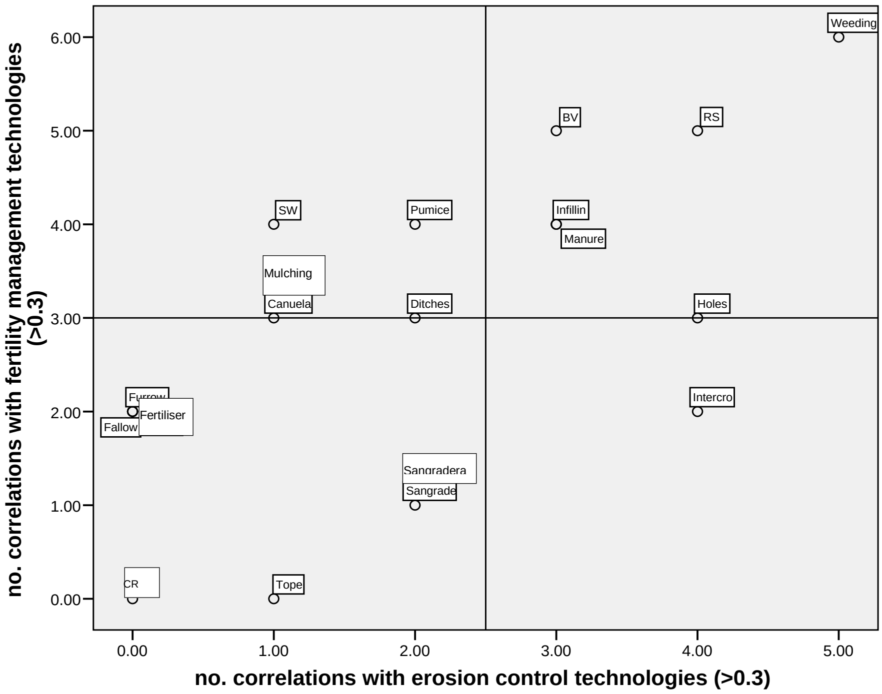
Expert farmers of La Era consider it the “best combination of technologies”. *Arena*-pumice sand is a practical way to assimilate sheep manure and urine left within the farm compound and to make use of it in the field. According to farmers, *arena*-pumice keeps manure’s “juice” rich in vitamins and organic matter and increases soil moisture. This is a win-win combination which improves soil texture and productivity. However, it is not strongly correlated, as the adoption of both simultaneously is associated with access to sand deposits, ownership of livestock (to produce manure and transport of *arena-pumice*), soil type and male labour, which varies between households. In addition, the application of these technologies is linked to inherited land management practices, particularly in sector La Era.

Furrow design & fertiliser & fallow are moderately associated (see p. 150, 137 and 140 for technologies descriptions). People that cultivate maize usually require furrow design and fertiliser. Adoption is not associated with any other technology, as they are the activities essential to grow maize. Fallow is negatively correlated to these two practices, as there is no cultivation of land.

In situations of modest association with correlations of the order of r = 0.3, there is no discernible and consistent pattern. Combinations of technologies are complex and diverse. This reflects the differential responses and interests of farmers in obtaining particular benefits from technologies. For instance, ***Tope*** (see p. 148 for description) **& mulching** (see p.135 for description) show a slight or weak correlation coefficient; however, this combination has a strong association in the field, as specific families inherited this land management technique and these households are recognised – and hence achieve local status – for this specific combination. A similar case is observed with infilling gullies.

Technology associations reflect the farmers’ rationale of looking for co-benefits when implementing sets of practices. In most cases, the combination chosen helps to enhance the performance of technologies and inputs needed for their adoption, maximizing resources and co-benefits. This rationale is more clearly observed in Figure 5.2, which illustrates the numbers of significant correlations ($r \geq 0.3$) between technologies, differentiated according to their purpose as fertility management (vertical axis) or erosion control activities (horizontal axis)[83].

The most correlated technologies (with both fertility management and erosion control) are located in the top right corner. There are six technologies in this square (including **holes**, which are right on the boundary). For instance, **weeding** holds the highest number of positive relationships with six fertility management and five erosion control technologies. These technologies are more feasibly combined with others, thereby complementing and enhancing LaDC. At the top left corner are **stone wall** (see p. 146 for description) or ***arena*-pumice**, which are technologies with more associations with fertility management practices Technologies in this part of the diagram help to reduce run-off and soil loss; therefore, farmers combine them with fertility improvement practices to diversify benefits. **Intercropping** (see p. 138 for description) is the only technology located in the bottom right corner and it is usually combined with erosion control practices.



SW = Stone wall, BV = Boundary vegetation, RS = Reinstating sediments, Infillin = Infilling gullies, Intercro = Intercropping, CR = Crop Rotation, Furrow = Furrow design, Tope= Tied-ridges

Figure 5.2 Matrix of number of correlations presented by each technology according to technology purpose

Source: Field data

[83] Ten technologies were considered as fertility management and seven technologies as erosion control, including infilling gullies (see Table 5.1).

Finally, in the bottom left corner, technologies with few correlations are scattered in two groups. The first one includes ***tope*** and ***sangradera*** (see p. 148 for description), which show less than three correlations (mainly with erosion control practices). **Fallow**, **fertiliser** and **furrow design** technologies are another group which have correlations between them (negative relationships with **fallow**) and there are no clear associations with erosion control technologies. Their adoption is not generally dependant on other technologies.

In general, farmers' choices when combining technologies are to exploit complementary benefits rather than to overcome competitive tendencies. Combining technologies is part of an integral and wider land management strategy at the household level. Specific technologies adopted in each field provide a "package" of benefits to land users. When farmers diversify their choice of technologies, they diversify benefits and costs, generating gains and losses. Decisions about the adoption of LaDC technologies therefore involve trade-offs, a subject explored in later chapters.

5.5. Adoption of LaDC technologies in SPT by LUT

In the community of SPT, farmers adopted an array of 17 technologies in their units of production. The frequency of adoption of each technology varies between households. The rate of adoption of each technology in the study area is calculated from data of 291 units of land and is presented in Table 5.12.

Table 5.12 Adoption of LaDC technologies in SPT

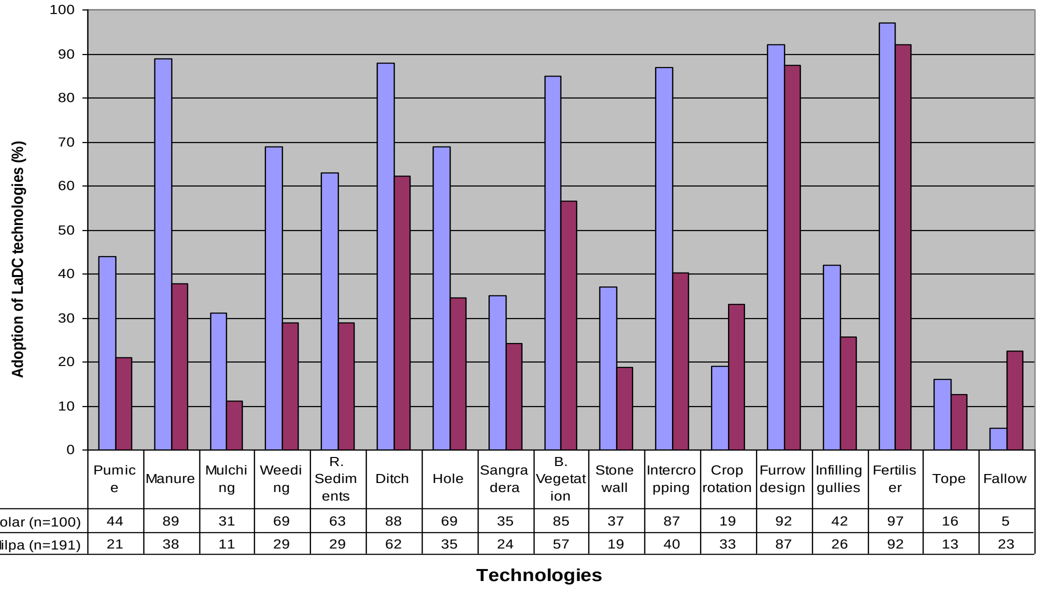
Technologies adopted in > 50 per cent of units of production		Technologies adopted in < 50 per cent of units of production			
	Per cent		Per cent		Per cent
Fertilisers & Furrow design	90	Holes	46	*Sangradera* & Crop rotation	28
Ditches	71	Weeding	43	Mulching	18
Boundary vegetation	66	Reinstating sediments	41	Fallow	16
Intercropping	56	Infilling gullies	31	*Tope*	14
Manure	55	*Arena*-pumice	29		

Source: the Field data

Farmers accounted for the high rate of adoption of fertiliser and furrow design by explaining how essential they are to obtain good maize yields. High labour demanding technologies such as *tope* are adopted less frequently. Technologies with low rates of adoption are usually carried out in specific fields or by particular groups. Likewise, not all pieces of land would require a *sangradera* or infilling gullies; this influences the total frequency of these technologies. In addition, farmers usually manage more than one piece of land in different LUT. Therefore, use and distribution of LaDC technologies may differ in *solar* and *milpa*, changing the adoption of technologies presented at the community level.

Historically, the use of resources within LUTs such as *milpa* and *solar* has been differentiated in the highland context of Mexico. As explained in the previous chapter, land utilization type has been an important driver for land management and conservation since the pre-Hispanic period. Throughout time, more intensive management has been given to the *solar* than *milpa*. On one hand, *solar* is where farmers have usually invested more resources over a longer time. On the other hand, *milpa* not only provides maize but also is the main area for farmer experimentation with alternative practices. Farmers may inherit or acquire a piece of land -to be the area of their *solar*- from parents or relatives who may initially manage it as a *milpa*. Previous land users may have adopted LaDC technologies, so the new land managers may also inherit LaDC technologies. In some cases, farmers will maintain inherited practices in their *solar* and/or adopt different technologies. *Solar's* management becomes more continuous or intensive when farmers settled their homestead in this piece of land. In turn, a *milpa* may evolve to be a *solar* if land users settle their home here. The LUTs' role within the farming system is crucial, especially in the allocation of resources and land use. Therefore, this research expected differences in management between LUTs. Capturing how the decision-making process develops will allow a better understanding of why a technology is adopted in one place and not in another, and why the adoption of technology varies within specific LUTs. In addition, this provides information about how farmers distribute their assets in each LUT in order to control LaDC.

In SPT, farmers have implemented technologies in both *solar* and *milpa*. Data collected during fieldwork (100 *solars* and 191 *milpas*) shows that there is a higher percentage of adopted technologies in *solar* than in *milpa*. Nevertheless, the percentage of each technology varies between LUTs. The statistical analyses (χ^2 and Z value) indicate that there are no significant differences ($p \leq 0.05$) in the adoption of fertiliser, furrow design and *tope* in both LUTs (see *Appendix* V.2). The first two are usually applied on more than 90 per cent of units of land and their adoption is related to maize production rather than LUT. *Tope* is not commonly taken up in the community. The rest of the technologies adopted were significantly different between *solar* and *milpa*. Figure 5.3 illustrates the percentage of adoption of each LaDC technology differentiated by LUT.



	Pumice	Manure	Mulching	Weeding	R. Sediments	Ditch	Hole	Sangradera	B. Vegetation	Stone wall	Intercropping	Crop rotation	Furrow design	Infilling gullies	Fertiliser	Tope	Fallow
Solar (n=100)	44	89	31	69	63	88	69	35	85	37	87	19	92	42	97	16	5
Milpa (n=191)	21	38	11	29	29	62	35	24	57	19	40	33	87	26	92	13	23

Figure 5.3 Rate of adoption of LaDC technologies by LUT (*solar* and *milpa*) in SPT

Source: Field data

5.5.1. Adoption of LaDC in *solar*

According to the fieldwork data, manure, boundary vegetation and intercropping are adopted in more than 80 per cent of *solars*. Manure and boundary vegetation are commonly chosen by farmers in this LUT. These are inherited land management practices, maintained over many years. In general, 9 out of 17 technologies are adopted in more than 50 per cent of *solars*. As illustrated in Figure 5.4, *solar* is delimited clearly by boundaries which distinguish them from *milpa*. The defined hedges are evidence of long and intensive land management carried out in this LUT. Weeding, reinstating sediments and holes are also technologies selected for *solars* (50-69 per cent).

Other adopted technologies in *solar* are *arena*-pumice, infilling gullies, stone wall, *sangradera* and mulching (30-49 per cent). The first three were adopted in the past and still provide benefits to the soil; therefore, farmers only need to maintain them. In the case of infilling gullies, farmers adopted this practice if gully formation was affecting their land. As *solar* is more carefully managed, after infilling the gully there is no need to adopt this practice again. *Sangradera* respond more to the fields' characteristics than to the LUT. Mulching is linked to the land management of particular households.

The less frequently adopted practices that are still significantly different between LUTs are crop rotation and fallow. This was expected, as farmers stated that the main production used for their food consumption is yielded in *solar*. Thus households are not willing to change and risk this yield for cash crops or fallow.

5.5.2. Adoption of LaDC in *milpa*

As shown in the above graph, only ditches and boundary vegetation are taken up in more than 50 per cent of *milpas*. These technologies are chosen mainly to control erosion and delimit fields. This is particularly useful if *milpa* is located far away from the homestead. However, the diversity, extension and maintenance of boundary vegetation in *milpas* is not as continuous as in *solar*. Hedges in *milpas* have been recently planted (when compared to *solar*) and are not well defined, as shown in Figure 5.4.

From the full sample, it was found that 13 out of 17 technologies are adopted by less than 50 per cent of households in *milpas*. From these, manure, IC, holes, crop rotation, weeding, reinstating sediments, infilling gullies and fallow are adopted in 20-40 per cent *milpas*; these require more human and natural assets and distance may affect land management. For instance, IC provides co-benefits such as the production of forage, which enhances soil fertility. *Arena*-pumice, SW and mulching are rarely chosen for this LUT. *Arena*-pumice application is labour demanding, and SW and mulching require transportation of materials, which limits their feasibility for adoption. Finally, farmers in SPT would prefer practices which provide erosion control and avoid soil loss, especially in *milpas* located far away.

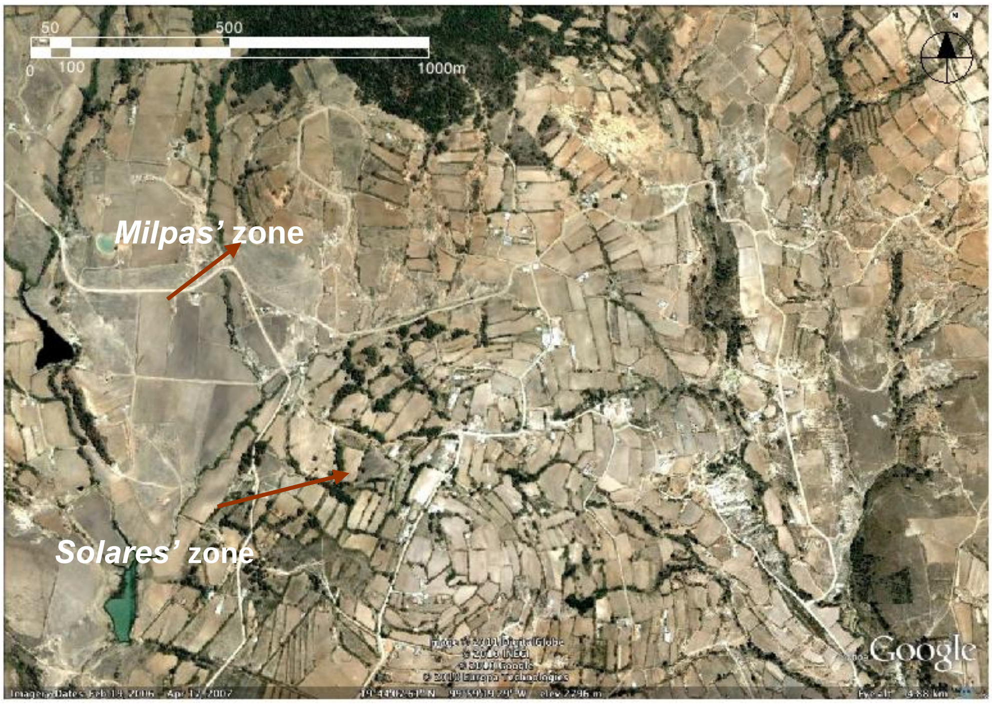


Figure 5.4 Examples of location of *solar* and *milpa* zones in SPT

Source: Google Earth accessed 2008

Analysis of LaDC according to LUT indicates that the more productive and the closer the fields are to homesteads (*solar*) the more they tend to have intensive management and labour-demanding technologies (e.g. *arena*-pumice, manure, reinstating sediments). In *milpa*, technology adoption is less, especially practices focussed on fertility management. There is a marked differentiation of land management between LUTs. This raises the question: do farmers value the adopted technologies in a different way? If so, is there any relationship between the technologies' value and their adoption in each LUT? These questions will be addressed in the following chapters.

5.6. Factors influencing the adoption of LaDC technologies

Biophysical attributes and household socio-economic characteristics are associated with decisions about land management (Paudel and Thapa, 2004). Appreciating how these factors are related to technologies is relevant to understanding the farmers' decision-making process. Niemeijer and Mazzucato (2000) points out that understanding farmers' reasoning may explain how local technologies are embedded in the environmental and social context. However, the research challenge remains as to how to identify the key drivers that induce farmers to adopt one or a combination of technologies. Farmers gave individualised accounts, but this research seeks to find patterns of adoption and the reasoning behind the employment of technologies.

In order to identify the influential factors in the adoption of LaDC technologies, a logistic regression analysis is employed at the unit of production level. The logistic regression calculates the probability of adoption of a technology on a piece of land considering the values of the independent variables[84]. Fifteen technologies are analysed with logistic regression (one regression per technology). Furrow design and fertiliser are omitted, as they are technologies adopted in more than 90 per cent of production units.

A dummy variable indicating adoption of a technology in a field (0 = non-adoption, 1 = adoption) is used as the dependent variable. This variable is based on data obtained during fieldwork about technologies on farmers' land irrespective of the year of adoption. The selection of independent variables is related to the biophysical attributes of the land and the socio-economic household characteristics in SPT (see Chapter 3, section on statistical analysis LG). Strongly correlated variables are dropped from the regression models in

[84] The logistic regression model allows identifying the probability of adoption or non adoption of LaDC technologies. This regression makes no assumptions about the distributions of independent variables, which could be a mix of continuous and categorical variables (Wuenshck, 2006).

order to avoid multicollinearity and heteroscedasticity[85]. The independent variables included in the model representing biophysical attributes of each piece of land are area (hectare), distance (five categories, each one treated as a dummy variable), soil type (each one treated as a dummy variable) and productivity (tonnes/hectare).

The independent variables describing the households' characteristics are: religion (0 = Catholic, 1 = Protestant)[86]; potential labour index (see Chapter 4); education of household head (HH) dummy variable (0 = no education, 1 = had access to education); sex of HH (0 = female, 1 = male); livelihoods dependant only on agricultural occupation (0 = no and 1 = yes); number of heads of sheep, equines and bovines (each one is a variable); land title held by household head or partner (0 = no, 1 = yes); age of household head (number of years squared); family type – nuclear, extended or solitary (each one is a dummy variable); and perception of erosion (0 = no, 1 = yes)[87].

The set of predictor variables chosen are relevant and presume a causal relationship with the adoption of LaDC technologies. Moreover, the selection of these variables is supported by the discussions in farmer focus groups in 2005. In these groups, the researcher presented preliminary results from pilot logistic regressions (from enter and stepwise methods) and farmers expressed their views about the results. Finally, an *Enter* procedure produced a better model

[85] A multivariate correlation analysis of all predictor variables was carried out to examine variables with strong correlations >0.8, as they could cause heteroscedasticity. In addition, a collinearity diagnostic was run to check variables with Tolerance values less than 1 and a Variance Inflation factor (VIF) >10, as they would indicate problems of collinearity, affecting the estimation of the probabilities of adoption of technologies.

[86] Sector (0 = Centro and 1 = La Era) and Religion (0 = Catholic and 1 = Protestant) are strongly correlated (r = 0.7). Sector Centro is mainly Catholic and La Era Protestant. Religion is chosen as a predictor variable because it generates better prediction models than sectors and their influence in other variables. In addition, religion affiliations involve access to social networks which are now important in coping with vulnerability in a context of low access to labour and elderly farmers, current social groups are more church-based than local indigenous networks. It also reflects local norms, philosophy, attitudes and perceptions important in the attachment of values to technologies (see Chapter 6)

[87] In the case of the age of the HH variable, the years squared is used to enhance its normal distribution. When applying logistic regression a reference variable is left out of the model to avoid correlation. For instance, in variables such as soil type, soil *Pejo* is chosen as the reference variable, as it has the greatest area and is a common soil in SPT. In livestock, sheep is the reference type, as it is easier to buy and is commonly kept by households. In the cases of distance and family type, the reference variables are the first categories (distance = next to house and family type = nuclear) chosen when using the SPSS v16 software.

(higher values of pseudo R^2 and fewer random results) in comparison to Forwards Stepwise procedure in SPSS software.

The predictor variables and the estimated coefficients significant at $p \leq 0.05$ and the odds ratio (exp B) of each technology are presented in Table 5.13. The odds ratios give the probability of adoption of a technology if there is a change in one unit of the predictor variable. If the odds are greater than 1 there is a positive relationship, or if less than 1 a negative relationship with the dependent variable.

Table 5.13 Logistic regression coefficients, significance and odds ratio in the adoption of LaDC technologies

	T1-*Arena*-pumice 82.6 per cent			**T2-Manure** 76.4 per cent			**T3-Mulching** 84.4 per cent			**T4-Weeding** 75 per cent			**T5-Reinstating Sediments** 78.1 per cent			**T6-Ditches** 78.5 per cent		
Variables	B	Sig	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Productivity (ton/ha)	**0.44**	**0.01**	**1.55**	**0.58**	**0.00**	**1.78**	**0.59**	**0.00**	**1.80**	**0.57**	**0.00**	**1.77**				**0.33**	**0.04**	**1.39**
Area (Ha)																		
Distance(1)*				**-1.62**	**0.00**	**0.20**				**-1.05**	**0.01**	**0.35**	**-1.19**	**0.00**	**0.30**	**-1.29**	**0.01**	**0.28**
Distance(2)	**-1.25**	**0.02**	**0.29**	**-2.04**	**0.00**	**0.13**				**-1.09**	**0.03**	**0.34**	**-1.29**	**0.01**	**0.28**	**-1.27**	**0.02**	**0.28**
Distance(3)	**-2.48**	**0.00**	**0.08**	**-3.79**	**0.00**	**0.02**	**-2.21**	**0.01**	**0.11**	**-2.62**	**0.00**	**0.07**	**-4.22**	**0.00**	**0.01**	**-2.22**	**0.00**	**0.11**
Distance(4)	**-3.24**	**0.00**	**0.04**	**-4.02**	**0.00**	**0.02**	**-2.00**	**0.03**	**0.13**	**-1.48**	**0.02**	**0.23**	**-2.19**	**0.00**	**0.11**	**-3.18**	**0.00**	**0.04**
*Arena***																		
Colorada										**1.95**	**0.00**	**7.01**	**1.83**	**0.00**	**6.24**	**1.10**	**0.02**	**2.99**
Polvillo										**1.12**	**0.02**	**3.05**						
Tepetate	**1.75**	**0.00**	**5.73**							**2.13**	**0.00**	**8.44**	**1.75**	**0.00**	**5.75**			
Negra																		
Religion	**1.54**	**0.00**	**4.64**				**1.08**	**0.02**	**2.96**				**0.90**	**0.02**	**2.46**			
Labour index							**-0.80**	**0.00**	**0.45**									
Education HH							**-1.18**	**0.02**	**0.31**							**0.96**	**0.02**	**2.62**
Sex HH																		
Agric. ocup.							**-1.02**	**0.03**	**0.36**									
No. Equids				**0.41**	**0.01**	**1.50**	**0.39**	**0.02**	**1.47**							**0.49**	**0.00**	**1.63**
No. Bovine	**0.32**	**0.01**	**1.38**															
Land title HH																		
Age HH (years^2)							**0.00**	**0.00**	**1.00**									
Familytype(1)	**-2.02**	**0.00**	**0.13**															
Familytype(2)																		
Per. of erosion	**-1.16**	**0.02**	**0.31**															
Constant	**-0.70**			1.23			0.09			-3.33			-1.17			-2.60		

*distance (ref)=*Next to house*; distance(1) = near house; distance(2) = medium; distance(3) = far; distance(4) = very far. Family type(ref) = nuclear; familytype(1) = extended; familytype(2) = solitary/single mum **Soil (ref) = *Pejo*

Source: Field data

Table 5.13 Logistic regression coefficients, significance and odds ratio in the adoption of LaDC technologies (continued)

	T7-Holes			T8-Sangradera			T9-Boundary vegetation			T10-Stone wall			T11-Intercropping			T12-Crop rotation		
	74.7 per cent			76.4 per cent			79.9 per cent			80.2 per cent			76 per cent			76 per cent		
Variables	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Productivity (ton/ha)																**-0.29**	**0.03**	**0.75**
Area (ha)																		
Distance(1)*	**-1.33**	**0.00**	**0.26**										**-1.97**	**0.00**	**0.14**	**1.07**	**0.01**	**2.91**
Distance(2)										**-1.18**	**0.03**	**0.31**	**-3.19**	**0.00**	**0.04**			
Distance(3)	**-1.29**	**0.01**	**0.28**				**-1.49**	**0.00**	**0.23**	**-2.30**	**0.00**	**0.10**	**-3.21**	**0.00**	**0.04**			
Distance(4)							**-1.44**	**0.01**	**0.24**	**-3.32**	**0.01**	**0.04**	**-2.95**	**0.00**	**0.05**			
*Arena***	**1.32**	**0.01**	**3.73**	**1.54**	**0.00**	**4.67**										**-1.28**	**0.04**	**0.28**
Colorada	**1.61**	**0.00**	**4.98**	**0.91**	**0.05**	**2.50**	**0.98**	**0.03**	**2.67**									
Polvillo				**0.92**	**0.05**	**2.52**												
Tepetate	**1.59**	**0.00**	**4.89**				**1.42**	**0.03**	**4.13**	**1.22**	**0.03**	**3.37**						
Negra																		
Religion	**0.92**	**0.01**	**2.51**	**1.05**	**0.01**	**2.85**				**1.17**	**0.01**	**3.21**	**0.87**	**0.02**	**2.38**			
Labour index							**-0.37**	**0.04**	**0.69**									
Education HH																		
Sex HH																		
Agric. ocup.	**-0.84**	**0.01**	**0.43**															
No. Equids																**0.43**	**0.00**	**1.53**
No. Bovine				**-0.26**	**0.02**	**0.77**												
Land title HH																		
Age HH (years^2)										**0.00**	**0.04**	**1.00**						
Familytype(1)																**-1.22**	**0.00**	**0.30**
Familytype(2)	**-1.18**	**0.02**	**0.31**															
Per. of erosion							**1.03**	**0.01**	**2.79**									
Constant	**0.16**			**-2.33**			**1.53**			**-1.46**			**1.56**			**-1.84**		

*distance (ref) =*Next to house*; distance(1) = near house; distance(2) = medium; distance(3) = far; distance(4) = very far. Family type(ref) = nuclear; familytype(1) = extended; familytype(2) = solitary/single mum **Soil (ref) = *Pejo*

Source: Field data

Table 5.13 Logistic regression coefficients, significance and odds ratio in the adoption of LaDC technologies (continued)

	T14-Infilling gullies			**T16- *Tope***			**T17-Fallow**		
	83.3 per cent			88.9 per cent			82.2 per cent		
Variables	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Productivity (ton/ha)	**0.35**	**0.02**	**1.41**				**-1.11**	**0.00**	**0.33**
Area (ha)							**1.11**	**0.02**	**3.04**
Distance(1)*									
Distance(2)									
Distance(3)	**-2.00**	**0.01**	**0.14**						
Distance(4)	**-3.32**	**0.00**	**0.04**				**2.56**	**0.00**	**12.93**
*Arena***									
Colorada									
Polvillo									
Tepetate	**2.10**	**0.00**	**8.18**	**2.03**	**0.01**	**7.63**			
Negra									
Religion	**1.70**	**0.00**	**5.50**						
Labour index				**0.61**	**0.02**	**1.84**			
Education HH				**-2.99**	**0.00**	**0.05**	**-1.03**	**0.04**	**0.36**
Sex HH									
Agric. ocup.	**-0.80**	**0.05**	**0.45**						
No. Equids									
No. Bovine									
Land title HH									
Age HH (years^2)	**0.00**	**0.03**	**1.00**	**0.00**	**0.01**	**1.00**			
Familytype(1)				**-1.78**	**0.01**	**0.17**			
Familytype(2)	**-1.96**	**0.00**	**0.14**	**2.37**	**0.00**	**10.70**			
Per. of erosion									
Constant	**-3.45**			**-5.72**			**-0.57**		

*distance (ref)=*Next to house*; distance(1) = near house; distance(2) = medium; distance(3) = far; distance(4) = very far. Family type (ref) = nuclear; familytype(1) = extended; familytype(2) = solitary/single mum **Soil (ref) = *Pejo*

Source: Field data

The odds ratios indicate the relationships between independent variables with the adoption of LaDC technologies, summarised in Table 5.14. The results from regression analyses indicate that the adoption of LaDC technologies in the study area is mainly influenced by factors such as **productivity** (maize production in tonnes/hectare), **distance of plots, soil type** and **religion** (related to sectors).

Table 5.14 Relationships between predictor variables and adoption of technologies[88] ($p \leq 0.05$)

Variable	Positive relationships – increase in a unit > probability of adoption	Negative relationship – increase in a unit < probability of adoption
Productivity (ton/ha)	T1,T2,T3,T4,T6,T14	T12 T17
Area (log)	T17	None
Distance(1)*	T12	T2,T4,T5,T6,T7,11
Distance(2)	None	T1,T2,T3,T4,T5,T6,10,T11
Distance(3)	None	T1,T2,T3,T4,T5,T6,T7,9,T10,T11,T14
Distance(4)	T17	T1,T2,T3,T4,T5,T6,T9,T10,T11,T14
*Arena***	T7,T8	T12
Colorada	T4,T5,T6,T7,T8,T9	None
Polvillo	T4,T8	None
Tepetate	T1,T4,T5,T7,T9,T10,T14,T16	None
Negra	None	None
Religion	T1,T3,T5,T7,T8,T10,T11,T14	None
Labour index	T16	T3,T9
Education HH	T6	T3,T16T17
Sex HH	None	T2
Agric. ocup.	None	T3,T7,T14
No. Equids	T2,T3,T6,T12	None
No. Bovine	T1	T8
Land title HH	None	None
Age HH (years^2)	T3,T10,T14,T16	None
Familytype(1)	None	T1,T12,T16
Familytype(2)	T16	T7,T14
Per. of erosion	T4, T9	T1

*distance (ref)=*Next to house*; distance(1) = near house; distance(2) = medium; distance(3) = far; distance(4) = very far. Family type (ref) = nuclear; familytype(1) = extended; familytype(2) = solitary/single mum

**Soil (ref) = *Pejo*

Source: Field data

[88] T1 *Arena*-pumice incorporation, T2 Manure, T3 Mulching, T4 Weeding, T5 Reinstating of sediments, T6 Ditches, T7 Holes, T8 *Sangradera*, T9 Boundary vegetation, T10 Stone wall, T11 Intercropping, T12 Crop rotation, T14 Infilling gullies, T16 *Tope*, T17 Fallow.

High productivity has a positive influence in the probability of adopting technologies. Its influence could be addressed in two ways: high productivity as an outcome of implementing LaDC technologies or as a cause to adopt them. Maize production may be improved as an outcome of implementing LaDC practices; a higher productivity would mean an economic gain, food production security and social recognition in the community which may persuade farmers to keep adopting LaDC practices. However, farmer may decide to maximize their resources and invest only in productive soils to enhance even more their productivity, therefore, high productivity is a cause to adopt technologies. In both ways, high productivity increases the probability of adoption or motivates farmers to continue technologies (e.g. *arena*-pumice, manure, mulching, weeding). Land users with greater area and production will have greater access to discretionary resources and be more likely to invest in conservation (Amsalu, 2006, Amsalu and De Graaff, 2006, Amsalu and De Graaff, 2007).

There is a negative relationship between technology adoption and distance. The probability of adoption decreases in distant plots, as observed in *solar* LUT, the productive field located next to the household, which have high adoption of technologies. *Solar* is closer historically and culturally relevant in land management. Farmers emphasise that there is insufficient financial means or material to implement technologies on all pieces of land. Therefore, they invest more in the nearest units. Mr Leode comments:

> *I have a big milpa in the llano (flat area) but I cannot cultivate it because is very far away, and I do not have transport to go and work on it. Besides, it is Pejo soil and it is very difficult to work with the plough.*

The results indicate that soil types such as *Colorada* and *Tepetate* demand more intensive care than *Pejo* (reference soil). The probability of adoption on other soils increases when compared with *Pejo*. Soil types are important determinants for the choice of technology. For instance, Mr Teodoro considers that *Colorada* soil usually needs a hole or *sangradera* and *Pejo* does not. These findings help the hypothesis introduced in last chapter to be accepted, i.e. that in addition to soil type differences, which are relevant in the adoption of practices, the greater the distance from the homestead the less the adoption of LaDC.

Regarding religion the results indicate that being Protestant has a positive influence in the probability to adopt LaDC practices. Religion has a high correlation with sector, which also reflects the differences in sectors regarding access to a social network, especially for labour exchange. In this case, religion affiliations allow to explore how farmers have strengthened church-based networks which are now equally or more important than other local networks (e.g. *Mazahua* indigenous group or political groups). Religion is closely linked to family networks as people tend to follow their relatives' faith. Protestant members have close family ties and this strengthens their social links. Religion reflects local norms, beliefs and perceptions relevant in households' decisions, especially regarding allocation of resources and attachment of values to technologies, issue explored in the next chapter. For example, a Protestant farmer considers that Protestant farmers have a greater availability of time and therefore work more on their land. He says:

> *Protestant people do not drink alcohol; this help us to use that time in working the land rather than being drunk* [1, protestant farmer].

Education, livestock (equids) and age HH are other significant factors related to at least four technologies ($p<0.05$), while their influence is less clear in other technologies. Owning equids increases the adoption of technologies such as manure, mulching and crop rotation more than having sheep. Equids provide a greater quantity of manure that lasts longer than manure obtained from sheep, and they are used as a means of transport. Smallholder farmers usually have livestock to cope with seasonal cash flow and to adopt new technologies (Sambodo, 2007). Also, farmers who own equids usually work mostly in agricultural activities such as *yunteros*, for which social recognition in the community is important A similar case is the households head's age: older farmers are more likely to be dependant on farming; they have more experience, interest and opportunities to experiment in land management (e.g. infilling gullies or *tope*); younger household heads prioritise their children's upbringing and often migrate. There is a negative relationship between technology adoption and education, specifically in cases such as mulching, *tope* and fallow. Farmers with more access to education spend less time on agricultural activities, having low labour availability[89]. In addition, they might regard local practices as technologically less advanced.

The results show that holding land title is not a significant factor in the adoption of technologies (at $p<0.05$) in the study area. Ownership as opposed to security of tenure is not always a necessary condition (Lapar and Pandey, 1999, Anim, 1999). Parents working their children's land could be motivated to leave a better quality field for future cultivation by their own children or grandchildren. Moreover, the nature of the variable is focused on household heads or partners having legal ownership of land. There is no differentiation between the type of land title such as *ejido* and private property. Farmers initially responded that having title was not relevant to the adoption of a practice; it was more related to a willingness to take care of the land. However, farmers later revealed during the focus group discussions that they invest more in land which holds a private property title, as it has a higher economic value than in *ejido*. Therefore, it would be more appropriate to analyse the adoption of technologies after 10 years of acquiring the land title. The factors affecting adoption of LaDC technologies in SPT are in accordance with the factors found in other empirical research of sloping environments (see Table 5.15).

The results provide empirical and statistical evidence to test the hypothesis proposed in the last chapter. In general terms, the results from logistic regressions are in line with farmers' opinions regarding factors affecting their choice of technologies. The influential factors point to the specific attributes of fields driving farmers' choices regarding LaDC technology adoption. This explains the rationale of farmers' decision-making process about land management. However, there are other elements not included in this analysis due to a lack of data such as slope, participation with research programmes, income and migration, highlighted by farmers during focus group discussions[90].

---

[89] According to Okoba and De Graaff (2005), better-educated people seem to invest less labour in SWC in Peru but more in Bolivia. Likewise, Sambodo (2007) states that farmers with more formal education usually have a more positive attitude towards technology adoption. The effects of education are not always consistent (Kaliba et al., 1997; Ramsom et al., 2003).

[90] Farmers consider that these factors also drive their decisions regarding land management and experimentation.

Table 5.15 Factors affecting technology adoption in empirical research

Empirical studies	Factors affecting adoption of technologies
Gould et al. (1989)	Age HH^{+}
Lynne and Shonkwiler (1988)	Land tenure, income, farm terrain and farmers' attitudes
Holden and Yohannes (2002) Ethiopia	Perception of soil erosion, household and farm characteristics, farmers perception of technology-specific attributes and land quality
Baidu-Forson (1999)	Area of degraded land, extension education, lower risk aversion and availability of short-term benefits
Lapar and Pandey (1999) Philipinnes	Age HH, education level, land ownership, access to markets, labour exchange arrangements, slopes
Anim (1999) South Africa	Awareness of soil erosion problem and increase in long-term profit
Moor (1996) Zimbabwe	Perceived property rights
Araya and Adjaye (2001) Eritrea	Family size, perceptions about effects of soil erosion on yield, perceptions about profitability of technologies, off-farm employment, system of land ownership
Gebremedhin and Swinton (2003) Ethiopia	Long-term investment: security of land tenure, labour availability, distance to farmstead, learning opportunities (extension services) Short-term investment: land tenure and participation in programmes
Bekele and Drake (2003)	Plot level adoption of technologies: access to information, support programmes for initial investment, slope, area of plot, landholding per economically active person
Paudel and Thapa (2004)	Institutional factors: extension services^{+}, training^{+} Social factors: cast affiliation^{+}, agr. labour force size^{+}, education HH^{+}, participation in LM projects^{+} Ecological factors: soil types (prone to erosion)$^{+}$ and slope^{+}
Tenge et al. (2004)	Education level, perception of erosion, security of land tenure, off-farm activities, short-term benefits, fragmented land in different location
Hammad and BØrresen (2006)	Farmers' perceptions, land ownership and geomorphology
Kessler (2006b)	Surface condition, field location and land tenure
Anley et al. (2007)	Land to labour ratio Education level HH Distance of the plot from home Slope of the farm Area of cultivated land Age^{+}, distance^{-}
This research	Productivity (ton/ha), distance, soil type, religion, education HH, no. of livestock (equids) and age HH

Source: adopted from Anley et al (2007) and the author.

Note: Underlined= factors from the studies which are also found significant in this research, + = positive relationship.

5.7. Clustering technologies

The key factors identified provide a framework to scale up the analysis and explore technologies in relation to households. The aim is to identify groups of technologies according to the household characteristics of the adopters. In order to achieve this, cluster analysis is employed using seven representative factors to classify the technologies: productivity (ton/ha), distance, soil diversity, number of equids, age of HH, religion HH and education HH. Aggregated data at household level is used to estimate the mean values of these factors considering only adopters of each technology.

Different numbers and types of cluster analysis were carried out, changing the methods of linkage, the number of factors and similarity measures in SPSS Software. However, a hierarchical cluster analysis is preferred to classify technologies, as it provides more constant and sensible groups. The variables (technologies) are clustered according to the households' mean data (cases). Ward's method is chosen to link technologies (each technology begins as a cluster in itself). Squared Euclidean distance as a similarity measure and standardising values (cases) by Z scores were chosen for this analysis (Field, 2000).

Technologies are grouped in four clusters based on their similarity, visually represented by a dendrogram (see Appendix V.3). It provides a basic picture of how technologies are aggregated according to the characteristics of the adopters' families. The clusters are constructed in relation to these specific household attributes. Clusters are labelled according to type of technology, purpose and assets needed for adoption (see Figure 5.5).

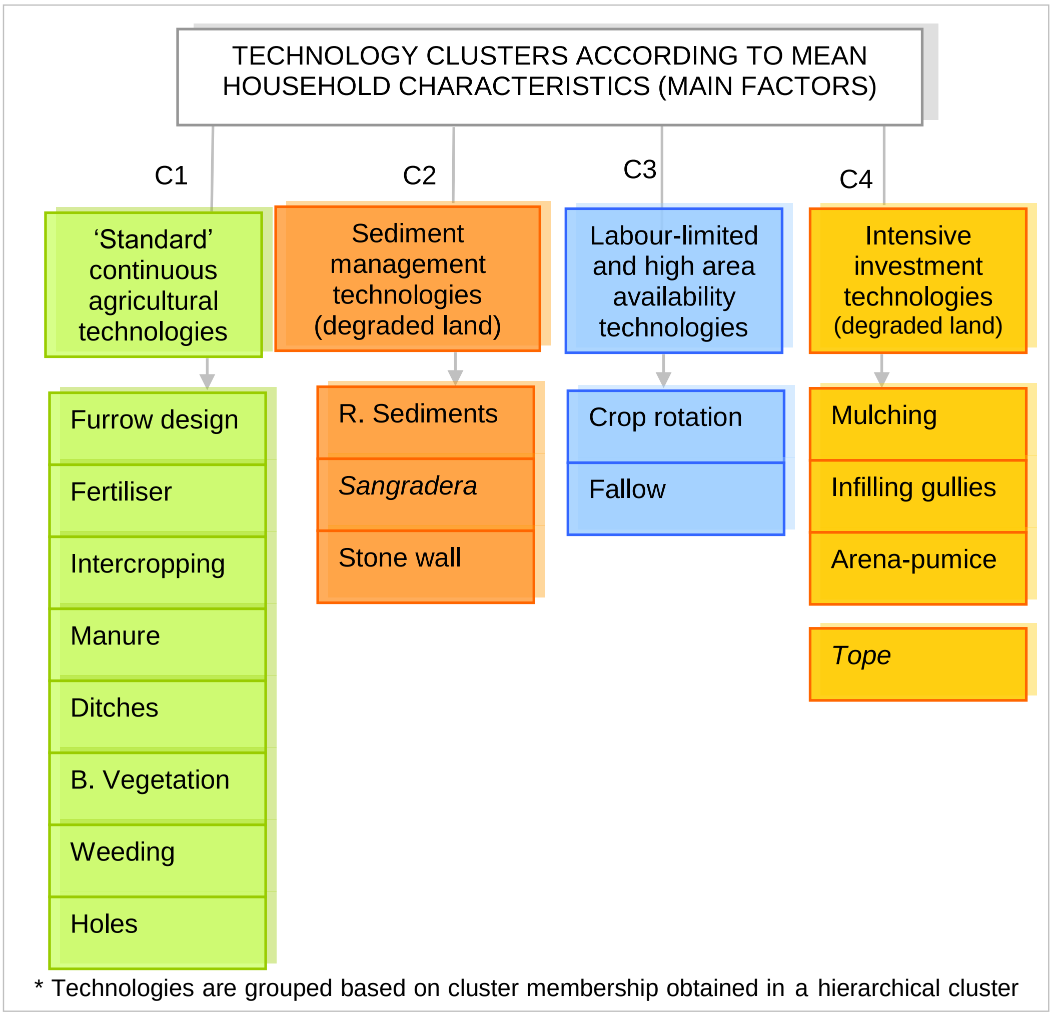


Figure 5.5 Technology clusters based on adopters' mean characteristics.

Source: The author

The first cluster (C1) groups technologies that are generally common or "standard" when there is continuous cultivation of land. There are similar mean values of household characteristics. This cluster represents a "basic package" which could be promoted to farming households interested in producing maize each year. Technologies aggregated in the second cluster (C2) are focused on sediment management. This cluster reflects households that are affected by soil erosion processes and where there is a need to capture sediments, as land might be already degraded or soil fertility needs to be maintained or improved. The third cluster (C3) illustrates households with limited labour and high land availability. These households have more flexibility to take risks such as changing crops or leaving land fallow (i.e. are less risk-averse) due to greater access to land. The final cluster (C4) includes intensive investment technologies[91]. These practices require either large investments of labour, time and/or financial assets. Households using this group of technologies are concerned about improving maize production on land prone to degradation or land that is already degraded. Therefore, they need to invest more and have access to assets involved in their adoption.

The cluster analysis is an intuitive tool which allows groups of technologies with similar driving characteristics and similar household conditions which favour the adoption of LaDC technologies to be understood. This is crucial for the development of strategies directed to land management and conservation. Technology promotion would be addressed according to clusters, targeting specific groups' characteristics to encourage the success of the conservation project.

5.8. Conclusions

In SPT, farmers have responded to land degradation processes through the adoption of technologies. There is a diversity of LaDC technologies – seventeen separate technologies identified in this research - fitting local requirements. Farmers are involved in the decision-making process to select which technologies to adopt, and they design and adapt them to the current conditions. Chavez (2007) defines them as the shaper of their landscape. The current technologies integrate two systems of land management: inherited/traditional management and introduced (promoted) practices. The customary technology summaries enrich the detail and contextualise local land management in Highlands systems. Number, type and general distribution of technologies in a field are partially determined by the fields' attributes, availability of assets and the farmers' needs. Farmers will often choose combinations of technologies which enhance their performance, reduce inputs needed for their adoption and produce

[91] Tope is not grouped in the C4 by the cluster analysis; however, it was located in C4 due to its similarities with the other technologies such as intensive investment in labour and time.

co-benefits. The allocation of assets to the adoption of technologies illustrates the households' strategies to manage and maximise their resources, particularly of land. Slight differences in household assets between La Era and Centro could indicate farmers' preferences for specific technologies. LUTs such as *solar* and *milpa* play a relevant role in the distribution of resources related to control of land degradation. The adoption of technologies changes between *solar* and *milpa*, the first having a more intensive management. The differentiation of land management is focused now on LUT rather than by Sector

The productivity of the units of production, the distance of the plots from home, soil type and religion are influential factors in taking up LaDC technologies in the case study. Likewise, education and age of HH and livestock ownership (equids) are relevant for particular sets of technologies. Identification of clusters of technologies based on the adopting households' mean characteristics is a strategic approach to identify broad adoption similarities. This is important when considering technology promotion and development and implementation of local policies.

The analysis of technology adoption in relation to characteristics, assets, associations, influential factors and clusters contributes to a partial understanding of the farmers' decision-making process regarding land management. However, this process also involves farmers' individual characteristics (perceptions, motivation, attitudes) regarding other outcomes obtained through the adoption of technologies in order to meet specific household needs, which are explored in the next chapter.

Chapter 6. Appraising Multiple Values of LaDC Practices

A farmer who constructs a drainage ditch is better by far than one that sows without it
(Quoted in Amsalu and De Graaff, 2006)

6.1. Introduction

As this research has shown so far, the identification of the biophysical and socioeconomic conditions driving farmers' adoption of LaDC technology explains a substantial part of the ability and rationale of farming households to manage their land (see Chapter 5). However, farmers' knowledge of and decisions about agricultural land management, including LaDC, are also influenced by prior values, motivation, perceptions and experiences, as well as by individual needs (Paudel and Thapa, 2004). Hence, different farmers have different attitudes and commitments to the adoption of conservation technologies, resulting often in widely divergent decisions as to choice of LaDC technology on adjacent farms with similar characteristics. Multiple functionality as perceived by the land user is a primary criterion for the design of most local practices adopted by farmers (Reij *et al.*, 1996). People value multiple functions and enhanced outcomes in their farming practice as they contribute to achieving specific objectives in their livelihoods (Bellon, 2001). This is often contrary to the perception of 'outsiders' such as technical specialists who will often see functionality of a conservation technology solely in terms of its performance in retaining soil or occasionally also in its ability to support production, but rarely in other roles related to land users' livelihoods and social status. Therefore, farmers' decisions about the implementation of technologies may not always be seen as best agricultural and conservation practice by external actors (Paudel and Thapa, 2004, Hammad and Borrensen, 2006, Wilson et al., 2009). Farmers in the case study area choose technologies according to their specific positive and negative effects. How farmers perceive and value these multiple functions is central to exploring the outcomes of LaDC in their livelihoods and revealing the intricacy of land and land-related resource management in hillside areas.

This chapter details the methodology developed in this research to identify and appraise the multiple values associated with LaDC technologies. It presents the values of the technologies as assessed by farmers from three aspects: technology, capital assets and indicators. The analysis focuses on values involved in technology clusters with regard to their impact on capitals and differences in the farmers' socioeconomic standing. The next section compares the rankings of currently adopted technologies with their associated values. Finally, the multiple values linked to the adoption of an LaDC technology and use of livelihood assets is presented

6.2. Multiple values of LaDC practices

The multiple values concept is linked to the multifunctional perspective on agricultural systems (see Chapter 2). This highlights the other services that farming provides in addition to its main function. LaDC technologies are part of farmers' agricultural and resource management activities, thus the implementation of these technologies simultaneously aims to fulfil the various goals and needs of their livelihoods at different times (Hengsdijk *et al.*, 2005). Multi-functionality has both spatial and temporal rationality for land users.

The decision-making process in adopting LaDC practices is strongly influenced by both economic and 'non-rational and subjective aspects' (Kessler, 2006b, p.42). The economic aspect relates to people's interest in increasing production or improving their assets. Critchley and Mutunga (2003, p.159) state that "conservation is never divorced from production in the eyes of the innovators". They point out that conservation practices are usually developed to improve crop production (food and cash income) as a short-term primary aim. The non-rational and subjective aspect involves people's perceptions and motivations, their interests besides the direct economic benefit, which is also defined as intrinsic motivation: doing something because it is pleasant and/or attractive (Kessler, 2006b).

In the case study, growing boundary vegetation is a clear example of the multiple functions or goals achieved through the implementation of an LaDC technology. In SPT farmers choose to plant *maguey* as boundary vegetation because it helps to retain the soil and delimit the fields. The *maguey* has short-term spatial multifunctionality as a boundary marker and conservation practice. Later, when the plants have grown sufficiently, it protects the crops from animals and wind. After approximately 20 years *maguey* is ready for use as *pulque* (fermented drink) for consumption or sale or as a source of income from selling the plants themselves. In addition its leaves are used as fuel or in cooking *barbacoa,* a traditional Mexican lamb dish. From the aesthetic angle some farmers prefer to see their land surrounded by *maguey*, upholding the tradition throughout the Highland area (Chávez, 2007). Therefore, in making an original decision to plant *maguey* the land user will likely have had short-term spatial reasons related to field demarcation and trapping soil, supported by longer-term production opportunities and social reasons; in short, a complex mix of spatial and temporal drivers that might well influence most of an individual's farming career.

Decisions, however, are off-set in land users' minds by costs and lost opportunities. Boundary vegetation involves costs such as reduced area for maize cultivation, harbours pests and animals and competes with maize plants for soil moisture. Farmers identify the evident purpose of plants used as boundaries, yet they recognise that other values attached to technologies (natural, economic and social) directly or indirectly influence their decision to take up this practice.[92]

In view of this, the multiple values concept is useful for examining these aspects of the decision-making process. The different values that each technology represents are linked to farmers' individual perceptions. Identification and appraisal of the values associated with LaDC technologies is central to understanding the hidden drivers conditioning farmers' decisions about resource use. Exploring differences in perceived values helps in the appreciation of how

[92]The function of boundary vegetation to protect land and crops is highly valued by farmers in the highlands of Central Mexico. Socially, this practice could help to keep traditions/customs which could be positively valued such as cooking barbacoa. At the same time there are negative values attached to these practices due to plants' competition for moisture and the potentially productive area given up for hedges.

farmers consider they benefit or lose by controlling land degradation.

This research employs a typology of values derived from the five capital assets used by farmers to develop their livelihoods – natural, human, physical, financial and social – as promoted in the sustainable rural livelihood (SRL) framework (see Chapter 2). The SRL framework employs a capital asset pentagon as a way of differentiating different categories of resources necessary to support livelihoods. This research has similar but more specific objectives, and so it was considered appropriate to borrow the SRL methodology to allocate clearly differentiated streams of resources that might influence a land user's choice of technology. The 'capital asset' typology helps to link specific farming household activities, in this case related to adoption of LaDC technologies, with the management of the current capital assets base and livelihood strategies.

A matrix was designed as a way to appraise the multiple values of LaDC technologies. Initially a preliminary (pre-fieldwork) version described capital value types in relation to the components of technologies in the short and the long term, with no indicators defined. After the first stage of the fieldwork, a set of five indicators per capital were derived, based on data collected from farmers about the benefits and costs of adopting technologies and reasons for taking care of the land. The natural capital indicators selected focus on the impact of technologies on land attributes (i.e. soil moisture, fertility, topsoil, capture of sediments in the field and area). The human capital indicators relate to type of labour and time required in LaDC technologies' implementation from farmers' perspective, involving issues of knowledge, skills and capacity to take on practices (i.e. labour needed - no. of people-, quality of labour-who can do it- referring to age and gender, maintenance labour, skills and knowledge demanded in adoption-specialisation of labour- and impacts of technologies on availability of time to do other activities). The physical capital indicators capture effects that technologies have on access to and management of land (i.e. accessibility of fields for cultivation practices and land manageability after implementation of technologies). These indicators also include access to physical capital such as tools and material needed for adoption and access to land (e.g. nearby roads) because farmers highlighted these as important aspects in their decision to adopt technologies. Financial capital indicators concentrate on the impacts of technologies on crop production, economic land value, household savings and practices as a source of income; farmers' perceptions of monetary investment required to take up technologies is included here. Finally, social indicators address the effects or causes of social norms and organisation and individualistic attitudes in adoption process (i.e. aesthetic, customs and traditions, recognition in the community, personal incentives and networks). The same number of indicators was allocated per capital type so that there was equal initial weighting. At the same time, each indicator per capital type was chosen to be materially different from other indicators in the set so that double-counting of similar attributes was minimised. This typology of values and list of indicators were discussed by the researcher and the key informants in informal interviews to generate the final version of the matrix.[93] The matrix, therefore, contained twenty-five indicators, with each indicator measured by a scoring system related to the short and the long term. It was tested in two trials, in which each farmer assigned scores from 0 to 4 to each of the indicators with 0 = severe constraint/very negative, 1 = slight constraint/negative, 2 = no value, 3 = slight value/benefit, 4 = large value/very good (see *Appendix* III.2)

The objective of this exercise was to establish a framework for valuing the technologies using specific indicators, allowing comparison and analysis of their implications for households' capital assets under a common ground. The scores are used as indicative elements to explore the decision-making process. The exercise did not intend to determine values to be extrapolated at other levels. Nevertheless, it contributed to appraising the values of the technologies in relation to land users' perceptions.

Farmers assessed the 17 LaDC technologies identified in the study area (see Chapter 5) using the matrix. Adoption of technologies, age, gender and farmers' location in the community (covering most areas in both sectors) were the criteria for selection of the farmers participating in the exercise.[94] This increased the variability of responses but allowed capturing perceptions of values of farmers

[93] During the trials the way and type of questions were corrected in order to improve clarity and avoiding leading questions. The measurement of values by means of this method required a participatory approach, in which farmers felt free to express and elaborate on their opinion regarding any of the issues.

[94] Five farmers were not willing to participate; in that case, other farmers with similar characteristics (such as age, gender and farm's location) were invited. Finally, 31 farmers assessed LaDC technologies in this exercise.

with different conditions and experience. The original sampling design intended to use scoring by five adopters and five non-adopters, giving a total of ten measurements per technology. In the event, it proved difficult to achieve this exact balance between adopters and non-adopters, and the design was relaxed to allow additional responses (and in one case – T13 – fewer responses).

Seven small groups of farmers were arranged for the appraisal, which took them about three hours to complete. Farmers in each group generally shared similar conditions such as age, gender or networks. Each farmer individually evaluated at least six technologies (adopted and non-adopted). Due to the nature and dynamics of the groups some technologies were scored by more than ten farmers. The exercise was done individually by five farmers who could not attend the meeting or preferred to do it alone. These changes produced the final number of assessments shown in Table 6.1.

Table 6.1 Number of assessments of technologies by adopters and non-adopters

Technology	Adopters	Non-adopters
T1. Incorporation of *arena*-pumice	8	7
T2. Manure	6	5
T3. Mulching	7	5
T4. Weeding	9	6
T5. Reinstating sediments	6	6
T6. Ditches	6	5
T7. Holes	8	8
T8. *Sangradera*	5	6
T9. Boundary vegetation	8	8
T10. Stone walls	5	8
T11. Intercropping	7	6
T12. Crop rotation	6	6
T13. Furrow design	11	1*
T14. Infilling gullies	11	6
T15. Fertiliser	6	6
T16. *Tope*	6	6
T17. Fallow[95]	5	8

Source: Field data

The values of the scores were changed after a preliminary analysis and recoded so 0=-2, 1=-1, 2=0, 3=1 and 4=2 (originally land users had scored each indicator by using a range from 0 to 4). With this recoding, negative and positive values are better identified (e.g. before, 2 represented “no value” and is now illustrated by 0). The rationale for this change was to capture the negative values that represent trade-offs, and neutral values for technologies that farmers perceive as having no significant function.

Descriptive statistics such as means and standard deviations were obtained using the recoded scores.[96] As the sample size obtained in the field is not as originally expected, the scores of the 25 indicators of adopters and non-adopters are compared using a t-test. The results show no statistically significant

[95] It was not possible to find more cases of non-adopters of this technology in the community.

[96] Despite the fact that values are based on ordinal data, which implies some limitations in the analysis, descriptive statistics and t-test were conducted to manage the data and study the behaviour of the variables.

differences in the mean values of the original database and the final sample size.[97] For a robust data-set, the database with all the cases was used for the analysis. In the following sub-section multiple values associated with the technologies are displayed by technology, capital asset and indicator.

6.2.1. Value of LaDC technologies

The values of the technologies help to reveal farmers' preferences and perceptions in adopting LaDC. Mean scores of indicators per technology were added to obtain the overall value of technologies as appraised by farmers, illustrated in Figure 6.1 which reveals that *arena-pumice* holds the highest value, followed by reinstating sediments, mulching, weeding, infilling gullies and manure. All of these focus on improving soil properties such as depth, moisture and fertility and contribute to reducing soil loss or keeping the soil in situ. The farmer may recognise all these functions. Kerr and Pender (2005) state that reinstating sediments on the field increases the moisture available to plants, as erosion sediments can contain up to five times more organic matter. This supports the farmers' high scores for positive impacts on fertility by reinstating sediments. Medium values were given to other soil erosion control and fertility improvement technologies – furrow design, intercropping, boundary vegetation, ditch and hole – which are generally taken up by households depending on their agricultural activities.

The lowest five mean scores are given to fertiliser, crop rotation, *sangraderas*, stone wall and fallow whose adoption involves constraints or disadvantages as perceived by farmers.

[97]A random selection of the five assessments per technology created a database as originally planned. A comparison between the original database and the final one that includes all cases was needed to identify significant differences. The mean scores of technologies between adopters and non-adopters were compared by using t-test in Excel, results showed no significant statistical differences (a). Later, t-test results of comparing overall mean scores of each indicator between databases indicated that none of the 25 indicators are statistically significantly different using SPSS v 16 (b). Finally, when testing the mean score differences of each indicator (25) per technology (17 types) between databases, only 10 cases are significantly different. This means that 25 indicators by 17 technologies is equal to 425 cases and only 2.35 per cent are different (see appendix VI.1).

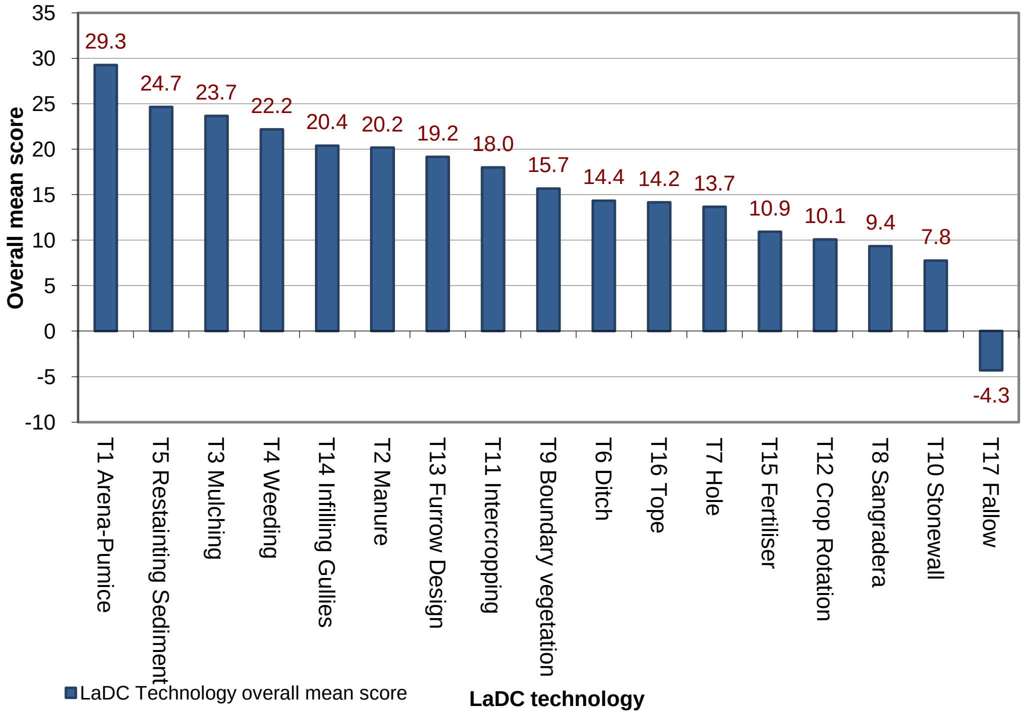


Figure 6.1 Mean score values of LaDC technologies

Source: Field data

Table 6.2 displays mean scores of indicators per technology and capital type. It shows the trade-offs involved in the adoption of technologies as scored by farmers. For instance, fertiliser has a great impact on production but requires access to cash; manure improves soil fertility but has a high impact on other activities. Particularly, fallow scores have negative impacts on social and natural indicators, as farmers express**:**

> *If you do not cultivate the land, the water [rain] drags the soil, the water cuts the land and it spoils the land (Mr Berna)*
> *Other farmers do not cultivate their land because they are lazy (male farmers)*

In Table 6.2 two cases are highlighted in green to point out that adopters and non-adopters have the same perceptions of the impact of *arena-pumice* on humidity and aesthetic indicators, giving a score of 2 (very good). Furthermore, the indicator score (1.9) for *arena-pumice*'s impact on production and topsoil still give a consensus of the benefits of this technology. However, the amount of labour needed for its adoption and access to land are constraints given a score of

-0.3, but farmers say that these are relevant in deciding whether to adopt the practice. The table highlights negative scores in red, the highest scores for each technology in bold and neutral values (0) in grey.

Table 6.2 LaDC technologies: Mean scores according to indicators

Capital	Indicators	T1 pumice	T2 manure	T3 mulching	T4 weeding	T5 r.sed	T6 ditch	T7 hole	T8 sang	T9 BV	T10 SW	T11 IC	T12 CR	T13 furrow	T14 Inf. G	T15 fertiliser	T16 tope	T17 fallow	Total
Natural	Humidity	**2.0**	1.1	0.6	1.3	1.5	0.4	0.8	0.1	-1.3	-0.1	0.5	0.3	1.1	1.5	0.3	0.9	-0.4	10.7
	Fertility	0.9	**1.7**	1.4	1.5	**1.7**	0.1	0.4	-0.2	-0.6	0.2	1.2	**1.1**	0.2	1.4	1.2	0.3	0.2	12.6
	Topsoil	**1.9**	1.1	0.8	1.3	**1.7**	0.5	1.3	-0.4	0.4	0.7	0.0	0.0	0.8	**1.6**	-0.3	0.8	-0.8	11.5
	Capture of sediments	1.4	0.6	**1.6**	1.4	1.3	1.2	**1.5**	**1.5**	1.2	**1.8**	0.7	0.3	**1.8**	**1.6**	-0.1	**1.7**	**-1.5**	18.1
	Area	0.0	0.0	0.3	0.1	0.3	-0.9	-0.9	-0.1	-1.2	**-1.0**	0.2	0.4	0.5	1.4	0.0	0.0	0.0	-1.1
Human	Labour needed (no. person)	-0.3	0.3	1.1	-0.5	0.7	0.9	0.8	1.1	1.3	-0.7	0.5	0.4	1.0	-0.2	-0.1	0.6	0.6	7.5
	Quality of labour (age, gender)	0.6	0.5	**1.8**	**1.6**	-0.6	-0.1	0.9	-0.4	**1.9**	**-1.5**	0.5	0.3	-0.3	**-1.0**	1.3	0.7	0.5	6.8
	Maintenance labour	1.1	0.6	1.3	-0.1	0.5	0.1	0.3	1.1	0.8	-0.1	-0.2	0.8	0.5	0.1	0.8	0.9	0.2	8.6
	Skills/knowledge required ado.	1.4	0.2	1.1	**1.7**	-0.4	0.5	0.4	**-1.5**	1.3	**-1.0**	1.0	-0.4	-0.8	-0.3	-0.1	0.3	0.2	3.5
	Impacts on other activities	0.7	-0.1	0.3	0.6	0.6	0.9	0.6	0.1	0.4	0.0	-0.2	-0.1	**1.6**	-0.7	0.3	0.4	**1.9**	7.5
Physical	Accessibility of fields	1.4	0.7	0.8	0.3	1.0	-0.5	**-1.0**	0.5	-0.5	-0.5	0.6	0.2	0.3	1.3	0.2	-0.3	0.0	4.6
	Manageability of land	1.8	1.5	0.8	0.7	**1.7**	0.3	0.3	-0.3	-0.3	0.9	0.4	0.7	0.8	**1.8**	0.4	0.3	**-1.0**	10.8
	Tools needed for adoption	1.5	0.6	**1.8**	**1.7**	1.1	**1.5**	1.1	**1.8**	**1.6**	0.8	0.8	0.6	1.2	1.2	0.8	**1.3**	0.0	19.2
	Accessibility to land (e.g. road)	-0.3	0.1	0.8	0.4	-0.1	0.0	0.1	0.1	0.1	-0.6	0.3	0.2	0.8	0.2	0.2	0.5	0.2	3.0
	Material needed	1.1	0.1	0.9	1.2	1.0	**1.5**	1.1	0.7	1.1	**-1.0**	**1.5**	0.6	0.9	-0.4	0.0	1.2	0.7	12.2
Financial	Impacts on production	**1.9**	**1.9**	1.4	1.4	**1.8**	0.3	0.3	0.7	-0.4	0.7	0.9	0.9	1.2	**1.5**	**1.8**	0.5	**-1.4**	15.4
	Savings (kind or money)	1.4	1.0	0.8	0.9	1.1	0.3	0.2	0.1	**1.4**	0.5	**1.5**	0.6	0.7	0.6	-0.1	0.1	**1.5**	12.5
	Income source	0.2	0.3	0.3	0.1	0.3	-0.1	0.0	0.0	0.8	0.0	1.2	0.8	0.1	0.4	-0.3	0.0	-0.6	3.3
	Economic land value	1.8	1.2	0.7	0.0	1.6	0.7	0.1	-0.1	0.7	**1.6**	0.1	0.3	0.2	1.5	0.2	0.2	-0.3	10.3
	Money needed for adoption	0.4	0.4	0.7	0.3	0.3	0.7	0.5	1.1	0.7	-0.5	0.2	-0.4	-0.2	-0.6	**-1.6**	0.9	0.1	2.8
Social	Aesthetic	**2.0**	1.2	0.9	**1.7**	**1.7**	1.1	0.4	-0.1	1.3	**1.8**	**1.5**	**1.5**	1.5	1.5	0.9	0.5	-0.8	18.7
	Customs /traditions	1.6	1.5	1.1	1.3	**1.8**	**1.8**	1.3	1.2	1.2	1.5	**1.7**	-0.6	**1.8**	1.6	**1.7**	0.0	**-1.2**	19.2
	Recognition in the community	**1.8**	1.5	1.1	1.3	**1.6**	**1.5**	1.3	0.7	1.3	**1.7**	0.8	0.6	1.5	**1.8**	1.5	1.2	**-1.2**	19.9
	Personal incentives (linked to land)	1.5	1.6	0.7	1.3	**1.7**	1.4	**1.5**	1.0	1.3	**1.6**	1.2	0.1	1.3	1.4	0.5	1.2	-0.5	18.6
	Networks	1.4	0.4	0.7	0.8	1.3	0.3	0.3	0.4	1.3	0.7	1.2	**1.1**	0.8	1.1	1.6	0.2	-0.5	12.9
	Total	**29.3**	**20.2**	**23.7**	**22.2**	**24.7**	**14.4**	**13.7**	**9.4**	**15.7**	**7.8**	**18.0**	**10.1**	**19.2**	**20.4**	**10.9**	**14.2**	**-4.3**	

Adopters and non-adopters are included in the mean score values. Green=the highest mean value in both adopters and non-adopters, red=negative scores, bold=the highest scores of each technology, grey= neutral values (0). r.sed= reinstating of sediments, sang= sangradera, BV=boundary vegetation, SW=stone wall, IC= intercropping, CR= crop rotation, Furrow= furrow design, Inf.G= Infilling gullies.

Source: Field data

6.2.2. LaDC technology value per capital type

Each type of capital is linked to five indicators and their mean scores aggregated according to capital type, as shown in the previous table. This presents a broad picture of how technologies contribute to or affect land users' capital assets based on their evaluation and thus their ability to choose livelihood strategies. Figure 6.2 illustrates the overall scores for capital asset type per technology.[98]

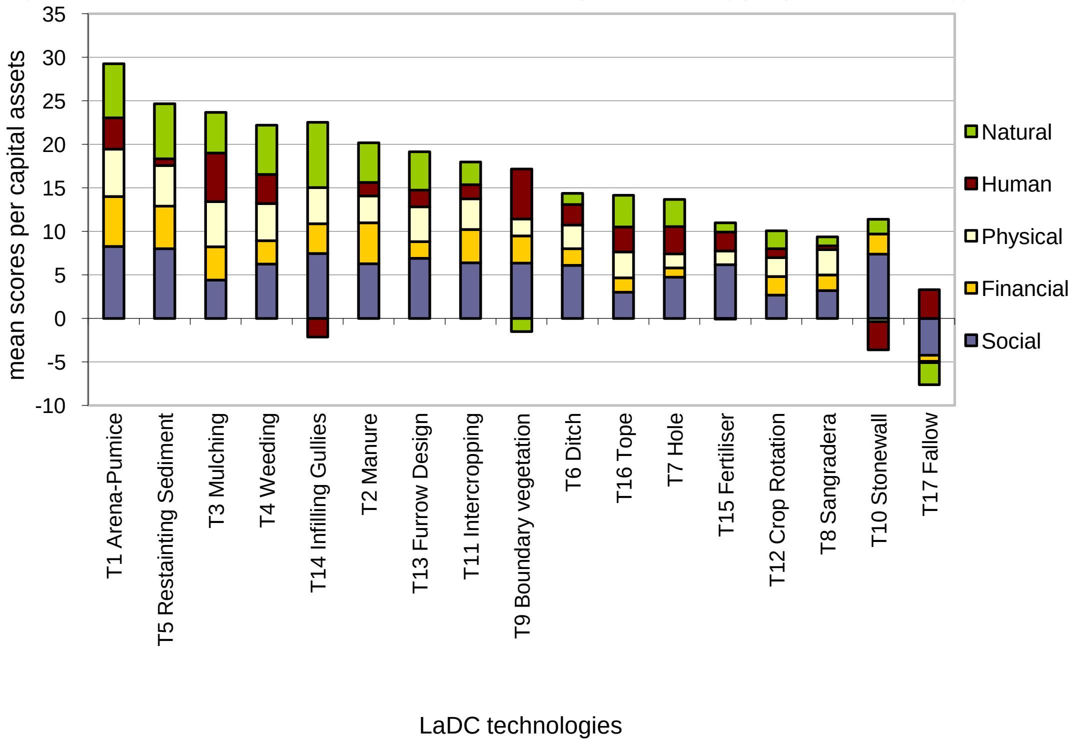


Figure 6.2 LaDC technologies overall scores aggregated by capital asset types

Source: Field data

In the figure, weeding, *arena-pumice*, mulching and *tope* are examples of technologies that deliver positive outcomes and a balanced distribution of values to each of the capital assets. The higher the mean score, the greater the perceived contribution to capital; capitals with low scores reflect farmers' opinion that the technology demands high use of capital assets, decreases the quality

[98] The overall score for each capital is obtained by adding the mean scores of the five indicators corresponding to each type of capital (e.g. overall natural capital score is calculated by the sum of humidity, fertility, topsoil, c. sediment and area mean scores.

and/or quantity of capitals to some extent, or has no relevance. Negative scores denote the main constraints or costs of adopting the technology.

In general, the mean scores for natural, human and financial capitals fluctuate more than those for physical and social capital. Human capital indicators such as skills/knowledge required, quality of labour, amount of labour needed or impact on other activities vary in value across the technologies. Indicators‘ scores of impact on production, economic land value and money needed for adoption scores (financial capital) also shift across practices. This is also observed in the natural capital indicators. The variation in scores reveals how important these indicators are in farmers’ choice of technology. The capitals that fluctuate most in terms of mean values represent potential shortcomings in the practices which could be considered and targeted by local or promoted initiatives in land management

Fertiliser and fallow are two specific cases in which an asset type is not illustrated in the graph. The negative scores cancel out the positive, giving mean values of zero or close to zero. For instance, the mean score for fertiliser’s financial asset is 0.08; this capital has a high positive score for increasing production, which is however counteracted by the negative value linked to fertiliser’s high price in the market. In the case of fallow, the positive scores for the physical asset are reduced by its negative implications for the manageability of the land, which gives it a mean value of -0.15. The trade-off of values is inherent when implementing practices which in turn affect farmers’ use of assets and choice of technologies for adoption.

Figure 6.3 shows five technology pentagons - capital mean scores in a visual representation of how the technologies are linked to farmers’ capital asset base. For instance, boundary vegetation has positive values in most capital types except natural assets, as plants compete for space, soil moisture and nutrients (see appendix VI.2).

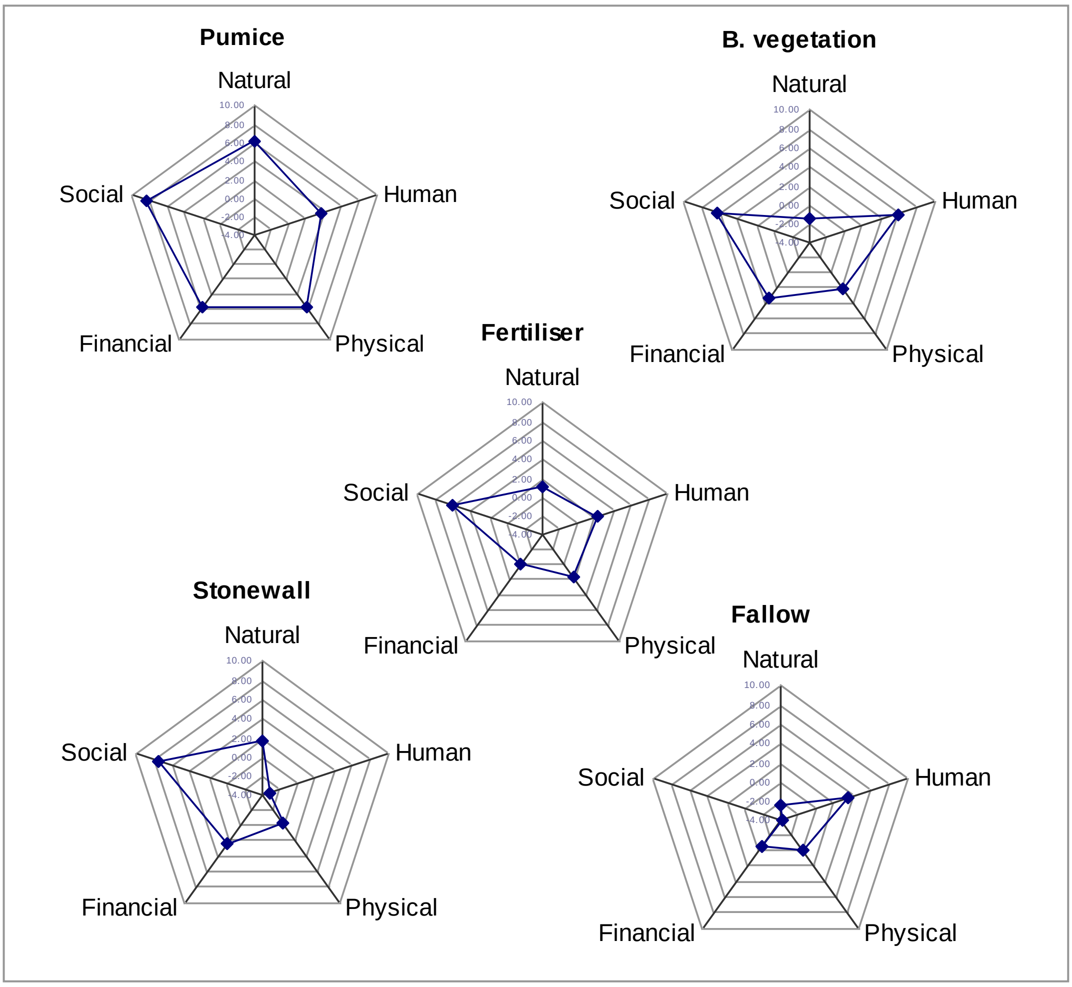


Figure 6.3 Examples of values given to LaDC technologies in relation to capital assets

Source: Field data

The fertiliser pentagon provides evidence of farmers' awareness of its limited contribution to improving or managing natural, human and physical assets. Its values are associated with impacts on fertility, quality of labour, crop production, customs/traditions and networks. As Mr Paulo says:

> *I think fertiliser is not good to land but maize plants "ask for it". That is why I combine manure and fertiliser. I put manure and a handful of fertiliser, but only to fool the plant…I need to buy fertiliser but I do not receive PROCAMPO because it is only given to their* [farmers friends of PROCAMPO staff] *friends. (Male farmer, 54 years old)*

The short-term benefits are the main reason for its adoption. The social belief is as follows:

> *Without fertiliser there is no maize production. If you want to harvest enough maize you need to apply fertilisers…you can use manure but there is not enough, and it is very expensive and difficult to transport.*

The methodology employed to appraise LaDC technologies has some limitations because of its simple scoring and the equal weight given to each indicator and each type of 'capital asset'. Thus, a high score for physical capital may be not as influential as a low score for human capital in deciding on what practices to adopt because a land user may attach greater importance to demands for labour – human capital – than to the equipment needed to construct a conservation measure – physical capital. The equipment, for example, could perhaps have been borrowed whereas the labour demand might have impacted on other opportunities in the household. To adopt a more detailed weighting exercise would have required assumptions and evidence beyond the scope of this research, and which would also have been subject to possible criticism. Therefore, specific scores with the equal-weight method employed should be treated with caution. However, such scoring does help to capture the multiple values attached to technologies and how farmers value them differently. There is an evident association between indicators, which could be considered a double-counting issue. For instance, fertility, humidity and reinstating sediments are related to productivity. However, farmers' perceptions about the increased productivity do not represent their views on how natural capital (e.g. soil depth, humidity) is benefited or affected by the adoption of each technology. Identifying how a specific technology could improve or undermine specific indicators is relevant in targeting particular problems and adopting the appropriate strategies. The appraisal of specific and related indicators shows how natural capital changes can be associated with production and other economical indicators as also with social, physical and human aspects. Furthermore, the scores provide empirical evidence of the technologies' performance and their links to the household asset base.

6.2.3. Indicators

To identify patterns between the indicators, all the farmers' scores were initially ranked and grouped according to their mean value.[99] Later the indicators were grouped using cluster analysis in the statistical analysis software used, SPSS. The groups created by cluster analysis and those created by ranking of means are similar, with the exception of four indicators. The cluster analysis groups were chosen because standardisation (Z-score) involves the standard deviation (SD) and sample mean (including all technologies).[100] However, three indicators were reallocated to a different cluster as originally proposed by the cluster analysis.[101] The changes take into consideration frequency of score, type of indicator and mean values to generate better groups. Table 6.3 presents the indicators according to the five corrected clusters, which are labelled according to their nature.

[99] Mean value of indicators based on scores of all 17 technologies by adopters and non-adopters.

[100]The scores of each indicator (25 variables) are clustered by using hierarchical cluster analysis in SPSS v.16. Ward's method, squared Euclidean distance (similarity measure) and standardising values (cases) by Z scores are chosen for this analysis (Field, 2000) (see appendix VI.3). The four indicators that differ are aesthetic, maintenance (labour), labour (no. people) and money needed.

[101] Reallocation of indicators is based on the mean, SD values and percentages of frequencies. Aesthetic indicator is moved from C2 to C1, and labour from C3 to C4 because their means and SD values are more similar to the other clusters. Maintenance is on the boundary between both clusters but is moved from C4 to C3 due to distribution of frequencies. The mean and SD values for money are low compared to other indicators grouped in C3. It is kept in this cluster due to similar frequencies and is related to inputs.

Table 6.3 Indicator clusters of LaDC technology values

Asset indicators (clustered)	Indicators	Mean Value	Standard Deviation	Total mean score	% Positive, neutral & negative values per cluster
Social Agenda Highest scores	Recognition	1.19	0.98	19.9	>71% positive 5-19% no value <18% negative
	Tools needed	1.14	0.91	19.2	
	Custom/Tradition	1.14	1.30	19.2	
	Personal Incentives	1.11	1.09	18.6	
	Capture of sediments	1.09	1.08	18.1	
	Aesthetic	1.12	1.09	18.7	
Agricultural Determinants Outputs Medium high	Impact on Production	0.89	1.12	15.4	42-67% positive 23-53%no value 4-16% negative
	Networks	0.78	0.92	12.9	
	Fertility	0.74	0.99	12.6	
	Savings	0.76	0.93	12.5	
	Topsoil	0.72	1.07	11.5	
	Manageability	0.65	1.05	10.8	
	Humidity	0.64	1.13	10.7	
	Economic land value	0.62	0.90	10.3	
Inputs medium	Material needed	0.71	1.37	12.2	44-59%positive 19-23% no value 20-32% negative
	Impact on other activities	0.43	1.37	7.53	
	Money needed Maintenance	0.09	0.09	2.82	
		0.49	1.13	8.59	
Human assets low	Labour for adoption	0.42	1.42	7.54	49-59%positive 9-12%no value 29-41%negative
	Labour Quality	0.42	1.45	6.79	
	Skills (labour)	0.26	1.45	3.54	
Land Access /area Constraints Lowest scores	Access of land	0.27	1.12	4.6	13-38% positive 37-63 no value 17-25% negative
	Access to land	0.17	0.90	3	
	Area	-0.06	0.78	-1.1	
	Income source*	0.21	0.69	3.29	

This indicator holds 77.6 % of neutral values (score of 0), higher than other indicators in the same cluster.

Source: Field data

The first cluster aggregates indicators with high scores that are mainly related to social aspects. One of the interesting outcomes of the surveys is that farmers generally say that they adopt technologies on the basis of crop production and improving the land; however, when they scored the technologies using the indicators in this study they rated social values more highly. The scores show that farmers (adopter and non-adopters) value the impacts of implementing LaDC technologies in their incentives, their recognition as good farmer and in following traditions. For instance, Mr. Teode expresses the aesthetic value of boundary vegetation:

> *I planted little cedar trees (Cupressus spp.) at the bottom of the gully in the calvario field to protect my [soil]. Now my trees are big, every morning I go and visit them. I like sitting there for at least half an hour to look at them… I like the countryside, I like the green colour of plants… I like the nature that God has created… this is beautiful.*

In general this cluster holds high values: Farmers rarely appraise the adoption of technologies with negative scores with regard to social indicators, with the exception of fallow. While keeping land fallow is recognised as a means of restoring fertility, it is widely held that fallow characterises a land user that does not manage land properly or a farmer who is lazy. Other technologies are seen more in a social light of measures taken positively by farmers. This line of reasoning is pursued further in the next chapter in considering trade-offs. The high scores denote indicators with a more defined positive function, perhaps showing that farmers value the technology for hidden or indirect reasons. These indicators may indirectly influence the type of technology adopted. This highlights the importance of careful analysis of multiple values, not just from the verbal responses but also from the semi-quantitative scoring, and indicates that farmers' verbal responses are sometimes conditioned by their expectation of what the researcher would like to hear.[102]

The second cluster includes indicators focused mainly on increasing the economic value of land and crop production through improving land characteristics, primary reasons for adoption expressed by land users. Thus the technologies' outputs regarding these indicators are highly valued. However, indicators in this cluster do not present the highest values, as the negative values given to certain technologies counteract the positive values of others, reducing the overall score of each indicator. For instance, humidity scores are high in *arena-pumice* incorporation and negative in boundary vegetation, affecting the score for this indicator. Network social aspects are also found in this cluster and this is a key attribute of social capital in subsistence agricultural livelihoods in hillside environments.

The third cluster involves indicators linked to inputs with medium values. High

[102] Farmers are generally familiar with issues related to productivity, although such issues may not have been prioritised by them to the extent that a professional researcher might have prioritised them. Therefore, in response to questions on productivity, farmers would expect that the researcher would rate this aspect highly and would respond accordingly to please the researcher. This is a common problem in research, for which triangulation is necessary – see discussion in Chapter 3.

demand for money/materials, maintenance labour or other activities is perceived as a constraint to households, generating negative scores and reducing the total mean value. In Chapter 5 labour is not statistically significant as an influential factor; however, the amount of labour perceived necessary for adoption may explain its influence when deciding whether or not to take up a technology by households. For instance, a stone wall requires scarce or expensive material and continuous maintenance.

Cluster 4 contains indicators related to human capital such as specialised knowledge, experience, skills or gender involved in implementing technologies; this impacts negatively on the scoring. It represents the effect of lack of education or training as a constraint in adopting specific technologies. The following quote expresses constraints to accessing materials (Cluster 3) and the type of labour needed to adopt technologies (Cluster 4).

> *Now it is very difficult to find arena [arena-pumice soil]: the deposits are far away. In the past my [male] children helped me…we could go 15 times a day to collect arena for a week or two. But now they have migrated and my wife cannot go because it is dangerous: there are bad people or animals in the forest and it is not work for women; then it is more difficult to bring arena to the land (Mr Franco)*

The fifth cluster arranges indicators associated with land access and area. The indicators for accessibility of and access to land show low values, responding mainly to no influence on adopting technologies (zero values) or constraints (negative values). Physical capital regarding accessibility of and to fields is not highly valued by farmers. The reason is that these are exogenous elements in the adoption of technologies, particularly, access to land since farmers do not decide where roads or paths are to be constructed in the area (it is a matter of community level organisation). Therefore, these physical indicators are not relevant in the attachment of technology's values (as pointed out in the previous section). Area is the only element with negative scores, which implies trade-offs that need to be explored. Income source is not relevant in the appraisal as 70 per cent of scores are neutral.

I planted fruit trees at the bottom of the field because there they do not get in the way (Mr Lupe)
I do not like tope because is difficult to walk in your milpa and it's easy to fall down. (Mr German)
It is better if there is a road next to your field because it is easier for the animals to enter and work the land (Mr Oscar)

When focusing on indicator level, clusters with low to mid-high scores show more dynamic interactions between indicators. These clusters appear to capture the benefits and costs involved in technology adoption, revealing possible current opportunity costs faced by farmers in making decisions between choice of technologies. The analysis indicates that with these low to mid scores, trade-offs are more likely to be operating – an aspect pursued in the following chapter.

6.3. Technology clusters and values

The scores given to the technologies and their implications for capital assets and indicators have been detailed to reveal their particular effects on farmers' interests and preferences. In this section the analysis focuses on exploring values aggregated by technology cluster (as identified in the previous chapter); particularly exploring the contributions of these clusters to farmers' capital asset base.

LaDC technologies adopted in the study area are grouped into four clusters according to similar specific household conditions for adoption (see Chapter 5). The cluster classification – C1 to C4 – is deliberately characterised to bring out clearly-defined differentiated features of how groups of technologies operate in the farming system. The C1 Standard cluster involves technologies generally applied by households depending on their agricultural activity. The C2 Sediment management cluster represents technologies focused on capturing and replacing sediments and is related to land degradation. The C3 Labour/Area cluster consists of technologies linked to limitations in labour, access to greater land area and risk-averse attitude. Finally, the C4 Intensive Investment cluster captures technologies that require considerable investment of money and labour on degraded land.

Mean values of the technology clusters are estimated per capital asset type. Indicators' mean scores are added in per cluster and presented in Figure 6.4. According to the results, C1 and C2 show similar positive values in all capitals apart from human, as C2 requires a specific quality of labour (who is doing it) and skills/knowledge related to reinstating of sediments and stone wall technologies. The technologies in C3 are valued for their contribution to human capital assets, particularly their impact on time available for other activities, but attracted the lowest and most negative scores in other capitals. Farmers consider that the technologies in cluster C3 (fallow and crop rotation) are not beneficial to their social and natural capital assets, as lazy farmers are not well thought of in the community.

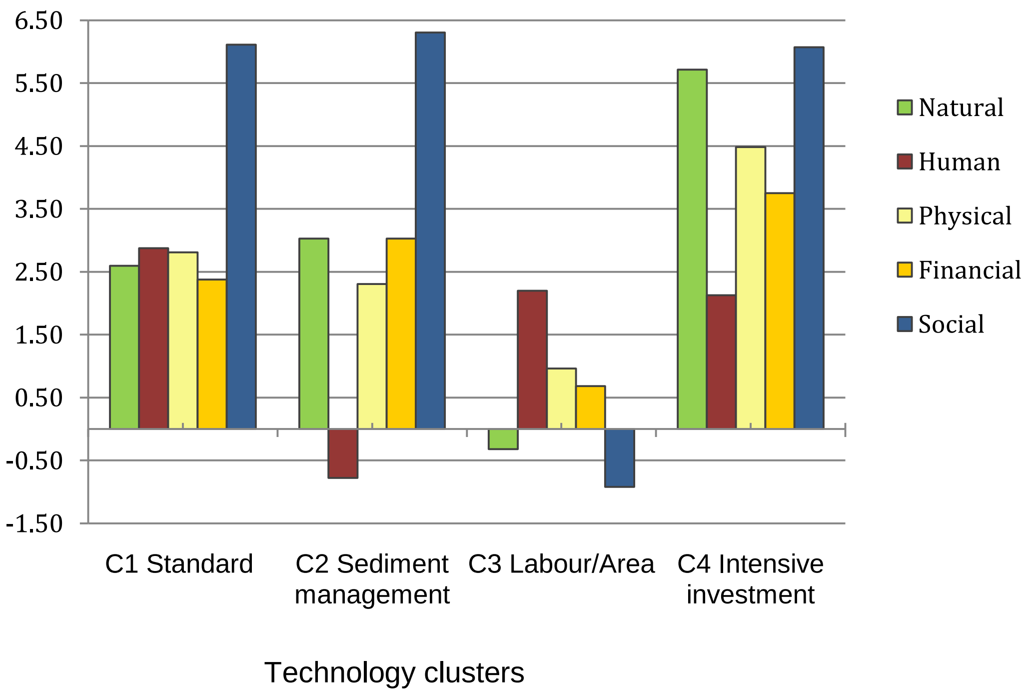


Figure 6.4 Mean values of technology clusters per capital asset type

Source: Field data

C4 presents high mean scores and the most balanced distribution between capitals apart from human capital. Its high values in natural and financial capitals are driven by the practices of *arena-pumice* and infilling gullies in this cluster. Material can be freely collected from communal areas using own draught animals. These technologies involve mainly male labour and focus on improving and restoring degraded land. Their adoption requires fewer physical capital assets, an aspect that farmers value.

The Kruskal-Wallis nonparametric test was used to compare the scores of the technology clusters in order to identify specific differences between indicators. The results show that 18 of the 25 indicators have statistically significant differences (at $p \leq 0.05$) across the four clusters (see *Appendix* VI.4).

Natural capital: Humidity, topsoil, capture of sediments, area;
Human capital: Quality of labour, skills/knowledge, impact on other activities;
Physical capital: Accessibility of land, manageability, tools needed, access to land;
Financial capital: Impact on production, economic land value;
Social capital: Aesthetic, customs, recognition, personal incentives and networks.

In particular the test results show that the five social capital indicators are statistically significantly different. According to the highest mean scores, C1 is highly valued regarding customs and traditions, as technologies included in the cluster are part of standard agricultural practices followed in SPT to cultivate maize and support the historical legacy of agricultural practices. C2 is greatly valued for both aesthetic and personal incentives to manage land. Some farmers underline their interest in having a specific feature such as a stone wall on their land or improving the land's characteristics (e.g. soil depth increase due to reinstating sediments). They highlight the incentive to pass on improved land to their children. C3 presents the lowest values in social capital, they are linked to negative perceptions regarding personal incentives and customs, lack of interest or 'laziness' to work the land well or taking care of the land (fallow) and changes in traditional farming practices which may not be well seen by some farmers (crop rotation) . Finally, C4 achieved high scores in recognition and networks. Farmers account for the high value of recognition by explaining that infilling gullies provides extra area for cultivation, *arena-pumice* increases humidity and yields and mulching improves fertility. These practices are associated with good, hard-working farmers. In contrast, *tope* technology, in this cluster, is carried out by a few farmers who consider themselves innovators but are seen in the community as “mad farmers”.[103] C4 helps to enhance land properties in the long term.

6.3.1. Adoption and technology clusters

The methodology for technology appraisal required the assessment of the conditions necessary for their adoption by adopters and non-adopters. As values attached to technologies are subject to people’s experiences, interests and other surrounding factors, differences in scoring were expected.

> *Adoption of technologies is highly dependent on the assumed benefits and risk attached as well as the personal perceptions and attitudes of the farmers…Assessment is largely dependent on the personal attitudes of the individual farmers which again are influenced by family-related and farm-specific factors. Their attitude is strongly influenced by own experience and acquired knowledge (Satler and Nagel, 2010, pp.70-73)*

In order to explore differences in adopters’ and non-adopters’ values, the mean scores for the technology clusters[104] were aggregated by adoption, as summarised in Table 6.4

[103] The local perception of farmers as “good”, “mad” or “lazy” is explored in Chapter 7.
[104] Mean scores of technology clusters are calculated from aggregating the values given by adopters and non-adopters

Table 6.4 Technology clusters and values according to adopters and non-adopters

Capital	Criteria	Adopters C1	Adopters C2	Adopters C3	Adopters C4	Non-adopters C1	Non-adopters C2	Non-adopters C3	Non-adopters C4
Natural	Humidity	**0.8**	**1.3**	0.2	1.4	**0.1**	**-0.1**	-0.2	1.2
	Fertility	0.8	0.8	**0.9**	1.1	0.5	0.4	**0.4**	1.0
	Topsoil	**0.9**	0.9	-0.4	**1.6**	**0.4**	0.5	-0.5	**1.0**
	Sediments Capture	**1.3**	**1.9**	-0.5	1.7	**0.8**	**1.3**	-0.8	1.4
	Area	-0.2	-0.2	0.3	**0.6**	-0.5	-0.4	0.1	**0.3**
Human	Labour needed for adoption (no. person)	**0.9**	0.7	0.8	**0.7**	**0.0**	0.0	0.3	**-0.4**
	Quality of labour needed for adoption	1.0	-0.9	0.7	0.5	0.7	-0.8	0.1	0.3
	Technology maintenance labour	**0.6**	**0.9**	0.6	**1.1**	**0.0**	**0.1**	0.3	**0.3**
	Skills and knowledge required for adoption.	0.6	-1.3	**0.5**	0.4	0.6	-0.7	-0.6	0.8
	Impacts on other activities	**0.9**	**0.9**	1.4	**0.5**	**0.0**	**-0.4**	0.6	**-0.3**
Physical	Accessibility of plot	0.1	**0.8**	0.0	**1.2**	-0.2	**-0.1**	0.1	**0.5**
	Manageability of land	**0.6**	0.8	-0.2	1.4	**0.3**	0.9	-0.2	1.1
	Tools needed for adoption	**1.4**	1.6	0.4	1.5	**0.9**	0.9	0.2	1.3
	Accessibility to land (e.g. roads)	**0.4**	-0.4	0.2	0.3	**0.0**	-0.1	0.1	0.3
	Material needed	**1.3**	0.3	0.9	0.6	**0.5**	0.2	0.4	0.7
Financial	Impacts on production	0.9	1.2	-0.1	1.5	0.8	1.0	-0.4	1.3
	Savings (kind or money)	0.8	0.8	1.5	0.8	0.7	0.4	0.8	0.7
	Income source	0.2	0.0	0.4	0.2	0.3	0.2	-0.2	0.3
	Economic land value	0.4	1.1	0.2	**1.3**	0.3	1.1	-0.1	**0.9**
	Money needed for adoption	**0.5**	**0.9**	-0.1	0.3	**-0.3**	**-0.3**	-0.2	0.2
Social	Aesthetic	**1.5**	1.4	0.8	**1.5**	**0.8**	1.1	-0.1	**1.1**
	Customs traditions	**1.8**	1.7	**-0.4**	1.2	**1.1**	1.4	-1.4	**1.2**
	Recognition in the community	**1.6**	1.6	-0.1	1.7	**0.9**	1.2	-0.6	1.3
	Personal incentives (related to land)	**1.6**	**1.8**	**0.4**	**1.5**	**0.8**	**1.2**	**-0.7**	**0.9**
	Networks	1.0	0.8	0.5	**1.0**	0.7	0.9	0.1	**0.7**
	Total mean score per clusters	**22.6**	**20.1**	**9.8**	**26.2**	12.3	11.7	-0.3	20.0

Source: Field data

A Mann-Whitney test was conducted to explore significant differences between adopters' and non-adopters' indicator scores by technology cluster. Table 6.5 lists the indicators with statistically significant differences at $p \leq 0.05$ (one-tail: see *Appendix* VI.5). The results confirm that adopters' mean scores are higher than those of non-adopters in all significant indicators.

According to the t-test results there are statistically significant differences between adopters' and non-adopters' mean scores across the four clusters (at p≤ 0.001) (see Appendix VI.6).[105] In general, adopters gave higher scores than non-adopters. Differences in values are explained to some extent by experience in LaDC technologies. Adoption provides knowledge about real costs and benefits as opposed to speculation. It also helps to appreciate other values which may be evident only after implementing a technology (the low/negative scores reflecting constraints or negative appraisal).

Table 6.5. Indicators with significant differences between adopters and non-adopters

	C1 (Adopter n= 61, NonAdopter n= 45)	**C2** (Adopter n= 16, NonAdopter n= 20)	**C3** (Adopter n= 11, NonAdopter n= 14)	**C4** (Adopter n= 32, NonAdopter n= 24)
Natural	Humidity Topsoil Capture of sediment	Humidity, Capture of sediments*	Fertility	Topsoil Area
Human	Labour Maintenance Impacts. on other Activities.	Maintenance, Imp. on other Act	Skill/knowledge	Labour maintenance Imp. on other Act
Physical	Manageability land Tools needed Access.. to land Material Needed	Access. of land	______	Accessibility of land (*Tope*)
Financial	Money*	Money	______	Eco value land*
Social	Aesthetic Customs Recognition Personal Incentives	Personal Incentives	Customs Personal incentives	Aesthetic Personal incentives Networks

*Significant at p=0.052 (one-tail); Adopters (n=120) and Non-adopters (n=103)

Source: Field data

[105] T-test results from comparing clusters' mean scores between adopters and non-adopters using Excel software show p values ≤ 0.001 (see appendix VI.4)l

For instance, in this case of recognition indicator, values might be recognised during or after implementing a technology. As a farmer expresses:

> *I was infilling gullies in my field and a researcher from CICA approached me and asked me to explain what I was doing. Since then, I have been working closely with researchers. People in the community notice that they come to talk to me and to see my fields. My work has been recognised by a person that has gone to the school [with higher education]. I went to a meeting in Michoacán [State] with farmers from other places…and now I like to experiment more to see what happens in my fields. (Mr Leode)*

Non-adopters might equally raise or lower the indicators depending on their perceptions of what others have gained or lost in taking up a technology.[106] For instance, 69 per cent of adopters rank the adoption of C1 technologies "very good" (scores of 2) for the recognition indicator in contrast with 26 per cent of non-adopters. Comparing appraisal based on experience of adopting LaDC technologies provides an insight into perceived values before and after the implementation of technologies, allowing the identification of differences between the two scenarios.

6.3.2. Farmers' characteristics and technology clusters

Appraisal may be subject not only to the experience of implementing a technology but also to differences in farmers' characteristics. Therefore differences in scoring were analysed in relation to the following characteristics: gender, age, religion, wealth proxy, education and family type. The indicators' mean scores of specific groups of each characteristic were initially compared by conducting t-tests and then with nonparametric tests such as Mann-Whitney (two groups) or Kruskal-Wallis (more than two groups). Results with statistically significant differences ($p < 0.05$, one-tail) revealed which of the above variables are relevant in the valuation of indicators.[107] The results identified statistically significant differences in the scores of the technology indicators between groups

[106] According to Sambodo (2007), the neighbour effect affects farmers' adoption of technologies as each farmer influences and is influenced by others in different ways.

[107] In the t-test and non-parametric test, p value < 0.05 in a one-tail test was chosen unless otherwise indicated, as it was expected that some groups would have higher scores. This is explained for each specific case.

of each characteristic, split by technology cluster.[108] Following nonparametric analysis the tests displayed mean rank values which allowed identification of the groups with the highest overall ranking, which corresponds to the highest scores.

In Table 6.6, the groups with the highest mean rank score for each characteristic that is also statistically significant at $p< 0.05$ (one-tail) are presented per technology cluster.

[108] This analytical stage required a large number of parametric and nonparametric tests. It is acknowledged that performing so many tests increases the probability of false positive results (identifying differences between groups where there is none). However, the tests were carried out with the purpose of obtaining an overview of the differences in appraisals by farmers' characteristics. The results revealed predicted and outstanding differences which were examined and linked to the characteristics of the cases included. Nonparametric analyses were used as categorical and ordinal (ranked) scales with very small samples are not normally distributed and groups have heterogeneous variances.

Table 6.6 Statistically significant indicators per technology cluster according to farmers' characteristics (highest mean ranks)

Indicators	C1	C2	C3	C4
Humidity	Adopters	Adopters	Literate	
Fertility			Adopters	
Topsoil	Adopters, Protestant			Adopters
Cap. Sed.	Adopters, Solitary, Illiterate	Adopters, Male		
Area	Young		Old	Adopters, Illiterate
Labour needed	Adopters			Adopters, Nuclear
Quality of labour	Female, Young, Poor,			
Maintenance labour	Adopters, Female	Adopters, Extended	Old, , Solitary	Adopters, Male
Skills and knowledge		Old , Catholic	Adopters, Catholic, Nuclear	
Impacts on other Act.	Adopters	Adopters, Male,		Adopters
Accessibility of plot		Adopters, Illiterate		Adopters, Illiterate
Manageability of land	Adopters, Female			Illiterate, Nuclear
Tools needed	Adopters		Old	
Accessibility to land	Adopters, Female, Young, Nuclear		Young, Poor	
Material needed	Adopters, Male, Medium	Nuclear	Old	
Impacts on production				Catholic, Nuclear
Savings (kind/ money)				Catholic
Income source	Catholic	Young, Poor	Literate	Young, Catholic,
Economic land value	Protestant, Illiterate	Catholic		Adopters
Money needed	Extended	Adopters, Protestant, Extended	Illiterate, Solitary	Male
Aesthetic	Adopters, Male, Illiterate			Adopters
Customs traditions	Adopters	Illiterate	Adopters, Catholic, Solitary	Illiterate
Recognition	Adopters, Protestant			Illiterate
Personal incentives	Adopters, Male, Protestant, Medium	Adopters, Male, Illiterate, Solitary	Adopters, Catholic, Rich	Adopters, Illiterate
Networks	Male, Rich		Literate	Adopters, Male, Catholic, Rich, Illiterate

C1: Standard agricultural practices. C2: Sediment management practices. C3: Labour and land availability related practices. C4: Intensive investment practices. *All cases significant at one tail $p<0.05$

Source: Field data and analysis

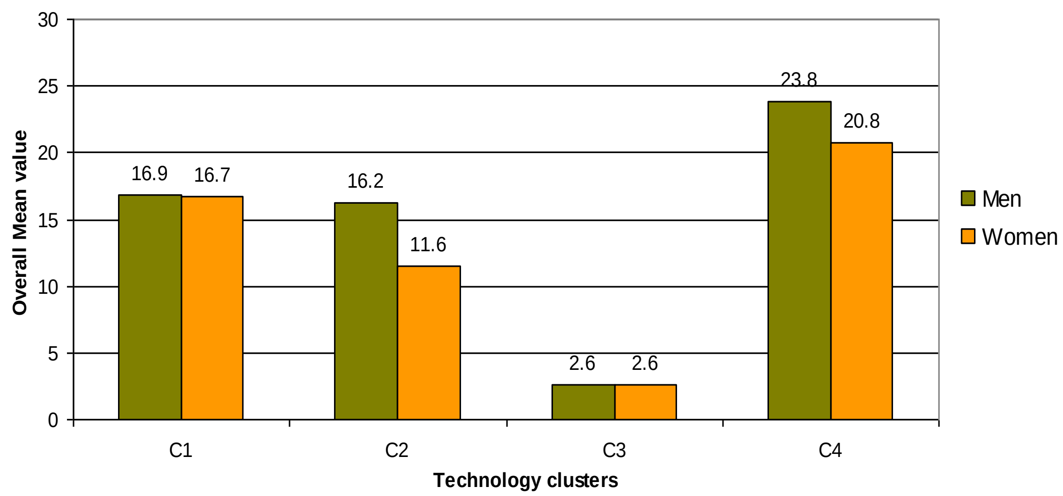
Gender

In the study area male HH farmers are typically in charge of land and crops. Female HH farmers are normally responsible for housework, grazing, weeding and harvesting. A female farmer mentions:

> My husband is now working in Mexico City and I need to take care of my land and look after my kids, the house and the animals. It is a lot of work…if I need to dig a ditch or sangradera I pay a peon to do it for me or I wait until I can or a relative can help me. (Mrs. Laura)

Female HH farmers face different challenges to those of male farmers, such as their restricted knowledge about the land, lack of experience and shortage of time. This raises the question whether gender affects valuation of LaDC technologies. The initial hypothesis was that men would value technology indicators (particularly human and physical capital) more, as they are traditionally responsible for LaDC activities. In Figure 6.5 mean values of technology clusters differentiated by gender of household head are presented. A paired-sample t-test indicates that there is a statistically significant difference between mean values for male and female farmers in C2 and C4.[109] Both clusters involve practices mainly adopted by men as they involve heavy labour (i.e. require digging out sediment from drains and putting it back on the land, building stone walls, digging *tope* or incorporating *arena-pumice*). C1 and C3 are not significantly different (see *Appendix* VI.7a).

[109] Indicator scores are aggregated by mean values according to sex and technology cluster. One-tail p≤0.05 value was chosen as it was expected that men would value indicators more than woman (in C4 p=0.051).



C1= Standard continuous agricultural technologies, C2= Sediment management technologies, C3= Labour limited and high area availability technologies, C4= Intensive investment technologies.

Figure 6.5 Mean values of technology clusters by gender

Source: Field data

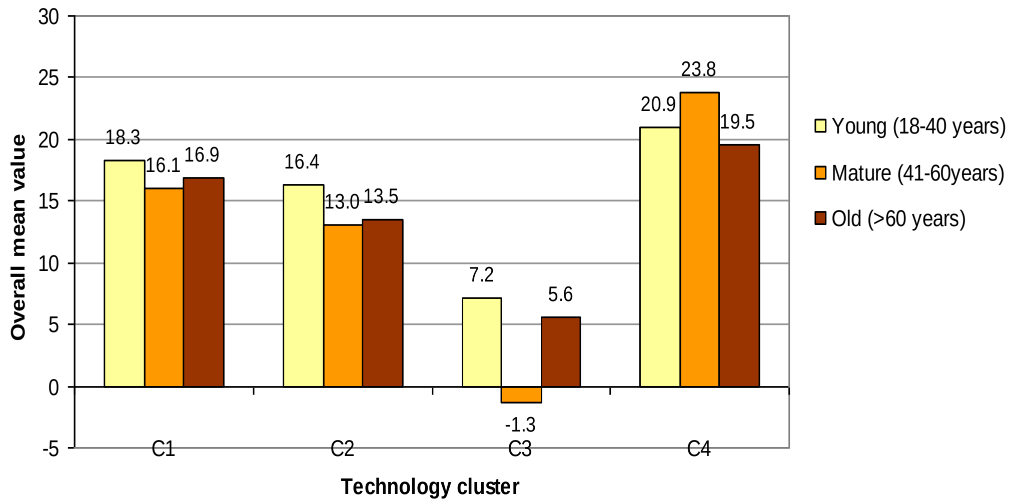
A Mann-Whitney test suggests that there are indicators with significant differences in women's and men's scores (see *Appendix* VI.7b). The mean ranks of C1 show that men score social indicators and material requirements higher than women. Particularly, they appreciate the social function of C1 in underpinning networks (i.e. through selling *maguey* from their field boundaries to other households or exchanging labour). Interestingly, male farmers value the aesthetic aspect of their units of production and their personal incentives more highly than female farmers (i.e. food self-sufficiency, improvement of land, leaving a legacy for their children usually to men). Men consider that the adoption of technologies in C1 does not require good access to land or much in the way of materials. In contrast, women's mean scores for C1 indicated a higher regard for specific human and physical indicators. They reveal that most of the technologies in this cluster do not require a specific type of labour – "Anybody can do it … men, women, children" – and only need low maintenance.

Men value the control of run-off (technologies in C2) slightly more on increasing labour availability for the adoption of other technologies or related agricultural activities. With regard to C4, men value the low maintenance requirements and the small sums of money needed for adoption as well as the potential for strengthening networks.

Women scored C2 and C4 technologies lower than men in indicators such as personal incentives, networks and money needed for adoption, and proved more likely to be non-adopters.[110] In SPT the adoption of these practices is viewed as men's work which may be considered to constrain culturally or physically the women wishing to adopt them. Moreover, intensive management may not be a priority for women because of lack of labour or interest in farming activities.

Age

The age of the farmer (land manager) may influence his/her attitude, experience and motivation in adopting technologies. It was expected that older farmers in the study area who are usually dependent on agricultural activities may value indicators related to labour more than younger household heads, as old farmers are more likely to adopt a technology (see Chapter 5). Mean values of each age group per cluster are presented in Figure 6.6. According to the results, mature groups are statistically significantly different to the young and old groups in C3 and to the old group in C4 (all significant at $p < 0.05$, one-tail). This group may require more land for maize cultivation to feed their children and therefore fallow is not attractive for them.



C1= Standard continuous agricultural technologies, C2= Sediment management technologies, C3= Labour limited and high area availability technologies, C4= Intensive investment technologies

Figure 6.6 Mean values of technology clusters by age groups

Source: Field data

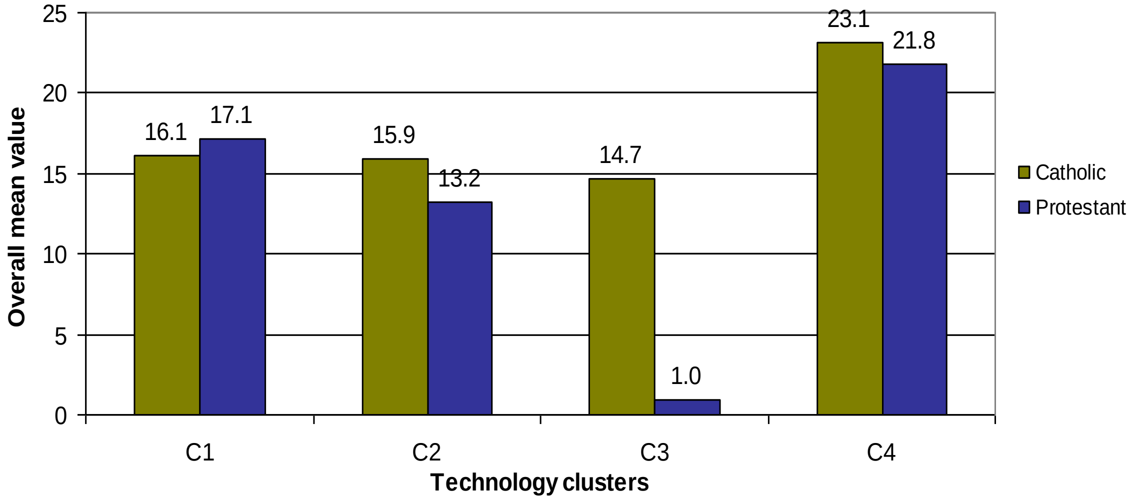
110 Non-adopters: 44 per cent of males and 66 per cent of females in C2; 24 per cent of males and 58 per cent of females in C4.

The results of the Kruskal-Wallis test suggest that old farmers consider that C3 practices do not use up land area and inputs (maintenance labour, tools or material), as reflected by their high scores. This is to be expected, as they face shortages of labour and income. The mean ranks indicate that the old group do not consider that specialised skills and knowledge are required to adopt technologies in C2 as they may already have more experience of implementing these, thus this indicator attracts the highest scores. The younger group gives the highest scores to indicators in C1. Young farmers value these technologies more highly as their implementation does not demand so much skilled labour or good access to roads. The oldest group scores the least in these indicators as they may perceive more valuable benefits from intensive labour technologies (see *Appendix* VI.8).

Religion

There is a marked difference between Catholic and Protestant church members in the study area. This religious differentiation could influence farmers' assessment of LaDC technologies. Protestant farmers generally appeared to give higher scores to indicators than Catholics,[111] but the t-test results indicate that there is only a statistically significant difference between Catholic and Protestant mean scores in C3. This may be explained by differences in sample size: the Protestant group is considerably larger, causing different sample distributions. It also can be related to differences in the number and size of landholdings owned by Protestant farmers which tend to be smaller than those by Catholics. Other clusters do not show statistically significant differences in the means. Mean values are presented per group and cluster in Figure 6.7, below.

[111] This takes into consideration that religion was identified in the previous chapter as an influential factor in the adoption of LaDC practices in the study area and that Protestant church members show a positive influence on taking up specific technologies (see Chapter 5). The two main sectors of the SPT community are highly associated with religious practice (r=0.7). Centro is mainly Catholic and La Era is predominantly Protestant, as mentioned.



C1= Standard continuous agricultural technologies, C2= Sediment management technologies, C3= Labour limited and high area availability technologies, C4= Intensive investment technologies.

Figure 6.7 Religion and mean values per technology cluster

Source: Field data

However, Mann-Whitney test results detected statistically significant differences between Catholic and Protestant farmers' indicator scores (see Appendix VI.9). Protestant farmers have higher mean ranks than Catholics in four indicators related to standard agricultural technologies (C1) such as the contribution of practices to improving top soil depth and economic land value. A Protestant farmer mentions:

> The value of a piece of land that has been cultivated is higher than that of one which has been abandoned or where the water has cut the soil. (Mr Pedro)

Recognition and personal incentives were also highly rated by Protestant farmers. An examination of frequencies shows that 88 per cent of these farmers are mature or over 40 years old and are therefore more dependent on agricultural activities, explaining the values of these indicators to some extent. Catholics see C1 technologies as a possible source of income from the sale of boundary vegetation such as *maguey* to produce *pulque*. Protestants are encouraged not to drink alcoholic beverages and therefore the value of *maguey* as a source of income is lower. In addition, *pulque* is being superseded by carbonated soft drinks for all household members, particularly men.

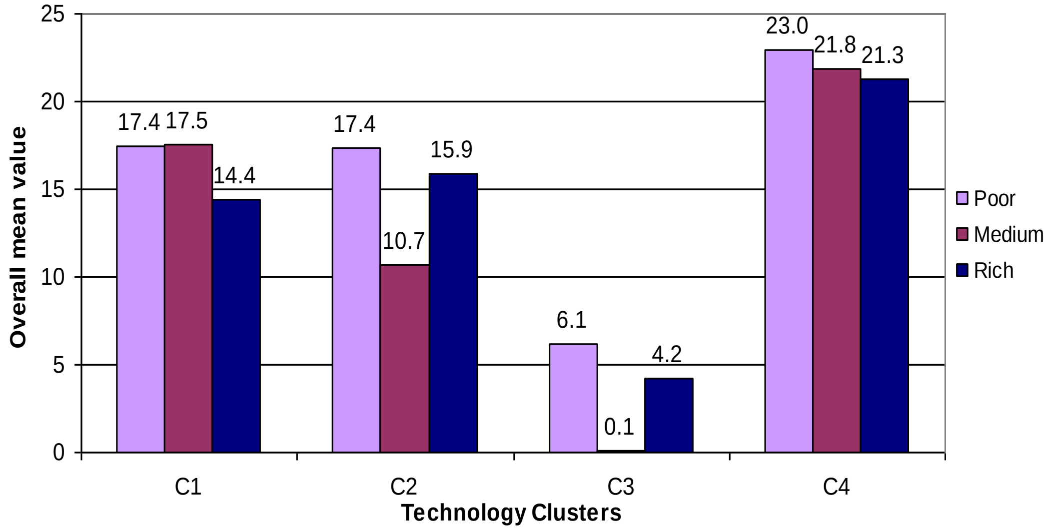
Regarding C2 values, Protestants gave higher scores to the money indicator than Catholics. This is linked to two factors; the first is that Protestant farmers use their available labour for these activities and therefore do not consider that much financial investment is needed to hire labour; the second is that the difference between the mean rankings of Protestant and Catholic farmers is explained by the high proportion of non-adopter Catholic farmers in this cluster, with 7 out of 9 Catholics non-adopters in comparison to 14 out of 27 Protestants. Being mainly non-adopters, Catholics rate the low demand for skills and knowledge in adopting C2 practices and how they may help to increase the economic value of land higher based on their perceptions rather than experience. In C3, all the Catholic farmers are adopters, generating higher mean scores in skills/knowledge and customs and personal incentives.[112] For instance, C3 is not highly valued by Protestant farmers, as it is not their practice to leave land uncultivated. While keeping land fallow is recognised as a mean of restoring fertility, Protestant farmers depend more on on-farm activities and smaller landholdings than Catholic. Thus, they keep cultivating their land each year to meet households' maize demand for self-consumption. In addition, Protestant farmers usually owned more livestock (e.g. sheep and mules) than Catholics, demanding more quantity of forage to feed their animals. This reduces in some cases the opportunity to fallow land. Finally, Catholics' mean rank scores are higher in C4 in networks and three financial indicators: impact on production, savings and income source. These last indicators may reflect the impact of these practices on the household economy. In general, the results show that Catholic farmers present higher mean ranks in most indicators across clusters than Protestant ones(except C1).

Wealth

Considering claims that degraded land and declining production demand resources from poor farming households in order to develop their livelihoods, differences in wealth may reveal differences in how farmers assess LaDC technologies. This research examines such differences using wealth proxy

[112] Protestant farmers' mean ranks include scores from adopters and non-adopters, which may reduce the overall value because non-adopters may score some indicators negatively.

categories for poor, medium and rich households as defined in Chapter 4. The overall mean values of the technology clusters are differentiated by wealth category and are presented in Figure 6.8.[113]



C1= Standard continuous agricultural technologies, C2= Sediment management technologies, C3= Labour limited and high area availability technologies, C4= Intensive investment technologies

Figure 6.8 Overall mean values of technology clusters by wealth category

Source: Field data

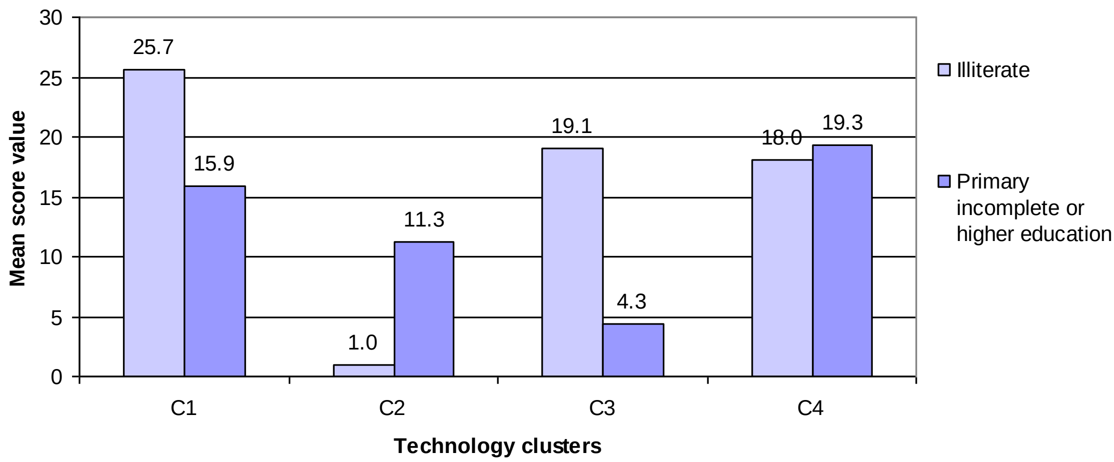
The Kruskal-Wallis test results show few indicators with statistically significant differences in scores across wealth categories (see *Appendix* VI.10). The quality of labour needed, in terms of who can adopt technologies, by C1 practices is rated higher by poor farmers than by other groups. Medium-wealth farmers allocate higher scores to material and personal incentive indicators in C1 than other groups. Rich households generally give higher values to networks in C1 and C4 and personal incentives in C3 than other groups. For instance medium wealth farmers may lack of labour to carry out farming activities or may owned livestock, increasing forage demand therefore, they do not leave land fallow. They are better adopters of these clusters because they have greater access to

[113] A T-test revealed significant differences across clusters. C1 rich households' mean score is statistically significantly different from those of poor and medium households; C2- medium households' valuation is statistically significantly different those of poor and rich; C3- Poor households' means are statistically significant different from medium; C4 no statistically significant difference.

assets such as land, social capital and money, or have secured maize production for a certain period.

Education

Access to education to some extent influences how farmers appreciate technologies and their associated values, as it provides external knowledge input and interests (see Chapter 4). Thus lack of education may be linked to following traditional knowledge and practices. Mean values of each education category per technology clusters are shown in Figure 6.9.



C1= Standard continuous agricultural technologies, C2= Sediment management technologies, C3= Labour limited and high area availability technologies, C4= Intensive investment technologies

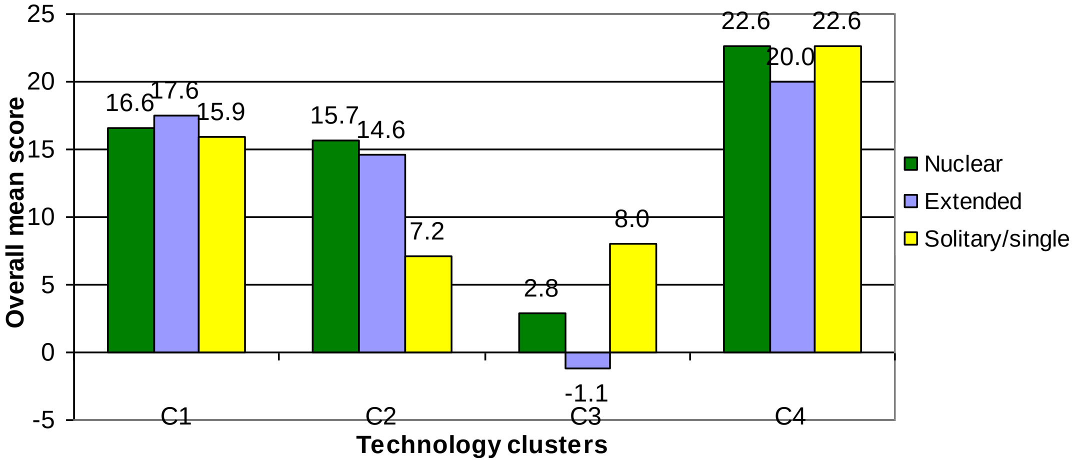
Figure 6.9 Mean values of technology clusters by education category

Source: Field data

According to the results of the Mann-Whitney test (see *Appendix* VI.11), illiterate farmers give higher scores to most of the indicators across clusters than those who had access to education. Illiterate farmers value the performance of C1 standard practices in capturing sediments, increasing the economic value of land and aesthetic aspects. A cultivated unit of production under continuous management and with control of soil erosion has a higher economic value for farming households than one without it. Likewise, illiterate farmers assigned high rankings to C2 technologies that improve the accessibility of land, traditional management and personal incentives. Finally, uneducated farmers consider the practices in C4 are particularly good as they do not reduce area for crop cultivation, they improve the manageability of the land and strengthen social values (customs, recognition, personal incentives and social networks). Illiterate farmers' rankings highlight the negative impact of fallow on soil humidity through longer periods of exposure to climatic conditions without the protection of crops and income. In contrast, literate farmers (with incomplete, primary or higher education) only gave higher values indicators of humidity, income source and network in C3. However, slightly more of them are non-adopters of these technologies than illiterate farmers.

Family type

Family type allows a somewhat simplistic measure of the availability and type of labour that would be needed for the adoption of LaDC technologies. The assignment of values may be associated with family type (nuclear, extended, or solitary or single mother).[114] Figure 6.10 shows the mean scores for the technology clusters disaggregated by family type.



C1= Standard continuous agricultural technologies, C2= Sediment management technologies, C3= Labour limited and high area availability technologies, C4= Intensive investment technologies

Figure 6.10 Mean values of technology clusters by family type

Source: Field data

[114] Family type is significant factor in the logistic regression results in specific technologies, specifically extended type in comparison with nuclear.

Farmers in nuclear families related particularly to human capital demands for technology adoption – specifically, they picked out the limited need for skills/knowledge to adopt C3 and the low labour requirement for C4 practices. These mean score values were significantly higher for those living in extended and solitary households. Adoption by the nuclear families in these clusters is low (see Appendix VI.12). Extended families' scores reflect the fact that they find it easier to obtain materials for C1 practices and appreciate the low maintenance and small financial requirement of C2. A large family can provide more labour and in some cases additional income from members with paid work than from the other family types. Solitary families value the contribution of C1 technologies (mainly those linked to run-off control technologies and saving labour) in capturing sediments more than the other family types. Moreover, they appreciate the personal incentives associated with C2 (e.g. their children inheriting better-quality land). This type of family usually faces labour constraints, which makes them appreciate the low maintenance and small financial outlay in C3 technologies. In addition, farmers of solitary families score higher the custom indicator in C3, which could be related to their age or the possibility of meeting their maize needs more easily than nuclear or extended families. Therefore, they are able to leave some of their units of production fallow.

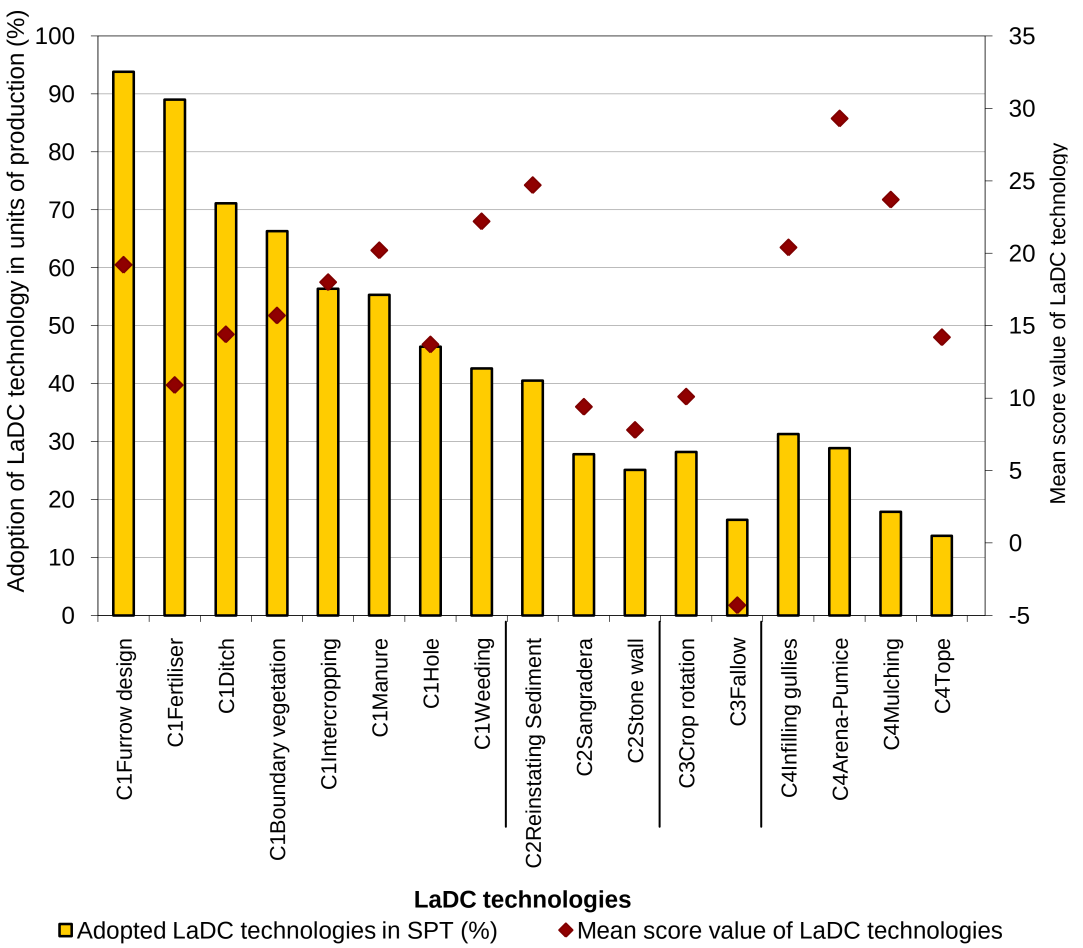
There is heterogeneity of conditions and values in each technology cluster. In most cases, the non-parametric test results confirm score differences between indicators across groups depending on the characteristic selected. However, the adoption criteria are critical in the appraisal of values of LaDC technologies, as they present more consistent significant differences between indicators. Farmers' education, religion, sex, and family type are relevant to better understand their evaluation of specific indicators across clusters.[115] These characteristics explain partially regular constraints reflected by the farmers' scores such as lack of labour, materials, money, and knowledge. This complements the previous findings from the logistic regressions regarding factors influencing the adoption of technologies. The farmers' scores reflect the complexity of how they value the different technologies, but provide a framework to explain the rationale of

[115] The significant correlations between characteristics at $p \leq 0.05$ are presented as follows: very weak correlations ($r \leq 0.2$): education & sex (+), education & religion (-), education & family type (-); weak correlation ($r=0.3$): religion & family type; medium correlation ($r=0.4$): has family type & sex (-).

particular cases which could be targeted by strategic actions per groups according to each cluster.

6.4. Ranking values and current adopted technologies

This section presents the mean scores for the technologies as assessed by the farmers and the percentage of farmers adopting them. In the case study area, results obtained from the general survey (see Chapter 5) are presented in Figure 6.11. The graph links the perceived values of the technologies with their current adoption rate.



C1= Standard continuous agricultural technologies, C2= Sediment management technologies, C3= Labour limited and high area availability technologies, C4= Intensive investment technologies

Figure 6.11 LaDC technologies' mean scores value and rate of current adoption in the SPT (%)

Source: Field data

This study is based upon the hypothesis that the most valued practices are those that are adopted most in SPT. However, the data show another perspective. Standard technologies in C1 are adopted most and have medium to high mean values (e.g. boundary. vegetation, ditch and fertiliser: the higher the percentage of adoption, the lower the score values). Technologies in C2 are given a combination of medium and high values which may tally with their adoption, except for reinstating sediments, for which the values are higher. In C3, fallow is accorded low values in comparison to its adoption. This means that land users choose this practice even if they consider it not very good for the land or in their personal interests. This may be a response to biophysical or socioeconomic constraints such as lack of labour or distance to units of land. In contrast, crop rotation has a value higher than its rate of adoption would suggest. Finally, it is remarkable that the technologies in C4 are the most valued and the least adopted.

Technologies with high values are linked to intensive investment, which involves much time, money and/or labour. Farmers usually adopt these practices in degraded fields as they are effective in improving soil properties. The adoption may be gradual, or may occur when resources become available. Farmers consider that not all units of production need intensive practices and nor is their implementation always viable, particularly in flat areas and depending on soil type. As one farmer expresses:

> *Colorada [red soil type] needs a lot of water: it dries quickly. It eats the arena, you put a little bit and next year there is nothing left, it's all gone. You never win with colorada. It is better to put arena in tepetate and mix it with manure. (male farmer, 70 years old)*

Farmers recognise and value the impact of these technologies but are not interested in adopting them as their plots do not demand it, the benefits are not clearly perceived or they lack the needed resources.[116] Furthermore, mean values per capital show that technologies with high social value such as *arena-pumice*, weeding, or reinstating sediments are not widely adopted. This could

[116] For instance, according to the sample of 291 pieces of land, SPT has 30 per cent *colorada* soils, 13 per cent *negra* soil and 12 per cent *arena* soils. These three soil types represent around 55 per cent of total soils and do not require the incorporation of *arena*-pumice or gully-filling practices (see Chapter 4).

indicate that when the decision to implement a practice is taken social values may be relegated in order to achieve household food demands, short-term benefits and improvements in other capitals such as financial capital from crop production or natural capital from sediment capture. On the other hand, farmers may need to adopt technologies with high social value in specific units of productions in order to gain the desire social benefits, therefore their interest in implementing usually intensive labour or expensive practices in other fields decrease.

Social indicators usually accord with the factors that appear to control the clustering of technologies into distinct categories (see Section 6.3.) such as customs and traditions linked to standard agricultural practices (C1), aesthetic and personal incentives in sediments management technologies (C2), negative values in personal incentives and custom in fallow and crop rotation activities (C3) and high values in recognition and network related to intensive investment practices (C4). Social capital values are indirect factors influencing farmers' decision regarding adoption of technologies which in most of the cases generated positive side effects. However, this appraisal does not allow determining to what extent social capital drive in the decision-making process or how it is trade-off by other values in order to meet primarily needs as food security and improvement of natural assets base, issue analysed in the next chapter.

As observed in the appraisal of values, land users acknowledge which technologies are appropriate to improving soil attributes and controlling soil erosion. The farmers' appraisal also shows the relevance of their perceptions in choice of LaDC, Farmers evaluate their options to adopt a technology according to their asset base and intrinsic motivation. They may implement a technology even if it is not the most desirable or effective one, due to scarcity of assets. Therefore farmers' decisions on LaDC often do not match those promoted by external stakeholders. And their actual decisions may not reflect the value they say they put on the technologies.

6.5. Multiple values and livelihood assets

The multiple values linked to the adoption of technologies and the availability of assets are illustrated in the following example concerning the incorporation of manure in SPT. Differences between La Era and Centro are highlighted.

SPT farmers generally use manure on their *solars* because this type of land is close to the house and livestock shelter. In this way they save on transportation and labour costs. Manure is not only linked to improving soil properties such as fertility, moisture and the protection of topsoil; it also implies livestock ownership as a household livelihood strategy. Arriaga-Jordan et al. (2005) give a detailed analysis of the role of livestock in SPT farming livelihoods:

> *The goal of campesinos is to own their working animals which enable them to undertake ploughing and cultivation task at optimal times allowing for better performance of crops... Owing their animals means saving cost on renting ploughing teams for tilling and cultivation…Cattle are kept mainly to produce claves that are raised and sold when there is a need of cash or when prices are favourable. Cattle are seen mainly as a means for long term savings and for adding value to forage resources* (Arriaga-Jordan et al., 2005, p.832).

Ownership of livestock provides households with diverse benefits. For instance, owning sheep is very valuable because they graze on common land, thereby not incurring fodder costs; they provide manure, the benefits for which last for about three years and, most importantly, they are seen as a form of insurance against future shock (Gonzalez et al., 1996b). The number of sheep that households own has increased due to demand for *barbacoa* (a lamb dish) to sell or eat on important social occasions such as birthdays and weddings. Shelters for sheep are usually built next to the house and their quality depends on the sheep's economic contribution to the household (*op cit*). The many uses of sheep make them a significant element in the economic stability of hillside communities of SPT.

Sheep manure requires women's labour, while manure from equids is related to men's labour. Therefore the gender of the available labour influences the type of manure used in the land. According to Arriaga-Jordan et al. (2005), households living in SPT now use horses and mules as draft animals instead of bulls, which are traditional in the region. This change reflects variation in needs and values. Bulls are difficult to manage for old people on steep slopes and have higher feeding and shelter costs. Despite cattle providing larger quantities of manure than other animals, farmers generally prefer to own sheep, horses and poultry (see Table 6.7) which are easier to sell or exchange and to manage.

Table 6.7 Sources of manure and performance

Source of manure	**Length of time the benefits of manure lasts**	**Observations**
Cattle	4 years	Provide more manure than other animals and is the preferred type
Sheep	3 years	Most common but provide less manure than cattle. May be enough for a plot (usually used on *solars*)
Horse /mule	4 years	Provide less than cattle but more than sheep
Poultry	Up to one year	Applied to a small garden or individual ornamental plants

Source: Adapted from Arriaga-Jordan et al. (2005), and field data

Households can access to different types and quantities of manure depending on the livestock ownership. According to the survey data, 41.8 per cent of households in La Era own 7 to 15 sheep and 7.3 per cent more than 15 sheep, 69 per cent of own two or more heads of equids (e.g. horses or mules) and 35.5 per cent of have one or more heads of cattle. In Centro, 30 per cent of households have 7 to 15 sheep, 39 per cent of households own two or more heads of equids and 17 per cent own cattle (commonly one to two heads). This suggests that there could be greater availability of manure in La Era than in Centro, which may influence farmers' decisions to apply it to the land.[117] Farmers say that the manure available to them is not enough to cover all the plots of land they hold. Therefore they prefer to use it on their *solars*, on plots of higher economic value or on rented private land (Chavez et al., 1998; see also Chapter

[117] Manure from poultry is not taken into account, as the quantity and use do not impact significantly on land productivity in farmers' plots. It usually is applied to ornamental plants and trees growing next to the house.

7). Manure is highly valued for improving soil fertility: however, its adoption implies trade-offs related primarily to livestock ownership, space for animal shelters and personal interests. The trade-offs involved in adopting technologies are explored more fully in Chapter 7.

6.6 Conclusions

The multi-functionality of LaDC practices induces farmers to associate a series of values with each technology related to a complex system of value-sets which this chapter has sought to explore. This analysis of multiple values of LaDC based on capital asset typology has identified a common standpoint from which to evaluate the technologies. This typology helps to link specific actions such as the implementation of the technologies and their likely impacts on a household's asset base. The appraisal method employed in this study is a useful tool for analysing farmers' perceptions of multiple values. Its limitations regarding weighting issues and the interpretation of certain scores are recognised: nevertheless, the combination of semi-quantitative and qualitative analysis allows a better understanding of farmers' rationales for adopting and valuing particular functions of technologies.

Examination of the scores reveals important differences in values according to type of technology, capital assets and indicators. The most valued technologies are those that improve soil properties and at the same time contribute to reducing soil loss. The most fluctuating scores in capital asset types per technology expose potential shortcomings in the choice of technologies for land decisions. Low and middle scores for indicators reveal interesting value trade-offs as assessed by farmers. Results at the technology cluster level reveal that indicators are valued differently according to the specific characteristics of the household head, such as first-hand practical experience of the technology, education, religion, sex and family type.

The analysis suggests that farmers' main priority is producing maize for household consumption and fodder. Hence, they favour economic value as represented by increased crop production. Any technology directly or indirectly contributing to this objective attracts a high score. However, there are other values that offer indirect benefits and influence land users' decisions to a lesser extent but which may be critical in final adoption. These are related to the social implications of practices: recognition, developing social networks and aesthetic land value. The findings highlight how perceptions and allotment of value may vary according to type of technology and the household head's socioeconomic characteristics and practical experience of the technology in question. Farmers in SPT have a high adoption of technologies which encompass more trade-offs. For instance, short vs. long term outcomes; technology area vs. crop area; money vs. labour; short vs. long distances are some of the common trade-offs farmers face in their decisions about land management. Their decisions about allocating resources in land management involve trade-offs that vary according to their household asset base, land users' interests and needs and pressures from the surrounding environment. Trade-offs is the subject for research in the following chapter, as this chapter has clearly demonstrated that trade-offs form part of the farmer-perspective rationale for decisions over which technologies to employ for land degradation control in SPT.

Chapter 7. Trade-offs in LaDC practices

There are no solutions, there are only trade-offs.
(Tomas Sowell)

7.1. Introduction

As analysed in the last chapter, different farmers assess the multiple values associated with LaDC technologies in different ways. There are gains and losses to be negotiated in each technology, and multiple issues to be considered in each combination of technologies. Multiple values indicate the possible trade-offs involved in the adoption of one or more technologies. Decisions about trade-offs may depend on farmers' needs, interests and the surrounding environment. Perceptions may differ among the stakeholders involved. Therefore an exploration of farmers' trade-off choices is central to appreciating land management in an agricultural context. This chapter will reinforce one of the conclusions of this research that approaches to land degradation control and sustainable land management must capture the values and complex realities of land users who are the guardians of the land and managers of the technologies that will conserve the land for future generations.

This chapter addresses the trade-offs involved in the adoption of LaDC technologies in the Mexican Highlands. Based upon an analysis of the actual trade-offs made by the farmers taking part in the case study, the implications for farmers' livelihoods are explored. This chapter presents the framework developed for approaching trade-offs in LaDC from the farmer's perspective. These explain the trade-offs from three main perspectives, spatial, temporal and intrinsic, which are influenced by the external factors defined below. The objective of this chapter is to explain farmers' technological choices in land management in order to gain a better understanding of their decision-making processes.

7.2. Trade-offs

In hillside farming systems, trade-offs are an inevitable and unavoidable part of farming life. Forced by scarcity of assets and challenging environmental, economic and political contexts, farmers make decisions daily about where to allocate their resources. Trade-offs are part of households' strategies to sustain their livelihoods; they involve forsaking one technology in order to adopt another, balancing the costs and benefits of one over the other in the simplest of cases. The multiple values linked to technology adoption are involved in these trade-offs (see Chapter 2). A trade-off is defined as a choice in general terms of what, where, when and how much a value or objective associated with technologies will be forsaken or not in their adoption (Wolf and Allen, 1995). As identified in previous chapters, decisions about trade-offs among LaDC technologies are influenced by factors such as farmers' personal interests and needs, appraisal of value, past experience and knowledge, the availability of assets and stakeholders involved. Moreover, socio-economic conditions and institutional pressure from local and national policies affect farmers' trade-offs due to their influence on household livelihoods (see Chapter 4). Trade-offs involved in the adoption of LaDC practices are attracting growing interest in discourses on natural resource management (NRM). Hence they are central to our current understanding of production dynamics, decision-making processes in resource management and livelihoods.

7.3. Farmers' perspectives of LaDC trade-offs

In exploring the factors involved in accepting or rejecting a technology, this research has already found a number of trade-offs in farmers' adoption of practices in SPT (i.e. trade-offs made in terms of area, production, labour, distance). Trade-offs are not only influenced by economic or productivity-related factors: they also entail other social benefits and utilities. The evidence shows that trade-off decisions are not easy to disaggregate as they are nested within each other, adding complexity to the analysis. In order to bring some order to the complexity and to study the trade-offs made by farmers in the case study area this research focuses on a categorisation of three broad types which appear to capture most of the issues involved in the farming systems and local society: trade-offs between LUT; short- and long-term temporal trade-offs; and trade-offs informed by farmers' experience and the values they attach to the technologies they are choosing between.

The rationale for selecting LUT is based on historical and current differences in the management of *solar* and *milpa* LUT, particularly regarding the adoption of LaDC practices (see Chapter 4). These are recognised broadly by all involved in the study as the two primary land use types, between which many decisions have to be made over allocation of resources. The focus of land utilisation is linked to the biophysical conditions, area and location of each unit of production. This generates a land-based view referred to in this research as a '**spatial'** perspective.

Land users distribute the inputs and outputs of LaDC practices over time, identifying and differentiating the costs incurred and the benefits gained at various times within the production time horizon – and sometimes beyond. Timing of benefits/costs is central to the adoption of technologies. For instance, farmers take up LaDC technologies at different points in the agricultural year to meet their goals and avoid overlapping activities (e.g. labour-demanding technologies are carried out before or after activities which by their very nature are fixed in the calendar, such as planting, harvesting or temporary off-farm/non-farm opportunities). As temporal factors influence land users' trade-offs, they are designed within a **'temporal'** perspective in line with LUT. For example, Mrs Yahira, a 44-year-old female farmer, adopts *arena-pumice* on her *solar* because of its long-term benefits, but does not want to do the same on her *milpa* because she is seeking short-term benefit there.

Finally, the last category of trade-off brings together farmers' experience and acquired knowledge about land management and the values linked to LaDC technologies. The intention of this category is to capture the sum influence of historical experiences, views, prejudices and influences on the minds of farmers which are then used to determine whether a technology is adopted or not. These factors may have a pivotal influence on the selection of practices and thus on the necessary trade-offs, which are often made according to personal values. They require the farmer's subjective and objective judgement of what is to be gained or lost, not only in terms of productivity but also in terms of personal and social interests. Appreciating this personal element reveals an **'intrinsic'**[118] perspective of trade-offs through the identification of specific technological choices. The framework here uses data about farmers' past and current responses to the land degradation problem. The spatial, temporal and intrinsic perspectives are nested within each other and the intention of the categorisations is to help to disaggregate trade-offs choices. This is the basis of the framework developed to analyse trade-offs in LaDC from the farmer's perspective, as illustrated in Figure 7.1.

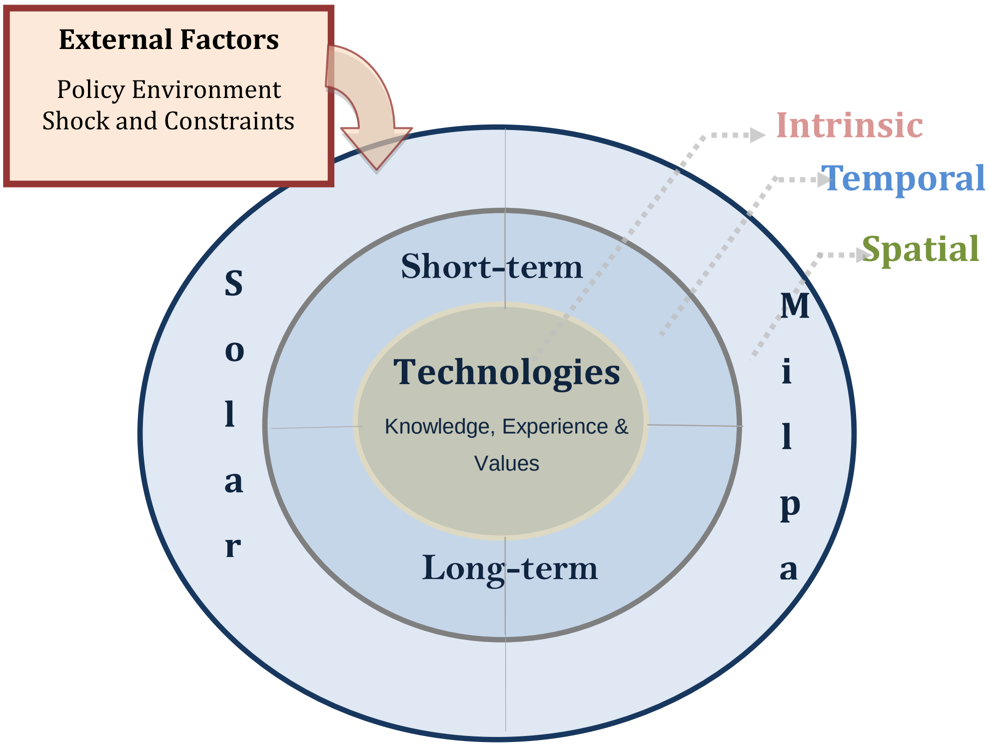


Figure 7.1 Trade-offs from a farmer's perspective

As observed in Figure 7.1, the perspectives are based on the working definition of 'trade-off' employed in this study. The spatial perspective explains where trade-offs between LUT are taking place. The temporal perspective accounts for

[118] The intrinsic motivation is associated with farmers' attachment to the land and the desire to practice land husbandry (Ryan, et al 2003).

when trade-offs between technologies deliver benefits: in the short-term or the long-term.[119] The intrinsic perspective reveals what technology may be taken on according to the farmer's personal interests, knowledge and needs. The integration of the three perspectives allows identification of which trade-offs are being made by land users. The perspectives are intrinsically interrelated: they influence each other. In other words, farmers will assess the temporal and spatial perspectives based on their own views, knowledge and experience. However, their intrinsic views may change according to attributes of and access to LUT and to other assets in order to generate short- and long-term benefits. Unravelling each perspective underlines part of the farmers' rationale behind the choice of trade-off. This framework acknowledges that a land user's decisions are made in a far wider context of local, regional and national policy and of the vulnerability of the local environment, which external factors are illustrated in a separate box in Figure 7.1 so as to differentiate those factors which derive from the farmers' views and those from the broader context. The framework illustrates how policy changes have influenced farmers' trade-off decisions regarding LaDC. For instance, rural policies promoted in the study area have important implications for Mexican farming systems and LaDC which affect the LUT and temporal and intrinsic perspectives (e.g. policy to increase subsides for inorganic fertilisers or land titling of private property).

Because of the complexities involved in trade-off analysis, this research investigates trade-offs associated with the adoption of LaDC technologies in highland areas from a qualitative approach rather than in a precisely measurable framework. The framework developed seeks to recognise the theoretical and practical implications of trade-offs in land management and resource use, and particularly the influence of policy in defining farmers' choices.

7.4. Spatial perspective: trade-offs between *solar* and *milpa* LUT

The spatial perspective gives an account of the significant influence of whether land use is occurring on the *solar* or *milpa* LUTs and how land management is

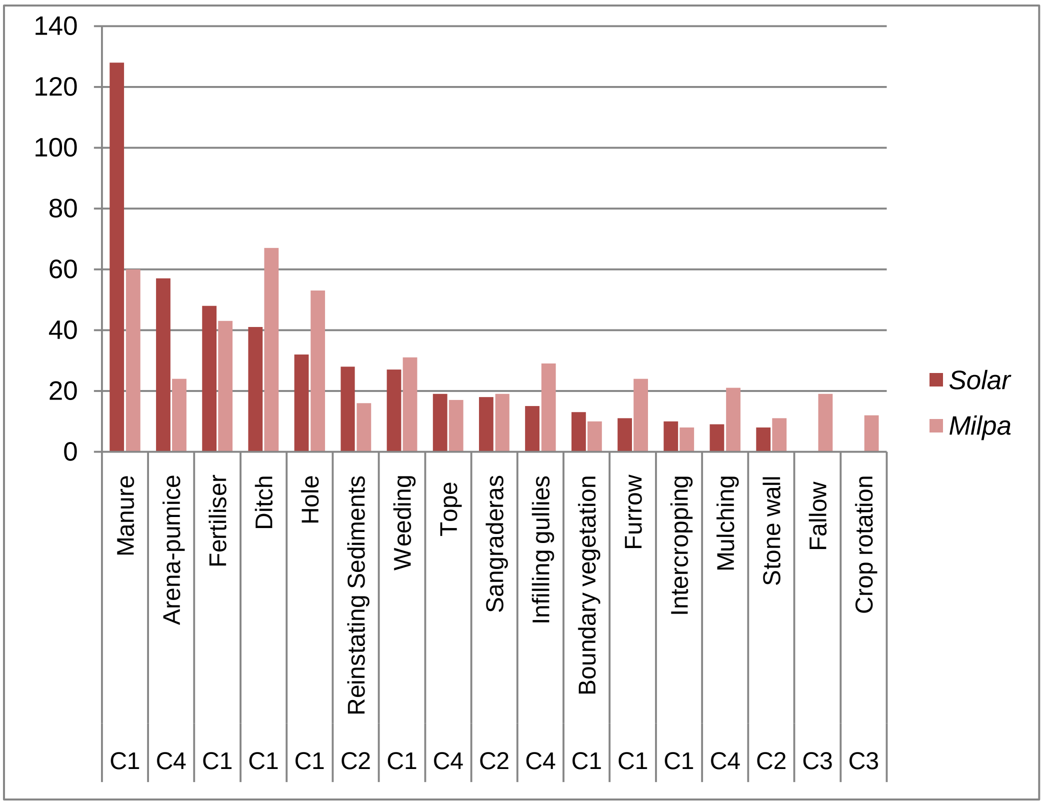
[119] 'Short-term' refers to one to five years' benefit/cost and 'long-term' involves benefits which last for more than five years or are observed after five years of adoption. For example, manure lasts 1 to 3 years and *arena-pumice*, about 20 years.

correspondingly different in the Highlands of Central Mexico. There has been explicit differentiation between these LUTs throughout history (see Chapter 4). *Solar* is the production unit established next to the farmer's homestead where management is generally more closely supervised and intensive. It is an important source of maize for household consumption.[120] In contrast, the *milpa* is further from the homestead, less closely supervised, usually known for its mono-cropping of maize and has more extensive production. Some farmers in SPT report that *milpa* can be as important as *solar* for producing maize, depending on its soil type and distance from the homestead. The biophysical attributes of its land partly determines a household's natural asset base. Each *solar* and *milpa* has specific conditions, which farmers claim to take into consideration when defining their LaDC approach. Differences in management indicate that farmers are making important trade-offs between *solar* and *milpa* in their adoption of technologies.

What trade-offs are implicated by the differences in the technologies applied on *solars* and *milpas*? A participatory exercise was carried out to study trade-offs between different LUT. Thirty-one farmers selected the five most favoured and important LaDC technologies that they have employed on their *solars* and on their *milpas* (see *Appendix* VII.1).[121] Different weights have been given to the selected technologies based on the farmers' order of preference. The scores allow exploration of which technologies are being implemented and where, according to the importance that farmers accord them. The results are illustrated in Figure 7.2. The technology clusters of which each practice is a part are highlighted (see Chapter 5).

[120] Farmers may keep to traditional land management in *solar* but they may set aside a small area to carry out trials of new crops, especially if they have access to other pieces of land. After testing new crops on their *solar* they may continue to experiment with new crops on a bigger scale on a *milpa*. Farmers try out and modify LaDC practices (i.e. changes in size, position, material) on their *milpas.*

[121] For instance, 5 points indicate the technology that farmers consider most important; 4 the second, most important and so on. These weights are added to obtain a total score for each chosen practice.



C1 'Standard' continuous agricultural technologies
C2 Sediment management technologies
C3 Labour limited and high area availability technologies
C4 Intensive investment technologies

Figure 7.2 Score of most important LaDC technologies adopted on *solars* and *milpas* technologies as ranked by farmers

Source: Field data

According to the scores, C1 standard agricultural practices such as use of manure, ditches, fertiliser, holes and weeding are the top preferences. Manure is considered by far the best practice on *solar* (most farmers selected this as a first or second option, so it scores highly). Besides standard technologies, *arena-pumice* – part of the C4 intensive investment technology cluster – is ranked second for use on *solar*.

The ranking reveals the farmers' priorities and interests in improving land productivity on their *solars* at the cost of more labour-intensive technologies such as *arena,* the reincorporation of sediments and manure. No crop rotation and fallow are used on *solars*, which means that more labour-intensive ways of incorporating nutrients in the soil must be employed. In addition, intensive investment and sediment management technologies may be expected on the more degraded fields because the *solar* is positioned closer to the homestead and would usually attract priority attention. Although this initially suggests that *solar* soils are degraded, the location of the plots in the landscape is often on poorer soils. Older farmers, for example, particularly in La Era, pointed out that when they started cultivating their *solar* they did not produce anything because the soils were ‘not good’, which was a reflection of the fact that homesteads are located usually on upper, more stable, parts of the landscape where soils are often thin and stony. These older farmers began to adopt technologies in their *solar* more than 50 years ago, and over time and through intensive management they have built up soil quality. Empirical evidence in this research confirms that *solar* receives better and more continuous maintenance of technologies. As a reflection of this allocation of greater resources to *solar,* the results of the survey (about the adoption of technology in SPT) show that farmers apply a mean of 9.8 LaDC technologies on *solars* and 6 on *milpas*. In general in the current landscape, a legacy of half a century of technology application, there is now better quality or better improved soil on *solars* than on *milpas* (see Chapter 5).

Solars are often protected with hedges and stone walls, which increase their economic value and reflect good land management. Farmers consider them more productive as a result of working the land well and taking care of it (Chávez, 2007). Land users focus on increasing maize yields on *solar,* having controlled soil loss in situ through the use of other technologies such as ditch, holes, and hedges. In the present context the biggest investment in LaDC is mainly applied to the most productive plots in order to achieve the greatest marginal gains (Tittonell *et al.*, 2007).[122] This discloses the land user’s choice of cost-effective opportunities. *Arena-pumice* soil amendment is collected free from communal land, although there are associated labour and transport costs, and the greater the area covered by *arena-pumice* the more significant the gains. It is usually applied to units of production that are closer to the farmers’ house and which is more secure. According to Chavez (ibid), when there is a shortage of manure or *Arena-pumice* to cover all their plots, farmers usually decide to allocate preferentially to the *solar*, especially when they have a large number of units of

[122] Farmers adopt technologies on *solar* with mainly *Colorada*, *Arena*, *Pejo*, *Tepetate* and *Polvilla* soils and on *milpa* with *Pejo*, *Colorada* and *Polvilla* soils.

production. Trade-offs are then made at the LUT level: i.e. intensively managed *solar* vs less intensively managed *milpas*.

For some farmers, digging ditches is the most important practice on their *milpas* to reduce run-off and soil loss; however, others consider the incorporation of manure more important. This is explained by differences in the biophysical attributes and location of individual *milpas* and the availability of labour. A sentiment typically made by farmers is, for example:

> *You only apply manure to fields where 'water does not cut the land' [[run-off is controlled] and the soil is thin, and which are close to your home. (male and female farmers common opinion)*

Milpas are used for crops such as maize, weeds for livestock forage and edible wild plants and for experimenting with forage crops such as oats. *Milpas* have less boundary vegetation and appear more vulnerable to soil erosion. *Milpa* land management allows the control of soil loss to a certain degree, and farmers endeavour to maintain or increase the productivity of such land. Labour-intensive technologies such as infilling gullies or mulching are applied on *milpas* if the resources are available. Fallow and crop rotation are desirable on *milpas* as they improve fertility in the medium to long term. These practices reduce the costs of labour and maize production.

The ranking highlights the trade-offs between LUT; farmers gain and invest differently on their *solars* and *milpas*. On *solars*, farmers secure their maize production and their improved soils require less adoption of LaDC technologies, although as noted earlier more technologies are applied here already. This compares with the technologies applied on *milpas* which focus on reducing or controlling soil erosion. Farmers stated that the adoption of technologies on *milpas* is not at the same level and quality as those on *solars*. This underlines, overall, the lower priority and value accorded *milpas* over *solars*. For instance, *milpas* have less manure, *arena-pumice* or sediment applied than on *solars*; maintenance labour and the area taken up by the adoption of LaDC technologies is less, too. Farmers gave lack of labour and resources as well as personal interests as reasons for such differentiation.

Three cases were examined to identify the trade-offs in terms of area dedicated to LaDC and to compare how much land area farmers are giving up to LaDC technologies on their *solars* and *milpas*. The percentage of the area occupied by technologies[123] on three farmers' *solars* and *milpas* is summarised in Table 7.1 and illustrated in Figure 7.3.[124] Generally LaDC practices implemented on *milpas* located far from the *solar* used up less area than those closer to it. The *milpas* selected to measure the area taken by technologies were those close to the farmers' homesteads in order to give a better basis for comparison between the two LUTs since the *solars* were also close to the homestead.

Table 7.1 Trade-off in area used by LaDC technologies on *solars* and *milpas*

	Case1		**Case 2**		**Case 3**	
LUT	*solar*	*milpa*	*solar*	*milpa*	*solar*	*milpa*
% of area used by technologies	5.1	2.1	15.9	9.8	10	7.8

Source: Field data

[123] Percentage of area used by technologies is based on the measurements taken of the units of production through slope profiles during the fieldwork. The average distance between the *solar* and *milpa* selected is less than one kilometre.
[124] The percentage of area includes boundary vegetation, ditch, hole and stone wall technologies adopted in each LUT.

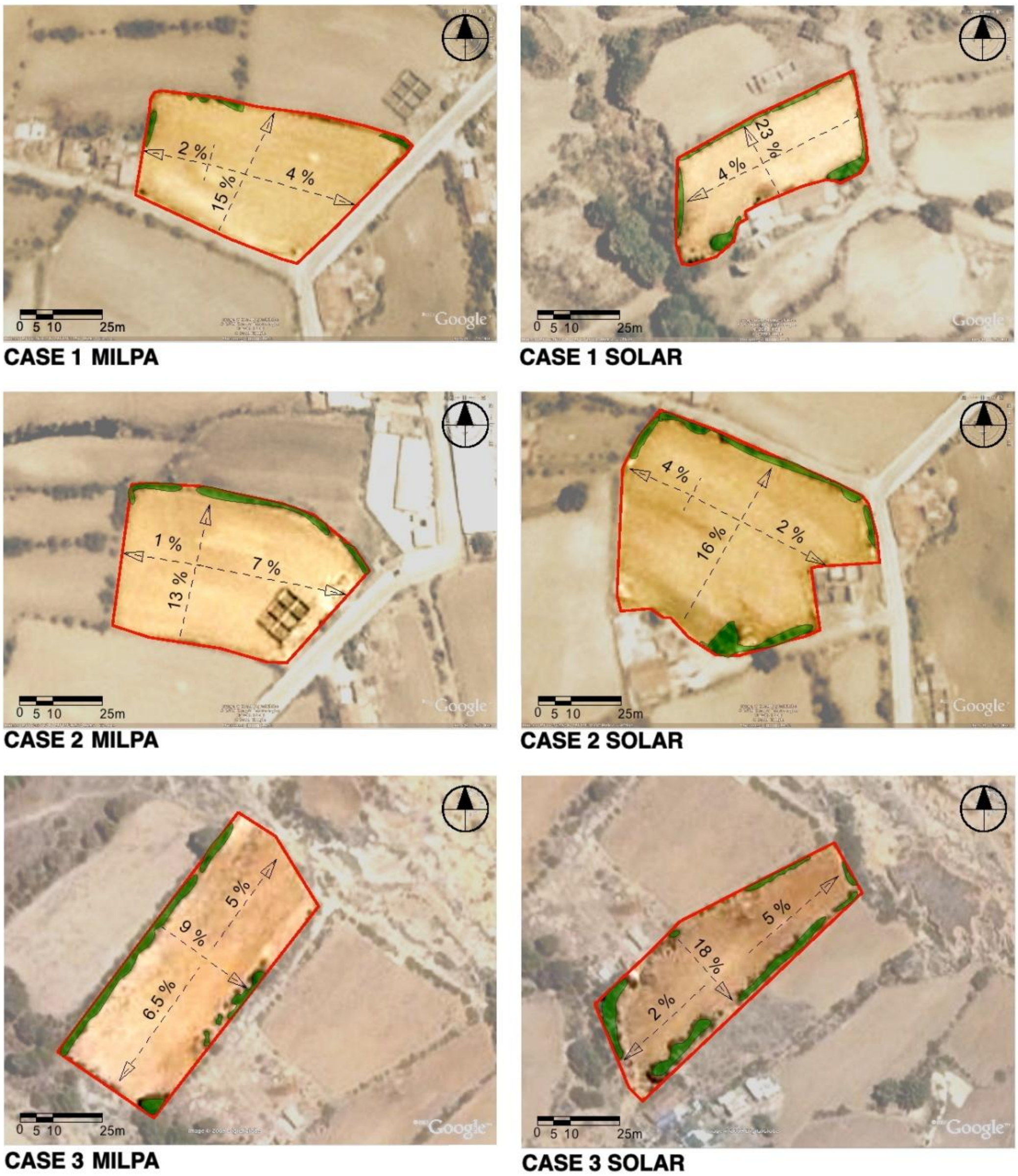


Figure 7.3 Area of *solars* and *milpas* used for LaDC technology adoption

Source: Field data

A greater percentage of the area of *solars* than of *milpas* is used by technologies. The soil on the *solar* is greatly valued by farmers because it has been improved or maintained for longer than that on the *milpas*. On *solars* the relative loss of area that could otherwise be used for maize cultivation is insignificant compared to the gains from reducing soil loss in situ. Farmers consider that protecting their fields is more valuable than a possible gain in production. As Mr Leode and Mr Teode say:

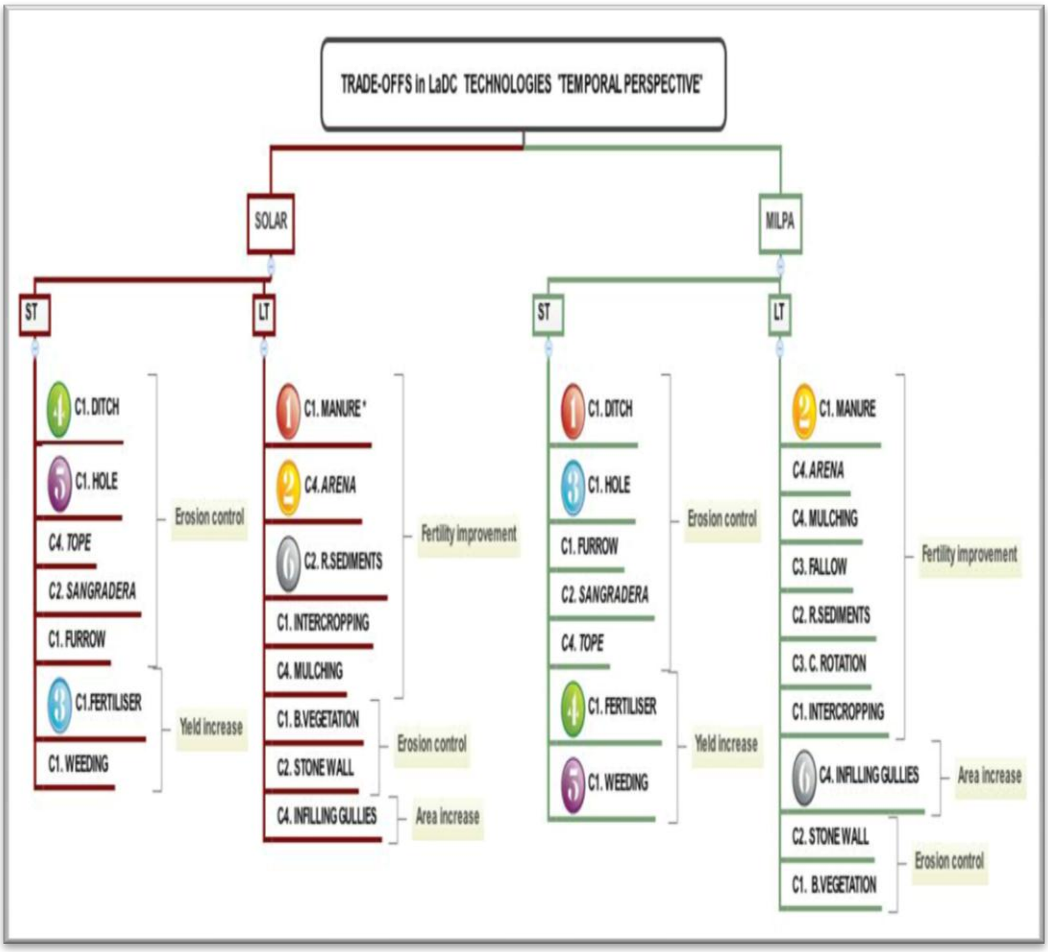
> *If you plant maize at the edge of your field instead of digging your ditch or hole you will lose soil. It is better to lose a few maize plants than soil. You can have more maize plants in the future but you cannot get more soil. If you lose soil you will have fewer plants next year and you'll need to collect soil from down the slope and carry it up, or add manure or sand. If your land is protected you don't need to worry about water cutting it. If you plant your maguey you protect your fields from animals entering it to eat your maize plants.*

Male farmers emphasise that their *solar* gives them greater prestige in local society as it is the place where their farming skills are primarily on show, and where the homestead household is unambiguously linked to the unit of land. Farmers who take care of their land, control run-off and bring in a good harvest are considered good farmers (intrinsic perspective).

Trade-offs between LUT generate changes in attributes at the field level (e.g. changes in soil quality and productivity) and encompass strategies at different periods which are presented in the following sections. The fact that land users own units of production with different attributes and invest in them differently reveals their decision-making rationale regarding space and time (Edwards-Jones, 2006).

7.5. Temporal perspective: short- and long-term trade-offs

In constrained environments, such as hillside rain-fed agricultural systems, farmers attempt to maximise their yields each year, improve the land and control land degradation in order to generate better returns in the future. This requires timing the investment and allocation of resources according to the interests of the household. In SPT the farmers' LaDC approach encompasses technologies with short-term (ST) or long-term (LT) benefits in order to distribute labour and benefits/costs. Trade-offs with a temporal perspective link the functional aspects of LaDC technologies such as erosion control and yield increase (ST) and fertility improvement (LT) with increased cultivatable area (see Chapter 5). Trade-offs from a temporal perspective are structured by *solars* and *milpas* and differentiated by the main function of the technology in question, as presented in Figure 7.4.



- Coloured numbers represent farmers' preference ranking of LaDC technologies . Manure is a ST technology but it is presented as a LT as the quantity incorporated is not significant in the ST. B. vegetation=Boundary vegetation. C. rotation= crop rotation, R. Sediments=reinstating sediments

Figure 7.4 Trade-offs in the adoption LaDC technologies in LUT according to their short and long-term benefits and function

Source: Field data

As shown in Figure 7.4, farmers spread the benefits and costs of their LaDC practices across different periods and in different fields by using different technologies. Overall, land users focus on LT (i.e. fertility improvement) on *solars* and ST (i.e. erosion control) practices on *milpas*. There are two main issues regarding trade-offs: the inputs and the outputs associated with the technologies. The inputs required may be committed in the ST or the LT depending on the availability of assets, the allocation of resources and the farmers' prioritisation of needs. On the other hand, outputs obtained through the implementation of technologies may be experienced at different times.

In the ST farmers prefer low-input technologies in terms of labour demand on both LUT: e.g. digging ditches and applying fertiliser are yearly ST practices. Land users are willing to invest in inorganic fertiliser to secure maize yields in the ST and so follow modern agricultural practice of providing an input to obtain an enhanced productive output in that immediate season. In the LT the management of the *solar* involves LT inputs and outputs. Famers need to continuously incorporate manure, *arena-pumice* and collected sediments in order to cover a significant area. These technologies are highly valued by farmers and require high labour/economic investment (particularly where incorporation of *arena-pumice* and sediment are concerned). Farmers attempt to gain *milpa* area by infilling gullies and improving the soil fertility with manure; however, the area recovered or the quantity of manure applied per year is not significant, so the benefits are only experienced in the LT. In the main, farmers in SPT focus on balancing the intensive management of their *solar* with less intensive management on their *milpas,* thus avoiding a clash in labour demand.

For instance, Mr Tomas states:

> *I don't use fertiliser on my solar; it doesn't need it. I've put down manure for a long time and it produces good yields, beautiful maize cobs. Manure is the best for increasing maize production. I try to put at least a little bit of manure on my other pieces of land, the ones that ask for it, as there's not enough manure [for all the plots]. I don't apply manure to all soils because in some soils it's used up very quickly. It's not worth it: manure doesn't last in this soil.*

Generally, improvement of soil fertility is experienced in the LT. Therefore, land users in need of ST outcome and with short-term time horizons will prefer fertilisers for its immediate benefits. In particular, young people and families with little available labour and/or few livestock to transport manure seeking to increase yields and needing a fast outcome depend on inorganic fertiliser.

There are also temporal trade-offs between different technologies and trade-offs in the implementation or modification of a single practice. An example observed in the study area was where farmers in SPT participated in planting fruit trees (apple and peach) in cultivated fields, a project promoted by the Secretariat of the Environment and Natural Resources (SEMARNAT) and CICA in 1999. The practice was intended mainly for environmental (control of soil erosion in situ) and economic benefits (income generation through the sale of fruit).[125] Land users dedicated a small percentage of their units of production, mostly on *solars*, to the fruit trees. After three years, most farmers had not noticed any gain and only a minority were able to harvest some fruit. For most, the fruit trees grew very slowly, but people were optimistic about the future benefits. The fruit trees were producing enough for household consumption after nine years, and in the best cases some families were able to sell fruit in the community or the nearby city.

The farmers do not consider the economic contribution from the sale of fruit significant to the household economy; however, they have kept the trees as boundary vegetation, preferring to use them as hedges to the traditional *maguey*, particularly on *solars*, because of the low economic value of *maguey.* Furthermore, the farmers not only commented on the price they get for *maguey* (about $1.50 for a ten- to fifteen-year-old plant) but also that it competes with maize plants for available water in the soil and encourages pests. In comparison, although the fruit trees also absorb water, the farmers like the look of them better than *maguey*, they can eat the fruit and it may provide them potentially with an additional source of income.

Land users are replacing *maguey* with fruit trees on *solars* but still choose *maguey* for *milpas* because people would steal the fruit if the alternative boundary planting of fruit trees had been implemented. Farmers are changing their landscape with the adoption of new trees and plants, particularly on

[125] In this case, SEMARNAT provided cash to buy all the material needed for gabions and to pay farmers' labour to construct them. CICA and SEMARNAT supplied money to buy the fruit trees for farmers who wanted to participate and the farmers only needed to provide the labour to plant them. Nevertheless, SEMARNAT paid 250 pesos ($25) for their labour (Garcia, 2002).

solars.[126] There are different trade-offs involved in this modification such as in the area planted with maize plants vs. that used for fruit trees, aesthetic preferences vs. traditional management, and changes in the accessibility of land for ploughing. The choice of what to plant also involves farmers' personal interests and attitudes towards change.

Technologies generating LT outcomes enhance land attributes and thus the farming household's natural asset base. Improving land helps to reduce its vulnerability to land degradation processes such as soil erosion. The temporal perspective reveals farmers' attitudes to tackling LaDC and the impact of technologies on their livelihoods over time. The implementation of technologies is not static; it is continuously being adjusted. Therefore the associated trade-offs are dynamic, evolving according to land users' values and needs over time. Understanding these technological choices provides a better foundation for appreciating the current and potential resource use of farmers and how decisions in the future may be shaped by the trade-offs they employ.

7.6. The intrinsic perspective: experience, knowledge and values

The intrinsic perspective allows for a better understanding of trade-offs by viewing farmers' experience, values and aspirations. This is linked to the social drivers of LaDC technology adoption which are often overlooked when assessing the apparent direct economic benefits of land cultivation (Giampietro, 1997). The choice of technologies to adopt in a specific place and at a specific time is a personal, specifically-individual decision. Two individuals with similar lands, resources and other attributes may often make different decisions, especially when it comes to complex issues such as choice of LaDC technology. Gains and losses are social claims based on peoples' perceptions, attitudes and experiences. As mentioned, a gain for one farmer may be a loss for another, depending on each individual. Farmers' experience and knowledge reflect local ideas and ways of understanding the benefits and costs of the agricultural process and LaDC (Saïdou, 2006).

[126] "Investment increases in adoption of practices that are integrated in a set of income generating rural development activities" (De Graaff et al., 2008:277).

Experience and knowledge are relevant in farmers' values and goals when adopting technologies. For instance, the farmers' appraisal of values revealed that adopters value LaDC technology indicators higher than non-adopters. The scores clearly show that adopters value social indicators such as aesthetic considerations, customs and traditions, recognition in the community and personal incentives related to land and networks (see Chapter 6) more than non-adopters do. Besides the need to meet immediate socio-economic needs (e.g. food security through maize production), farmers need to fulfil other social and cultural demands, as examined in the appraisal of technologies.

To consider these highly individualistic responses more fully, consider a farmer who prefers to dig a ditch, arguing that this technology requires only a minimal allocation of area of land; the ditch catches soil and water from uphill fields; it does not affect access to the land, and involves little labour. It is a traditional practice in the community. Land users like the aesthetic aspect of the ditch, which reflects good land husbandry and may enhance their local social status. Farmers feel that they are fitting into the community and supporting the continuity of history by following traditional land management. However, another farmer may prefer to use practices such as *tope,* an unusual practice in the area, for the same purpose and for almost the same reasons, as it is a family tradition and they are expert in its adoption. The primary difference between the two farmers is that the experience in adoption changes the perceptions of the farmer and alters the type of trade-off to affect final choice of technology (*op cit*). Some farmers find space and rational management more significant in their choice of trade-offs while others are more interested in intrinsic issues related to family customs.

In the case study, some intrinsic issues appeared to be more influential than others. Farmers' experience, knowledge and values are associated with socio-economic factors such as age, language and level of education were often identified as important drivers. There is an association between these three factors, which influence farmers' interest regarding knowledge and cultural inputs, as presented in Table 7.2.

Table 7.2 Impact of SPT farmers' language, education and age

Language	Education	Age group	Impact on knowledge and cultural inputs
Spanish	Primary, incomplete or higher	Mainly under 18	Reduces interest in *Mazahua* culture and agricultural activities. High external inputs.
Speak Spanish/ Understand *Mazahua*	Primary, incomplete or higher	Mainly 19 to 30	Appreciation of cultural and traditional *Mazahua* knowledge (mainly migrant).
(Speak Spanish/ *Mazahua*	Primary, incomplete or lower	30 and above	Key actor in the integration of cultural and indigenous knowledge with *mestizo* culture. Access to external inputs and high adoption rate of local practices
Mazahua only	No education	> 65 years old	Good access to local knowledge but little transfer of knowledge with other generations.

Access to formal education opens up opportunities to accept external interventions and take on the influences and perceptions of an increasingly-urban culture that is starting to prevail in Mexico. This transition decreases the importance of local knowledge and traditional land management. A large proportion of older people in the population help to maintain the indigenous culture and support the availability of local knowledge to current agricultural practices. In the study area old people play an important role in the household due to their experience and knowledge of farming systems.[127]

Recognition of the importance of 'taking care of the land' is an issue related to a certain degree of expertise and is often linked to 'expert farmers'. It is highly valued by the old, illiterate farmers in the community, most of whom started cultivating maize in degraded fields and are now proud to grow enough to satisfy their needs. A large majority of farmers believe that there has been a decrease in soil erosion across La Era. There is less sediment in the rivers because people are taking care of their land higher up. Farmers state that their soils are now productive as a consequence of the adoption of LaDC technologies and the use of fertilisers. The perceptions and experiences of the stakeholders involved influence the remedial actions taken. For example, Dr Esteban, a soil scientist

[127] Generally, households in which old people are in charge of agricultural practices and resource management do not expect remittances or use migrant labour (especially from young people) to carry out agricultural production and land husbandry. This has forced them to increase the number of farming practices with low labour demand. Social networks such as relatives and the church are important in coping with vulnerability.

working in the Mexican Highlands, claims that according to his experience:

> *If you ask farmers if in the past their soils were more or less fertile, the answer will be always yes, they were more fertile in the past. It is obvious that it should be a process of continuous depletion through ploughing and all the process involved in the land cultivation.*

Such a prevailing view is contrary to the perceptions of many of the older SPT farmers as reported in this study. SPT farmers are proud to increase their yields and control run-off. One of the most traditional and highly-valued practices is the combination of manure with *arena-pumice*; farmers claim that it is the best way to improve soil fertility, enhance soil moisture and increase productivity (see Chapter 5). Adopting both practices means that farmers 'work the land well' (Chavez 2007). There is no record of who started the tradition of incorporating *arena-pumice*. Farmers recall that *arena-pumice* has been added to some units of production for about 100 years. They know that their parents did it when they were young.

Mr Tomas comments:

> *My mother was widow and she used to go and walk in the forest collecting buckets full of arena and carry it on her back [a three-hour journey]; she did it several times. She also collected manure found on the paths that nobody wanted, and our household waste. She put all of these on the land for several years until she started to produce one or two maize plants. She was very hardworking. That's why I like to work the land as she did.*

Currently, *arena-pumice* is highly valued as deposits are scarce and the alternative soil amendment, manure, is only associated with livestock ownership, which represents economic security. None of the farmers directly accept that they seek recognition and prestige in local society; it is never expressed as a reason for implementing technologies. Recognition is more seen as an indirect gain or a by-product from the time and resources invested in land management. Expert farmers' reputation as hard-working people has led to research teams contacting them to ask them to work on projects, adopt new ways of managing land. Likewise, politicians have contacted them to persuade other farmers to join their political parties.

Family traditions are important in determining specific technologies: for example, one group of households is recognised for adopting *arena*-pumice and infilling gullies, and others, for their furrow design or stone walls. Most farmers have migrated for a certain period during their lives. This has exposed them to new thinking and different aspirations. Mr Camilo, for example, takes delight in being different and claims:

> *I am the only one who knows how to do a proper tope; it is the most effective way to control water and avoids it cutting your land. I also have stone walls at the bottom of the slopes. You don't need to do anything else to avoid losing your soil. You also put canuela and manure and you will have the best fields. You don't plough with animals. I am an innovator here in the community; I don't like to do the same as the others.*

Aesthetic values are important to farmers. For example, Mr Nicon identifies how his farming practices and technologies may look to others, when he states:

> *I don't like hedges on my land; I like to see just maize plants. I don't want any trees, maguey or any other plants around. It does not look nice. It looks dirty and messy. I prefer to dig holes and ditches to protect it.*

Mr Teode also identifies his personal preferences but combines these with some more practical issues, when he says:

> *I do like my trees around my milpas, maguey to protect them, holes and ditches, stone walls to avoid losing soil. I don't like tope because I cannot work it with my plough and it is not common here.*

Mr Pancho puts practical issues first but seals the decision with a comment on aesthetic attributes of grass contours:

> *I don't plant maguey any more because I've changed the way I made furrows and now the water doesn't take the soil outside the field [run-off], and therefore I don't need maguey. Instead of maguey I use grass contour; it looks better.*

Farmers acknowledge the different land conditions and requirements of their units of production. They also recognise their personal likes and dislikes in terms of landscape and the food they grow (e.g. particular colours of maize – white, yellow, red, blue – with which to make tortillas). The trade-offs involved in adoption generate social outcomes such as the satisfaction of protecting their land, keeping up traditions, strengthening social networks, inheriting improved land, creating aesthetically-pleasing fields and gaining recognition as good farmers.

However, trade-offs change regarding LaDC in distant *milpas* or communal areas where the intrinsic motives are less considered. An example of how farmers' interests and trade-offs change on communal land is observed in their participation in the Temporal Employment Programme (PET). Approximately 20 farmers from La Era were hired to dig ditches in forest areas and communal areas of the sector prone to soil erosion in 2004/5[128]. The programme included male and female participation (see Figure 7.5)

Figure 7.5 Participant farmers in the PET programme to control soil erosion in forest soil in Sector La Era.

Source: Field data

[128] The PET programme is promoted in marginal areas to pay for temporary labour to carry out conservation activities in forest areas. In the last decade, the municipality of San Felipe del Progresso has been targeted by government programmes to reduce land degradation because of its perceived severe environmental degradation – mainly soil loss – and the impact of this on agricultural and forest activities. SEMARNAT and PET have promoted these practices in the area. The programmes aim to tackle land degradation, increase land productivity and promote rural development.

The average wage was US$2.50 per day and the ditches are widely adopted by farmers. However, the programme focused on digging ditches in communal areas to be protected with *nopal* plants (edible cactus). Farmers expressed their lack of knowledge about the design and benefits of ditches in those areas. They followed approximate measures and instructions given by PET staff for implementation of the practice, yet farmers emphasised that the way they have constructed the ditches makes soils more prone to erosion. The programme was to provide *nopal* plants but farmers had not received them. Farmers are opportunistic (this is probably true for any actor); they traded labour for the money they earned from the programme. According to their experience, unprotected ditches increase sediment loss, which will benefit the farmers on the lower slopes. Land users claim that the conservation benefits for this community are limited and that they know digging ditches in this way on their *solar* or *milpa* takes up planting area and reduces accessibility to the land, and they do not like to adopt it. The conclusion is that the trade-offs change not only when farmers do not closely associate themselves with the practices being promoted but also where they clearly see trade-off inconsistencies in what is being promoted. However, this research does not intent to analyse management of gullies in common property or other erosion control community level actions in the study area, therefore it is not further studied as it is beyond the scope of this thesis which focuses on household level decisions (see Chapters 1 and 3). The next sub-section focuses on externally-driven interventions, and how these can fundamentally change trade-off decisions made by farmers.

7.7. External factors: policy interventions affecting trade-offs

Farmers make trade-off decisions linked to LaDC according to space, temporal and intrinsic conditions, as previously explained. However, the political environment has an effect on their decisions, particularly when policy implementation influences resource management in agricultural livelihood strategies. In Mexico there is a history of government intervention affecting land management through agrarian policy, land tenure regulation and social development strategies (Campbell and Berry, 2003). The impacts of policy interventions on farming livelihoods are complex and vary across the country.

This research focuses on three national programmes: CONASUPO, which is linked to access to crop markets; PROCAMPO, whose payments are often used to subsidise inorganic fertiliser; and the Programme for Certification of *Ejido* Land Rights and Titling of Urban lots (PROCEDE), which involves the formalisation of official land titles. These programmes have changed land management in subsistence agriculture in the Central Mexican Highlands.

According to Yunez-Naude (2003), the major component of Mexico's development policy from the 1930s to the beginning of the 1990s was directed at the agricultural sector. In the mid-1960s CONASUPO was created to promote economic and social development and regulate staple markets.[129] This encouraged a better relationship between producers and consumers by eliminating the intermediaries. It provided a secure market and guaranteed maize prices to farmers. Farmers in SPT pointed out that during the 1980s they had access to fertilisers using remittances or limited credit to increase their maize production. This allowed them to sell surplus production to CONASUPO. The secure market encouraged them to invest in their fields, increase the area they cultivated and use fertiliser to intensify production.

Mr Virgilio says:

> *At that time we could sell maize to CONASUPO for a good price; we were told that we were providing the country with food. We were feeding the nation, because without maize there are no tortillas. So we tried to cultivate all our plots. But now there is no CONASUPO, fertiliser is very expensive and the price of maize per ton is so low. Now it is very expensive to produce maize, so we cannot cultivate all our plots.*

CONASUPO was dismantled at the beginning of the 1990s as a result of new neoliberal policies, particularly with the creation of the NAFTA with its emphasis on industrial development. Changes in policies generated a reduction in subsidies and budgets for agricultural development (Campbell and Berry, 2003). The liberalization of prices generated insecure crop markets and changes in agriculture. Farmers started to sell their surplus through intermediaries, who paid

[129] The staples include the basic crops: barley, beans, maize, rice, sorghum, soybeans and wheat.

lower prices. The incentive to invest in agriculture decreased as the value of the output decreased. Migration and other off-farm activities increased during this decade.

During the mid 1990s PROCAMPO was designed as a transitional programme to compensate producers facing declining prices since the initiation of NAFTA.[130] This was a major policy instrument of the Mexican government to benefit the producers of basic crops, maize included. Income transfers were paid to farmers subscribed to the programme at a rate of 1,300 pesos (equivalent to US$110) per hectare of land cultivated/year (Sadoulet et al., 2001, Ruiz-Arranz et al., 2002, Yunez-Naude, 2003, IDB, 2010). It sought to improve the well-being of farmers by increasing their income. It encouraged farmers to cultivate at least 1 ha in order to access this support, working the land themselves, with relatives or by renting it.[131] Current participation is limited to units of production subscribed to the programme when introduced in 1994 (Saudolet et al., 2001, ASERCA, 2010). Most farmers in SPT are registered with PROCAMPO. They see the payment as a subsidy for inorganic fertilisers. Land-poor farmers cannot register with PROCAMPO unless they rent land for cultivation from other farmers in the community.

Mr Paulo comments:

> *PROCAMPO is only given to their friends; I am no part of [the programme] as it is only for some groups. I need to work harder to be able to buy fertiliser as the plants need it. And I like to use more manure; it is better but sometimes it is not enough.*

This subsidy has increased the use of fertiliser by farming communities. Now farmers think that using fertiliser has become traditional. It is the ‘modern way’ or the ‘only way’ to produce maize. This influences trade-offs, as it is related not only to yields but also to recognition and customs in the community. PROCAMPO has a direct impact on conservation, as farmers’ responses to land degradation are associated with their perceptions of decreased fertility and lower yields. Thus the greater use of fertiliser reduces farmers’ interest in soil conservation, since

[130] North American Free Trade Agreement (NAFTA).
[131] The only restriction is that land be used in crops, livestock or forestry or be part of an approved environmental programme as oppose to be left idle (Saudolet et al, 2001)

they are securing their annual production and satisfying current needs. However, there are cases where producers try to apply less fertiliser on the *solar* or nearer *milpas* if they have other pieces of land on which to grow maize for sale. Mr Pablo, who lacks access to subsidies, has to limit his use of chemical fertiliser and increase his application of organic fertiliser, which requires livestock ownership and labour to look after them.

The reform to Article 27 of the Constitution in 1992 brought about one of the most important changes to the Mexican rural sector. The reform allowed *ejidos* to be sold, rented or mortgaged to non-*ejido* members, converting *ejidos* into private property (Jones and Ward, 1998, CONAZA, 2010). Owners of *ejidos* (which could be *solars* or *milpas*) could certify their land rights if participating in PROCEDE (Program for Certification of *Ejido* Land Rights and Titling of Urban lots).[132] Assies (2008) highlights the fact that with this new legislation, farmers who legally own *ejido land* are no longer required to work the land themselves in order to retain their land rights. This affects land management, as migrant farmers can lend their land under a sharecropping agreement or rent it to others inside or outside the *ejido* without the risk of losing it.

The traditional way in which *ejidos* were inherited in the study area created land ownership without the need for a formal land title. Male children were guaranteed a piece of land on which to build their home and land for cultivation. In the main, there was no significant increase in land security with land titling. In a few cases farmers decided to put their *ejido* (generally *milpas*) in their children's name. When asked whether land titling has had an impact on or changed land management, farmers in SPT answered in the negative. Yet they are investing more in land with a higher market value accompanied by land titles.

In SPT women rarely inherit land; however, during the certification of land by the PROCEDE programme, a few land titles were given to women. During interviews where the adoption of technologies was discussed, male farmers indicated emphatically which units of production were owned by their wives. There is a clear and unambiguous differentiation of land units and associated management

[132] PROCEDE was an instrumental programme that gave juridical certainty to land tenancy, regularized agrarian rights and granted individual property certificates to *ejidatarios* (*ejido* owners) (De Ita, 2003).

between men and women. This has empowered female farmers, who can now access land independent of their marital status. It has also increased their responsibility for looking after plots in their name. Farmers encourage their daughters to take care of their land and to adopt LaDC practices, mainly to reduce soil loss.

Although farmers say that land management has not changed with the acquisition of land titles, they recognise that the adoption of technologies between pieces of land is no longer the same. Trade-offs in technology adoption have changed after 15 years of land certification. Farmers are concentrating on their most profitable units of production. Generally their children are migrants and therefore do not cultivate their land so the farmers keep producing on these plots themselves and adopting LaDC practices, but not as intensively as in the past. Land titling has influenced land users' interest in investing in land (the intrinsic perspective), as observed by Mr Carlos, who comments:

> *I cultivate my children's plots to harvest maize to sell. I don't think I'll look after these plots as I did, because they are not mine but theirs. I think I'll just keep taking care of mine.*

summarises the implications of the three programmes for land management in SPT. The policy strategies have had an impact on land security, crop prices and the use of fertilisers. These political changes may strengthen or undermine the adoption of certain practices as the trade-offs associated with them change depending on farmers' needs. For instance, participants in PROCAMPO with limited land area will reduce the amount of land they leave fallow to keep the subsidy. This encourages farmers to produce on their children's *milpas*, so they may adopt some standard LaDC technologies to protect these from soil erosion. However, some farmers will prefer to leave land fallow or rotate their crops, as these reduce the cost of cultivation and harvest, especially when maize prices are low. They may also intensify the use of resources on more productive land to which they have formal rights. The current political environment has redefined producers' trade-offs of values.

Table 7.3 Implication of PROCEDE, CONASUPO and PROCAMPO programmes for land management in SPT

Policy		Strategy/ programme	Period covered	Objective	Outcomes: With implementation	Outcomes: After implementation ended
Land titling		PROCEDE	1990s	· Certification of land rights to *ejidos* in Mexico	· Conversion of *ejido* to private property · Increase of area cultivated due to possibility of renting of land to non-*ejido* members for cultivation · Reduction in abandoned land · Changes in incentives to invest in land with land title.	· Investments focused on land with higher market value (privately-owned *solars* and *milpas*) · Women's empowerment with inheritance of land in SPT, increasing interest in adopting LaDC practices · Less intensive land management on children's *milpas* · Insecurity of farmers about disclosing information regarding land ownership
Interventions to Mexican agricultural sector	Access to market	CONASUPO	Mid-1960s to 1990s	· Promote economic and social development · Regulate staple markets for small producers (including maize)	· Incentive for maize production · Increase in area cultivated · Incentives to invest in protection of *solars* and *milpas* (adoption of technologies) · Extend use of inorganic fertilisers with lack of extension work · Shaping of food production, consumption and rural incomes · Guaranteed crop prices	· Insecure crop market · Lower maize prices · Migration · Land use changes · Subsistence agriculture · Increased need to buy maize
	Fertiliser subsides	PROCAMPO	1990s to present	· Income transfer to support smallholder producers In Mexico after implementation of NAFTA	· Direct cash income to farmers cultivating land · Keeping at least a hectare of maize per farming household affiliated to the programme · Income mainly used to purchase inorganic fertiliser, encouraging its use in rain-fed agriculture areas · Increased share-cropping agreement: those who cultivate a minimum of a hectare of land qualify for the programme · Reduce incentives for adoption of practices particularly to increase soil fertility in distant *milpas* or with degraded soils · Lack of trust of outsiders because insecurity to lose this income · Strengthening of social networks of farmers subscribed to PROCAMPO · Farmers excluded by the programme have no access to this social network	

7.8. Trade-offs according to the “expert”, the “mad” and the “lazy” farmer

In the same political context, farmers operate trade-offs on different pieces of land (spatial perspective), at different times (temporal) influenced by personal interests (intrinsic). Their trade-off decisions are linked to their own individual likes and dislikes, which in turn help to define their approaches to land management and LaDC. Land users share characteristics with others due to family links, networks, religion, location or political affiliation and these create similarities in their trade-off approaches. In order to illustrate how these individualistic traits operate, this section caricatures three types of farmers in the study area. The caricatures are based on farmers’ own comments about themselves and those of others in the study area, gathered during the surveys and interviews carried out for this research. Like all good caricatures an element of hyperbole may be found in the descriptions (not least in their headline titles) in order fully to identify typical differences between individuals that are well-recognised and accepted in the study area.

According to the farmers themselves, land users who manage their land well usually using traditional techniques are “good farmers”; those who do not follow traditional management approaches are “mad farmers”, and others that do not implement technologies or do not adopt them properly are “lazy farmers”[133]. “Expert” farmers participating as key informants in this research were generally regarded as “good farmers” by other land users in SPT. The research uses normative local terms expressed by farmer in SPT when referring to peoples’ attitudes or characteristics regarding land management. It recognises farmers’ manners to characterise themselves and others in the community. The comments are not researcher’s personal opinions and the terms are not employed by her in the field to approach farmers. A characterisation of these three types of farmers and their perceptions is presented in Table 7.4, which includes the researcher’s description, the farmers’ own perspectives and perspectives of other members of the community.

[133] These terms used by farmers to describe others in the community are employed to categorise farmers’ types. They are the actual terms, translated from Spanish, that expert farmers in the community use about their neighbours. In that sense, the use in this research is not meant to be pejorative about those who are labelled ‘mad’ and ‘lazy’.

Table 7.4 Characterisation of farmers based on their land management

	Farmer Type **"The good/expert farmer"**	**"The mad farmer"**	**"The lazy farmer"**
General characteristics (researcher)	•Hard-working, networkers, status-conscious, follow instructions, community-minded, bilingual (Spanish/Mazahua), migrant children, old farmers, illiterate, proud of livestock ownership, likes experimentation, likes traditions and challenges, active political and religious life. Sell maize.	•Eccentric, hard-working, individual choice, off-farm/non-farm activities, childless and labour-poor, has the luxury to take risks as household does not depend completely on land, returning migrants or married to outsiders, confident, bi-lingual (Spanish and *Mazahua*), illiterate. Produce enough maize for own consumption and livestock forage. Business-minded.	•Outward-looking, extremely opportunistic, land-poor, young adults, migrant, risk-adverse, follow tradition, household depends on off-farm activities, buys maize, hires labour to adopt technologies, speaks Spanish and understands Mazahua, literate (primary school).
Farmers' own perceptions	*I like to work hard. God wants me to look after my land. I am not the best farmer but I go and see my land. Ask the others about me. I work the land well. I want to pass on good land to my children. I like to see my pretty milpas produce my maize. Buying maize is for lazy people. I want my community to progress. People come and ask me to organise meetings in the area. There are special men in the countryside to work the land*	*I work my land differently to others around here. My method of working the land is very good. It is hard work: not everybody can do it. I like to experiment. I have better yields, bigger cobs. Water does not erode the land. I don't use a plough: I sow seed the old traditional way. I am the only one doing this [type of land management]. You can see my milpas: I look after them in the same way.*	*I more or less take care of my land. I'm neither good nor bad. I don't have time to look after it as I need to work in town. I cannot produce enough maize for my family and buy from neighbours. My fields are OK as I hire people to dig ditches or holes. I don't know much about other practices.*
How the farmers are seen by others in the community	*If you want to see a well-protected and cultivated plot go and look at their land. They are hard-working. They are nosy, but good people. They are old and experienced in farming, and have time to look after their land. Their milpas are really good, no weeds, no water eroding the land, nice maize cobs. They like working with others.*	*They are hard-working. They are mad; you can't work the land with a plough if you do what they do. Nobody does what they do. I protect my land like him but not exactly the same, only a small area [researcher did not observe this in the field] They don't follow traditions, but their ideas work. Different way of working land, but I'm not interested. They are weird. Nobody like that way, except them.*	*They're lazy and don't want to do weeding, or dig a hole or ditch. I don't know why they are lazy. They are young. Her husband is a migrant so she does not know how to look after her land. Their milpas have lots of weeds; that's why they don't have good maize. They aren't interested in land. They like drinking and partying. They have to buy maize and that is not approved of in the community.*
Common trade-offs	LT adoption *on solars* and a mixture of LT and ST on *milpas*, Distant *milpas* not looked after as well as close ones. Willing to risk or try new trade-offs (changing crops or maize types) Dedicate more area for LaDC practices; look after land for children to inherit. Participate in PROCEDE and PROCAMPO; sold to CONASUPO in the past. Still sell in the community	*Solar* and *milpa* management similar, a combination of labour intensive practices for ST and LT benefit. Maize yields are mainly fodder for livestock. Seek recognition as different. Intensive investment in technologies (labour) reduces the need to adopt other standard practices. Household have formal land titles and are signed up to PROCAMPO.	*Solar* and *milpa* ST benefits; in milpa less area dedicated to practices; less investment in fertility improvement; higher investment in fertiliser but may not cultivate enough to qualify for PROCAMPO. Work land under informal land agreement (no formal ownership of land). Adopt of standard agricultural practices but still need to buy maize, therefore little interest in increasing yields.

Source: Field data

The table allows the identification of the trade-offs made by each type of farmer. Three cases extracted from the fieldwork interviews are presented to explore farmers' experiences of land management and LaDC in the study area. Each corresponds to one of the farmer types identified above. The detailed information draws attention to the trade-off decisions involved in the adoption of technologies per farmer type.

The good farmer
Mr Gonzalez (79 years old, male, extended family): I have my six *milpas* [and *solar*]. I have worked on some of them for 45 years. When I started working on them they had gullies and *Tepetate* soil. You barely got any harvest from them except from the one I inherited on the plains. I take care of my land, especially the plot next to my house because I eat maize from that one; the others I use to feed my animals and for crops to sell. I used to sell maize to CONASUPO; it was very good for me. Now I just sell around the community. The government support is not enough: it is more expensive to cultivate maize, and the costs are higher than the gains. I don't want the government to do everything for me but we need more money for fertilizer or tillage. I have the responsibility to work too. Watching maize plants grow is my comfort and my hope … Look at my little peach tree that I planted here [*solar*]; every morning and afternoon I visit it. I like God's nature, the world's nature. Really, where everything is bare, where is the beauty? If everything is dead, there is no life. Making money is also my intention, my wish … In this town, not all of us were born with a good nature. A lot of people don't care about anything. I don't look for recognition, but my land shows how I do my work. Protecting the soil from [erosion by] rain is more important than its fertility. I leave land fallow because I can take my sheep to pasture there; there are only a few in my family. I have enough maize to eat and on the plain I have the very productive plot for maize to sell. If you have livestock you cannot leave weeds to rot in the land, as there is not enough forage. If you fill the gullies in your fields and add *arena* and manure dig a ditch, you will save time for other activities in the following years. It is important to make history and give an example of how to work the land; it helps you to network with people. We must love the land because it sustains us. Those who love the land care for it. At the end of each year I see where the water has cut my fields and think about what I'm going to do next year to avoid it. One year I do it in a particular way, I see what happens; if it works I do it the following year, if not I go back to the way I was doing it … Having so many sheep is difficult: if I go and look after them I neglect my milpas, then it is better to have land than sheep.

The mad farmer

Mr Camilo (67-year-old male, returned migrant): I inherited two pieces of land from my father. He was very well known for working the land well and taking care of it … Now I don't need *maguey*, as the water doesn't cut my land any more because I do *tope*; it is very good for stopping water and retaining soil. You have to do every hole by hand with a hoe and a spade. It's a lot of work but it's worth it. I don't have to plough; I just have to pay for labour for sowing. I do all the rest of the work. I cultivate my land to feed my bulls. I usually sell one or two a year at market; it's better than selling maize. I also have a small shop where people buy soft drinks, bread and small things. My wife is from another state; she doesn't know about cultivating the land. I am the only one working the land this way; you won't find it done this way anywhere else in the community. They may or may not like what I do, but I don't need to 'thicken' my land with soil; nor dig ditches, holes, *sangradera*, plant hedges. Also the *milpa* looks better with *tope*. I have PROCAMPO and it helps me to buy fertiliser, but I also put manure on my land because I have bulls. Growing maize is not a good business, but selling livestock is. I like to experiment and see how I can get better maize plants for my animals. I may change maize colour to see what happens.

The lazy farmer

Mr Felipe (34 years old, male, off-farm activities) …I only cultivate land to get maize for my family; I don't think about the land. I have one plot. Growing maize is not enough to sustain my family. I'm not in PROCAMPO, only in OPPORTUNIDADES. When I can I use herbicides; it's easy and the *milpa* looks pretty. If you put on too much it burns the land. When you don't farm, people in the community start asking why and they start helping you. I don't want to plant *maguey* because it will be there for 15 years and its roots will be soaking up the land's water and vitamins. The *maguey* is just a custom, that's all. If I don't put *maguey* along the edges grass will cover the area; you don't need it to plant it and it will protect the soil, but it goes into the *milpa* sometimes. Nobody drinks *pulque* now. I work as builder in Mexico City and I cannot look after my land; I have children and need to send them to school. I'm getting used to buying maize because I don't have any other option. It's always better to harvest your own.

The way farmers express their experience of land management and their use of LaDC technologies reveals the differences between the types. The "good" farmer expresses the intrinsic views attached to maize cultivation such as loving the land, religious commitment and sense of personal responsibility for his units of production. It confirms the idea that by growing enough maize to satisfy the household demand farmers increase the social value of land management. Control of LaDC is part vision and part necessity, as they have reduced their adoption of practices due to lack of labour or old age. "Good" farmers have increased the involvement of external stakeholders in the community and political life. “Mad” farmers cope with difficulties in access to land and labour and restricted networks in the community. This pushes them to demonstrate that the way they work the land is more profitable than the usual methods of land management. They diversify their livelihoods, securing their incomes with livestock ownership and commercialisation. “Lazy” farmers are constrained by lack of land and family responsibilities and their attachment to their land is undermined by migration, off-farm activities, lack of access to financial support for their farming and lack of knowledge and experience of farming. Their vision of land management is influenced by their formal education and perception of modern agriculture.

The analysis of trade-offs using farmers’ typologies provides a landscape of land users’ attitudes and perceptions. The different clusters of technologies are associated to a certain extent with this landscape of different farmer types, as perceived by different actors (the researcher, the community and the farmers themselves). There are some interesting implications in these findings for the design of future interventions in land management. The main lesson is that development projects need not only to consider the NRM that is actually used and accepted by land users but also should consider individual farmer characteristics as perceived and categorised by the farming community itself. Particularly, as external stakeholders tend to have their own normative views and criteria when implementing projects in communities, generally selecting ‘good’ farmers or in some cases ‘mad’ ones while ignoring ‘lazy’ farmers. In this view, local perceptions may themselves be seen as operational standpoints in order to avoid the exclusion of particular groups of farmers and to include often the poorer and less socially-advantaged individuals.

7.9. Conclusions

This chapter has illustrated how the adoption of LaDC technologies and the associated trade-offs are the result of direct interactions between farming households and their environment. Trade-offs are determined by the hugely complex sets of factors inherent in the challenging Highland environment. However, this research has shown that out of the complexity some order through qualitative categorisations can be gained to understand decision-making in LaDC, without excluding the very important role of individual preferences.

The framework for understanding trade-offs is based on spatial, temporal and intrinsic perspectives which provide a starting point from which to disaggregate the intricate decisions of what is to be gained and what lost, and where and when to do it in the implementation of a LaDC technology. A clear link between spatial LUT and temporal short-term/long-term views is observed. Land users may choose economic gains in the form of food security over other outputs in the short term, preferring *solar* LUT. However, intrinsic conditions such as aspirations and personal goals will drive trade-off choices when this need is met.

In order to consider the explicit role of interventions (i.e. external forces), this research shows how changes in the political environment have challenged land users' trade-off options, particularly in the use of inorganic vs. organic fertilisers. Trade-off decisions are ultimately farmers' choices embedded in space, time and intrinsic perspectives. This view allows the differentiation of spaces in LUT, recognition of land users' experiences, knowledge and interests and the effects of policy changes on land management decisions. The different perspectives are relevant in recognising the practical implications of past and current trade-offs in NRM. The deconstruction of farmers' experiences in land management according to farmer typology is an engaging – perhaps provocative - analytical exercise in enabling a qualitative approach to explore trade-offs in LaDC. Finally, trade-offs are regularly adjusted to socio-economic, cultural and environmental changes. Farmers depending on subsistence agriculture choose trade-offs to gain positive outcomes or at least to reduce negative trends in order to lessen the household's vulnerability (e.g. positive outcomes encourage decreasing abandonment of *milpas*, improving soil properties in *solar* to increase maize yields in the long term, making agriculture an appealing livelihood to their children). However, the pressure from political and economic contexts is pushing farmers to prefer increasing production by the use of fertiliser, herbicides, and monoculture and less fallow. In constrained environments such as hillside agriculture, the analysis of trade-offs from diverse standpoints is essential in informing the future direction of technical and policy interventions seeking to improve land use and rural livelihoods.

Chapter 8. Conclusions: LaDC in farming hillside livelihoods

These lands are thin, what they need is to be thickened
(Farmer of SPT)

8.1. Introduction

Land management in areas affected by land degradation, especially in small-farm hillside environments, has always been problematic. Partly, this is because the environmental conditions are conducive to high rates of land degradation; but partly also because there is often a mis-match between what professionals see as the problem and its solution and what local people actually do. Stereotypically, this lack of common understanding has led to technical solutions being promoted by professionals based upon their understanding of the issues and technical efficiency of the introduced technologies, and a resistance by local people to accept recommendations. In sequence, then this apparent rejection of technical remedies to land degradation has led in many places to further misunderstandings and, by implication, accusations that local people make irrational choices. Although shown to be wrong in many parts of the world, this discourse on land degradation control runs deeply. It needs to be countered by solid empirical evidence that land degradation is a complex challenge and that local people very often have sound technical, social and economic reasons for the choices they make. Understanding these reasons must be the starting point to trying to assist local people in their endeavours to control land degradation and improve their livelihoods. This research is about unravelling the complex issues surrounding land degradation control technologies (LaDC) and how local people respond to them.

Therefore, based on land users' knowledge, experience, perceptions and values of land management, in agricultural areas of the Mexican Highlands affected by land degradation, specifically in *solar* and *milpa* LUT, farmers' abilities to manage their natural resource assets have been thoroughly explored. The particular focus has been their natural resource base in an effort to control land degradation at the household level and the implication of this for their livelihoods developed from often fragile soils in hillside areas. LaDC is part of the agricultural production process and hence farmers' strategies for managing their resources and improving their livelihoods. The farmer in the headline quote above refers to thin land as a degraded land which in his view can be restored, especially, for cultivation. Although his solutions may be simplistic in the eyes of external actors, it illustrates the view that land degradation effects on agricultural land can be understood and addressed from a local standpoint. That understanding may sometimes even be the best technical solution; more often, though, it will be a balance – or trade-off – between competing influences that are not only technical but also relate to social status and economic support to farming livelihoods. However, in the quote farmers' decision-making process aimed at "thickening" the land or any other implementation of LaDC is complex because it encompasses the interaction of influential factors, values and trade-offs as presented in this thesis. This study, in endeavouring to achieve an understanding of land management, focuses especially on farmers' decision-making on LaDC and their implications for natural resource management and livelihoods in the Highlands context. The aim of this research was to appreciate how an understanding of farmers' management, value and associated trade-offs of LADC technologies can contribute to better natural resource management in hillside communities. The research was carried out in the context of the farming livelihoods settled in the Highlands of Central Mexico by using a case study of the *Mazahua* community of San Pablo Tlalchichilpa.

This concluding chapter of the research presents the broader implications that can be drawn from the analyses of empirical evidence presented in the previous chapters, in accordance with the research objectives outlined in Chapter 1. A detailed description of the historical land management changes in Mexico, the current household asset base characterised the setting where farmers' responses to land degradation are implemented. The analysis of the technology associations, the influential factors in technology adoption, the appraisal of the multiple values of LaDC technologies by farmers and a trade-off analysis has explained the rationale of farmers' LaDC from different but complementary perspectives. The findings provide further insights into the dynamics of the relationship between farming livelihoods and the environment, which are presented below in relation to the research objectives.

8.2. Revisiting the objectives

8.2.1. Farmers' LaDC in the Highlands of Central Mexico: setting, responses and driving factors

The research objective was to provide an overview of land degradation, historical land management changes and households' current assets, particularly of land, in order to identify and characterise the principal types of LaDC in the case study area as perceived by land users, and examine influential factors affecting the adoption of control technologies. This objective was achieved and developed in two chapters (Chapters 4 and 5). The first one concentrated on exploring the setting for land degradation, the historical land management changes in the Mexican Highlands and characterisation of livelihood assets base to better understand the historical background and current context on which to develop specific research questions and hypotheses (Chapter4). The second chapter presents the LaDC measures adopted by farmers and examines the influential factors driving their adoption (see Chapter 5).

The historical analysis of land management changes was central in understanding existing patterns of land use and land degradation control responses at the local level. It documented the origin of the main LUTs in agricultural areas in the Highlands of Mexico such as *solar* and *milpa*, managed since the pre-Hispanic period and influenced by later land organisations systems, patterns of allocation of land (e.g. *ejido* and private property), labour, migration and national policies affecting the agricultural sector (e.g. NAFTA, fertiliser subsides, crop markets). The analysis allowed the identification of past scenarios of land use, LaDC technological choices and the factors affecting the rural areas. This reveals the historical legacy prevailing in the current land management systems in the Mexican Highlands, the environmental and social diversity, cultural complexity, biophysical challenges and decision-making process on farming livelihoods.

The analysis of the geographical setting is an important element in understanding the natural asset base available to farmers to manage the land and its degradation. The detailed analysis of land attributes, specifically, soil type, soil diversity, and soil location, set out the current state of land managed by farmers, while the socioeconomic descriptions of households reveal the assets available for taking decisions in relation to land management and LaDC.

In the case study, the fusion of knowledge, cultures, languages and the physical characteristics of SPT are intrinsically related to farmers' management strategies. Hence, the geographical and historical context for land degradation together with the characterisation of livelihoods assets base were imperative factors to determine how and why present LUTs such as *solar* and *milpa* are constructed and how land users now face the challenge of present-day land degradation.

In the case study, land users can be seen to have responded to land degradation processes through the adoption of one or more many different technologies (see Chapter 5). The research identified seventeen separate technologies considered by farmers as contributing to their thinking of 'taking care of the land'. The technologies (inherited and promoted) are focused around two main objectives: 1) fertility management and 2) control of soil erosion by mean of mechanical or biological structures. Land users clearly distinguished soil and water conservation practices from fertility improvement practices. However, they combine them when 'taking care of the land', often utilising a complex suite of technologies over different units of land. The characterisation of the technologies by using customary technology summaries provides rich detail of the assets, time and methods of implementation used by farmer. This leads to a better understanding of their adoption and performance and contextualised local land management in Highland systems.

Farmers are the decision- makers when it comes to which technologies to adopt and how. The design, number and distribution of LaDC measures are partially determined by availability of assets and the biophysical attributes of each unit of production. Land users will decide on a combination of technologies which enhance performance, produce co-benefits and reduce inputs needed for their implementation. Influential factors driving the adoption of technologies in the case study are land productivity, distances of plots from farmers' homestead, soil type, religion, education, and livestock and age of household head. The results are in line with farmers' opinion regarding factors affecting their technology adoption. However, the results are contextualised and not generalisable. Empirical research has shown that these factors respond to local conditions (see Chapter 5). The research categorised the technologies in clusters based on the identified influential factors allowing the grouping of technologies according to broad adoption similarities. The categorisation of technologies in relation to the driving factors is a relevant and useful methodology to address potential promotion of technologies or support local strategies according to the context.

The analysis of the setting, technology adoption and driving factors, and clusters provides a partial understanding of farmer's abilities to take up LaDC, how technology implementation is dependent on livelihood assets and how the assets are benefited or undermined by these technological choices made by farmers.

8.2.2. The Multiple values of LaDC: hidden influential drivers in LaDC

The multi-functionality of agricultural activities, in particular LaDC technologies, induces farmers to associate a particular set of values with each technology linked to wider and more complex value-sets established at personal, household and community levels. The second research objective was to measure these multiple values of LaDC and develop indicators to analyse the values that drive farmers' decisions about adoption of technologies. The appraisal of the multiple values of LaDC was based on a capital asset typology. This typology provided a structure to develop the indicators required to disaggregate the different elements of the technologies. Most importantly, it helped analyse farmers' perception of multiple values and to link specific adoption of technologies and their likely impacts on a household's assets base. The examination of the scores indicates important differences in values according to type of technologies, capital assets and indicators. The appraisal shows how farmers value each technology differently, more specifically its functions and impacts on their livelihoods. Farmers value more highly the technologies that simultaneously improve soil properties -specifically soil fertility and moisture - and reduce soil loss. This is an important finding that emphasises that co-benefits of conservation strategies are critical. Farmers appreciate multi-functional technological designs and the importance of different conservation aims in general as well as their own units of production. The most fluctuating scores in capital assets per technology expose potential limitations in adoption of LaDC faced by land users. The low and middle scores for indicators identify the trade-offs in the technological choices as assessed by farmers. At the technology cluster level, the findings highlight how perceptions and allotment of value vary according to household head's socioeconomic characteristics such as gender, education religion, and family type and mainly to first-hand adoption experience of LaDC practices. The measurement of values allows the capturing of those perceptions in a semi-quantitative way, revealing the spatial and temporal rationality of multi-functionality for land users.

Maize production for household consumption and fodder is the main priority for farming households; therefore, they favour and value highly any technology aimed at increasing crop production. The enhancement of soil fertility and productivity is of utmost importance to farmers to develop their livelihoods. The implications of social indicator values such as recognition, developing social networks, aesthetics, personal incentives to manage land and custom and traditions offer indirect benefits to land users and influence their decisions to a lesser extent but these may be critical in final adoption. Land users' values and perceptions are factors driving households to choose LaDC measures as livelihood strategies. Evidence from this research underlines that land user's LaDC measures must increase - or at the very least not decrease - yields or not impair the quality of the crops. They must also avoid conflicting labour demands at critical times in the season, while improving farmers' personal incentives to manage land, build recognition in the community, keep traditions and challenge their knowledge. This is supported by similar evidence observed in the factors affecting famers' acceptance of conservation measures in Germany (Sattler and Nagel, 2010) . This indicates that farmers' decision–making in such contrasting scenarios operates in a context of bounded rationality and related goals.

Farmers usually know what the best practices are required in their fields and for their livelihoods. However, their ability to adopt the best technologies is undermined by limited access to resources and policies implemented by external actors in poor hillside communities. This explains why the technologies that are most valued are the least adopted. This may appear to a perverse finding but is based empirically in this research on findings that highlight that LaDC interest at the local level is related to production and livelihood outcomes in stark contrast to the environmental focus prevailing in external LaDC interventions. The multiple values appraisal reveals the complex and dynamic agricultural systems, the land user's personal views on which NRM is set up and active and potential trade-offs involved in technology adoption.

8.2.3. Trade-offs in LaDC: the strategy for farming livelihoods

Local approaches to control land degradation are part of a complex agricultural system developed by households in steep-slope areas over lengthy periods of time. Land users' decisions about allocating resources in land management involve trade-offs that vary according to their household asset base, land users' interests and needs and pressures from the surrounding environment. Therefore, the third and final research objective was to analyse trade-offs associated with LaDC according to farmers' perspective in order to better understand decisions related to natural resource management and livelihood outcomes.

Trade-offs result from direct interactions between farming households and their environment. Hence, inherent complexity and dynamism are hallmarks of the decision-making processes. Farmers claim to adopt technologies only when and where there is a need, revealing a spatial and temporal perspective in their decision-making process as observed through the multiple values analysis. Trade-off decisions are ultimately farmers' choices embedded in space, time and intrinsic perspectives. These perspectives provide a basis from which to disaggregate the intricate decisions made by land users of what is to be gained and what is to be lost, and where and when to do it. Trade-offs entail economic or productivity-related factors as well as other social benefits and livelihood outcomes. Spatial (land use system), temporal (short- and long-term) and intrinsic (such as aspirations and personal goals) trade-offs are intertwined. In particular, the analysis indicated how intrinsic conditions will drive trade-off choices in space and time when households' food security is met. Moreover, changes in the political environment challenge land users' trade-off options. The understanding of how specific policy changes have influenced households' trade-off decisions allow an appreciation of past values associated with LaDC and their implicit trade-offs. This understanding is relevant to and appreciation of current land users' decision-making processes in LaDC's.

In a subsistence agriculture context, farmers will often aim for trade-offs that promote positive outcomes or at least reduce negative outcomes in order to lessen the household's vulnerability (e.g. decreasing land abandonment, improving soil properties to increase maize yields in the long-term, making agriculture an appealing livelihood to their children). However, the pressure from political and economic forces is pushing farmers towards making short-term trade-offs (e.g. use of fertiliser and herbicides, monoculture and less fallow) that may decrease their interest in implementing LaDC.

Land users' experiences, knowledge about the different land uses systems, time rationality and how this influences their interests and livelihoods strategies are recognised in the trade-offs approach taken. Farmers have specific perceptions of the different types of land and land managers based on individual attitudes and land management (Okoba and De Graaff, 2005). The deconstruction of farmers' perception and land management experience distinguish specific differentiation patterns between land users. This differentiation provides the criteria to develop a farmer's typology from a farmer's perspective. This is used to identify trade-off decisions between farmers. The typology does not intend to discriminate but instead to capture their different livelihoods conditions and attitudes towards LaDC and a better understanding of the type of trade-offs selected by each farmer type. This standpoint allows the development of alternative scenarios around which to deliver specific packages or programmes in accord to land users' personality and livelihoods in order to avoid exclusions of farmers. In constrained environments such as hillside agriculture, the analysis of trade-offs from diverse perspectives is central in understanding agricultural systems, LaDC and related resources management and farming livelihoods.

8.3. Major empirical findings

The biophysical attributes and the socio-economic context of subsistence agriculture of SPT all combine to provide a basic understanding that land is made vulnerable to degradation through its use for legitimate farming purposes, especially through the processes of soil erosion. Land degradation, in turn, impacts back on farming livelihoods in a variety of ways and to various extents. The *Mazahua* and *mestizo* knowledge, cultures, languages and the physical characteristics of SPT are intrinsically related to farmers' strategies to manage the land. This is observed in the diversity of technologies adopted by farmers in order to control land degradation but most importantly to develop their farming livelihood activities. The technologies integrate two fundamental but related systems of land management: (1) inherited/traditional (e.g. since the pre-Hispanic period such as hedge, holes, reinstating sediment, intercropping) and (2) introduced (promoted) practices (e.g. tillage, fertiliser). Seventeen LaDC technologies were identified during the research that farmers use in SPT for two principal but again related purposes: (1) improvement of soil fertility and (2) control of soil erosion. The two purposes were found to be clearly differentiated in farmers' thinking. In general, farmers' choices when combining technologies are to exploit complementary benefits rather than to overcome competitive tendencies. Combining technologies is part of an integral and wider land management strategy at the household level. Specific technologies adopted in each field provide a "package" of benefits to land users. The technologies were categorised into four clusters on the basis of similarities in the influential factors that characterise each technology. This is one of the first times that cluster analysis has been used across so many technologies of land degradation control in order to group them into categories that can be typified by dominant process and rationale in farmers' thinking. Fertiliser is analysed as a LaDC measure as farmers recognised this as one of the technologies to take care of the land and their perceptions were the basis of this research.

At the core of farmers' thinking, their asset base and intrinsic motivation are employed by land users to evaluate their options whether to adopt a technology. They may implement a technology even if it is not the most desirable or effective option, because assets may be scarce or there is some intrinsic motive.

Therefore, land users' decisions on LaDC are often misunderstood and fail to match those recommended by external stakeholders. Their actual decisions may not reflect the value they say they put on the technologies because farmers are aware at the same time that their rationale is different from that of the external promoter of technologies. Farmer's appraisal reveals the indirect functions influencing adoption, especially in the selection of LaDC practices. The assessment of technologies varies depending on adoption experience, technology and household characteristics. The social indicators identified usually accord with the unifying factors that appear to control the clustering of technologies into distinct categories. Using the classification adopted in this research, the C1- Standard practice is highly valued for following traditional/customary land management; C2- Sediment management is linked to aesthetic and personal incentives to manage the land; C3- Labour and land availability reflect important but often unseen values in the community related to the interaction of these two key assets of land and labour; and C4- Intensive management was found to be related to indicators of social prestige and experience. Taking into consideration that the clustering of LaDC technologies is based on patterns of adoption, it encompasses relevant policy implications, in particular in future promotion of conservation practices by local or external stakeholders. By identifying and aggregating broad adoption similarities, the clusters organise LaDC technologies in different baskets from which farmers could select and combine according to their specific households' conditions and land biophysical attributes. In addition, as the clusters show linkages with values attached by farmers, clusters could influence positively in land user's attitudes and acceptance of practices. This acknowledges that units of productions and people's characteristics are never the same and change. Therefore, farmers could choose one or more technologies from the different baskets based on their very particular values in each specific units of production.

The analysis of trade-offs conducted in this research attempted to identify how different issues re-balanced in farmers' thinking, and how real decisions over technology adoption are driven by a complexity of often competing forces. It reveals that farmers manage their LaDC trade-offs in three principal ways: spatially (*solar* and *milpa*); temporally (ST/LT); and intrinsically. These three sets of factors appear to be the dominant sources of influence over technology adoption; yet, they are also nested within each other, and therefore trade-offs are made not only within one category (e.g. between *solar* and *milpa*) but also between category (e.g. short-term demands versus technical experience of a technology). The three different perspectives help to identify the actual trade-offs entailed in each of the technology clusters. In turn, the trade-offs determine the consequent effect on livelihoods. Farmers' priorities and interests in improving land productivity will be maintained by investments on their *solar or* more productive fields at the cost of more labour-intensive technologies such as *arena-pumice,* the reincorporation of sediments and manure (C1, C2 and C4 technologies). No crop rotation and fallow (C3) are used on *solars*, which increases the need for more labour-intensive ways of incorporating nutrients in the soil. C3 technologies will be chosen in *milpa* as well as C1; if resources are available they will be adopted on C2 and C4 practices. Trade-offs indicate an intensively managed *solar* with highly valued technologies vs. less intensively managed *milpas*. Farmers' livelihood strategies aim to balance the intensity of management between land utilisation types.

Trade-offs in LaDC lead to the adoption of practices which may not be considered the most adequate or needed but enable farmers to maintain their preferred standards. Trade-offs reflect distinct values driving past and current land users' decisions in allocation of assets, in this case, land degradation control management and its associated livelihood outcomes. The policy relevance of acknowledging local trade-offs is the ability to reflect values managed by land user's and the potential to link them to values promoted by external actors in order to establish a common ground of interest and action.

Farmers' typology of themselves as 'good' 'mad' and 'lazy' provides evidence of the essential role of understanding farmers' perceptions of people within their community, and the sort of individual personality that typifies how a farming problem such as land degradation is tackled by different people. Appreciating their attitudes and values regarding farming activities and LaDC enables a determination of risk, reward, coping ability and effect of vulnerability on their livelihood strategies. The farmer's typology as expressed by land users cross-cuts the three empirical chapter topics of this research: the socioeconomic scenario presented in Chapter 4, the selections of cluster technology (Chapter 5) and the values associated with technologies (Chapters 6). Thus, the typology of farmers helps understand through the eyes of local people those land users' different external characteristics (e.g. demographic, economic and social), which are drivers of LaDC adoption. For instance, a lazy farmer does not represent only an attitude but also the enabling environment in which households develop their livelihoods such as limited access to resources (e.g. labour, land, money) and their social needs and interests. The recognition of farmers' typology is a standpoint to appreciate local social differentiation and attitudes diversity. This has significant policy implications, particularly, when developing external interventions. As generally, external stakeholders follow their normative criteria to select farmers when implementing projects in communities, they often choose 'good' farmers to work with or in some cases; they require the 'mad' ones, tending to exclude in most of the cases the 'lazy' farmers which could be also benefited from the interventions. The influential factors in the adoption of LaDC technologies from different analyses are presented in Table 8.1. The linkages across findings are presented in Figure 8.1.

Table 8.1 Influential factors in adoption of technology in the case study

Research objective	Variables or framework employed	Influential factors identified
Adoption of technologies (17 LaDC practices)	Households' socioeconomic variables and biophysical attributes (Parametric analysis)	Land productivity, distances of plots soil type, religion, and to less extent education, livestock, age of household head C1 Standard continuous agricultural technologies C2 Sediment management technologies C3 Labour limited/ high area availability technologies C4 Intensive investment technologies
Multiple values appraisal (25 indicators)	Natural, Social, Physical, Financial, Human capital asset types (Parametric analysis based on perceptions)	Access to poor soils, perceptions of labour required by adoption, lack of labour, land, material and financial assets Positive influence of social indicators when households' need for food security is met (recognition, personal incentive to manage land, customs and traditions, aesthetic, networks)
Trade-offs of LaDC (Preferences exercise)	Spatial Temporal Intrinsic External factors	LUT- different scenarios of contribution for NRM SL/LT- farmers' attitudes towards past, present and future use of NRM, reflect needs and interests Intrinsic- Perceptions and incentives to particular NRM External- Pressures modifying the NRM and Farming livelihoods.

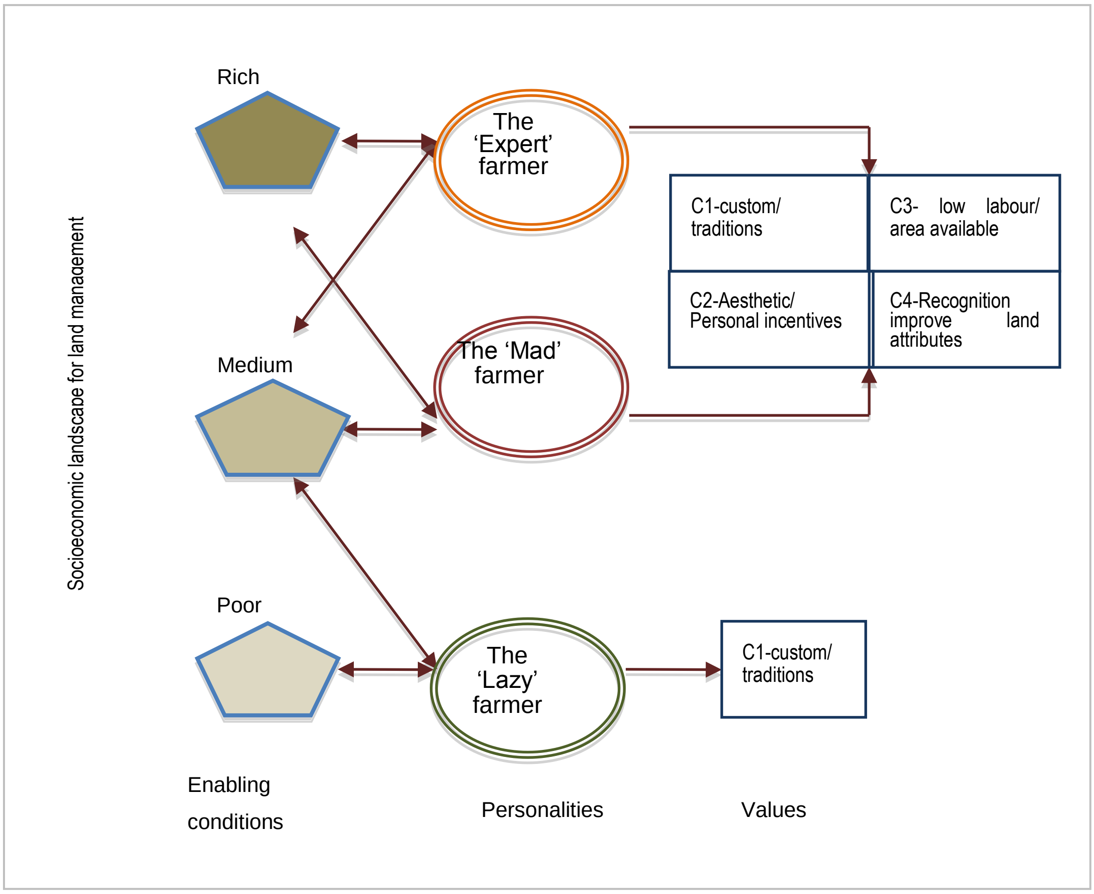


Figure 8.1 Linkages across empirical findings in the case study

8.4. Limitations and further research

Inevitably any research dealing with complex issues of environment, society and economics, undertaken in a finite time-frame by a single researcher who simultaneously had to develop many new research skills, will have some deficiencies. This final sub-section attempts to be candid about the limitations of this study and to point forward to how some of the deficiencies might be remedied and opportunities for new research be identified.

There are implicit limitations in this research related to the methodological choices selected to carry out this study. The methodologies had to be primarily developed before the nature and scale of the complexities of multiple values, for example, were known. The primary methodological limitation was the necessary selection of a single case study area, thereby foregoing the opportunity of generalisation or examining differentiation between other areas. The case study approach entails not only issues with the generalisation of data, as previously identified in the thesis, but also the contextuality of findings which could be explored to determine generalisable patterns of findings. It would have been good, for example, to know how far the results applied to other agricultural systems, livelihood sources and other farmers' decision-making processes. Another research limitation is the exclusion of community organisation level to tackle land degradation in communal areas in this thesis. This could have enriched the understanding of community social values and arrangements in land management. However, it was beyond the scope of this research that purposely focused on implementation of LaDC by individual households to better appreciate the relationship between agricultural production and land degradation control practices.

A further source of limitation concerns the previous involvement of the researcher with the community, her prior knowledge and close linkages with the Mexican context. Acknowledging that the researcher is another actor in the local landscape may have enabled some control over potential bias in the research process occasioned by prior knowledge and existing connections. Care was taken throughout the research to maintain an objective stance and to be neutral in dealings with farmers and other respondents, but inevitably some of the pre-existing social connections would have driven some responses to be different than if they were received by a researcher without prior connections. Therefore, there is an imperative for this researcher to employ the same methods of study in another area and context, even in different countries, to see how far prior knowledge may have influenced the result here. Such research would have to be undertaken under specifically controlled conditions.

A further area of limitation concerns the sample of technologies identified and the analytical methods employed. The research analysed as full a sample of technologies that could be identified within the time-frame of the research – so, a 100 percent sample, although if the investigation had been longer, more technologies may have been found – with the specific objective of capturing the complexity of the farmers' decision-making challenges. The advantage of this sampling design is the option to determine the influential factors in each technology and potentially to identify and develop specific strategies to target land degradation using local approaches. The choice of maximising the sample was a trade-off itself, because with the large sample size and finite time available, the methods of analysis had to be somewhat constrained. The use of parametric methods such as logistic regression attempted to overcome some of the limitations in allowing the predictions of odds for adoption which were not explored due to scope of this research. Logistic regressions were found to be able to provide detailed information for potential use in the promotion of technologies in the area. On the other hand, the large number of practices included in the analysis limited the opportunity to concentrate on the most influential practices or centrally-important technologies in household livelihoods. Further analysis could be indicated to focus on these technologies as 'best-bet' practices, and to identify with greater clarity the exact conditions for their adoption and by whom.

The methodology employed to appraise the multiple values also has limitations regarding weighting issues and the interpretation of certain scores, which may be needed to be addressed in revisiting this research. A scoring system was employed which, in effect, gave equal weighting to the various indicators used; yet there was no evidence-base that these indicators had equal influence. Indeed, it could be argued that real weightings would be bound to be different, and they might likely be different for different farmers. However, there was no way, without experimental simulation exercises with respondents, to determine anything other than equal weighting. Although the combination of semi-quantitative and qualitative analysis allows a better understanding of farmers' rationales for adopting and valuing particular functions of technologies, the management of such comprehensive list of indicators and technologies entails challenges in the analysis. A partial solution, without employing more sophisticated and intensive research techniques, would have been to simplify or reduce the number of indicators. However, then, some of the richness of the data would have been lost – another trade-off in terms of research.

The trade-off analysis itself from a qualitative point of view using farmers' perceptions provided an insight into the complexity of the core issue of the research, the adoption of LaDC technologies. There were, however, some possible missing issues that farmers would find to be important, the main one being the financial costs and benefits as experienced by the land users. In retrospect and with the benefit of hindsight, financial and economic drivers were inadequately handled. These may have better to identify the outcomes of trade-offs in farming livelihoods, especially when considered alongside social and technical factors. Similarly, the qualitative analysis of trade-offs highlighted how important farmers' personality and behaviour were in influencing the assets allocation, LaDC and livelihood strategies. It might therefore be asked whether the emphasis on people's personalities might have diverted attention from other, more generalisable issues that would assist with the better promotion of LaDC and local policies.

The research findings themselves demonstrated that there are issues that require further, more detailed, investigation, particularly in the area of looking at future development of local initiatives. One of these issues identified is the role of women in LaDC in agricultural areas. In the last decades women were able to inherit land and, therefore, they are now responsible for much of its management. However, LaDC practices are commonly considered not appropriate for women; there are cultural and physical constraints faced by those women wishing to adopt technologies; and there are substantial opportunity costs in women playing a more major role in LaDC technologies. The appraisal shows women assessed differently specific values of technologies from men. Is the access to land changing women's values and attitudes to LaDC and their livelihoods? This is a question that would need to be addressed if technologies were to be targeted at women farmers and decision-makers.

Land users' trade-offs are dynamic, adjusting to cultural and political changes. The current policy context is undermining many farmers' incentives to cultivate maize because of poor crop prices, inadequate markets and migration, affecting farmers' choices of trade-offs. Policy and institutions are aspects not widely explored in this thesis. This research concentrates deliberately on decision-making process made by individual households in the allocation and trade-offs of capital assets involved in LADC technologies' adoption and their implications to farming livelihood outcomes. Policy contexts, as the historical analysis at the start of this research shows, are vital in understanding the choices that farmers make.

Designing of appropriate incentives requires an understanding of current values and potential positive trade-offs. Policy changes and current trends in the economic circumstances of Latin American economies could be an area for fruitful examination in the context of LaDC technologies.

A further more specific limitation was that the research sampling design only considered households which manage both *solar* and *milpa* LUT. This was done in order to observe trade-offs between these two LUTs. Households managing only *solar* (land-poor) may provide interesting results of application to land management and LaDC which could contribute to any campaign to target these households which are amongst the poorest.

Finally, the understanding of how land users' manage values and trade-offs of LaDC technologies and related resources and their impacts on farming livelihoods is crucial for the development of strategies directed to land management and conservation. It would have been good if time and resources had allowed the exploration of conservation strategies that could have utilised the outputs of this research. Technology promotion could be addressed, for example, according to the clusters of technologies found in this research, targeting specific groups' characteristics including personalities to encourage the success of the conservation project. There is, as yet, no empirical evidence that the findings of this research are of practical use in technology promotion campaigns. This understanding could also be fundamental when informing the future direction of technical and policy interventions seeking to improve land use and rural livelihoods. The implication of responses to the local level provides paths – but no clear evidence - to demonstrate the benefits of local actions in global natural resource management.

As G.W. Allport, an American psychologist, is reported to have written in *Becoming* in 1955, "the scientist, by the very nature of his commitment, creates more and more questions, never fewer. Indeed the measure of our intellectual maturity, one philosopher suggests, is our capacity to feel less and less satisfied with our answers to better problems." This research on LaDC technologies in one small part of Mexico and in a highland environment shows that delving into the complex issues of relations between humans and their environment may achieve few answers but it certainly invites more and more questions.

Glossary

Arena-pumice	Volcanic pumice sand with high calcium content, very porous and light material. When incorporated to land it increases soil moisture and nutrients such as phosphorus, potassium, nitrogen and magnesium (Chavez, 2007). It is part of the LaDC technologies analysed in this thesis.
Barbacoa	Traditional lamb dish (baked mutton), cooked in an clay oven which has increased its popularity in the area and it has become a special dish on important social occasions such as birthdays, graduations or weddings or other special events (see also Arriaga et al 2005)
Ejido	Land tenure system in which farmers (members of the *ejido*) hold the land in usufruct as it is owned by the *ejido* not by individuals, After the reform to Article 27 of the Mexican Constitution in 1992, *ejido* land can be sold, rented or mortgaged to non-*ejido* members, converting *ejidos* into a private property systems.
Maguey	A Mexican plant (*Agave* spp.) traditionally used as boundary vegetation in maize fields. Ma*g*uey is a plant can be used to make *pulque* (fermented drink), delimit fields (edges) and cook (*e.g. Barbacoa* with maguey leaves). It can also be a source of fuel and fibre (textiles) among other uses.
Mazahua	The *Mazahua* is an indigenous group of Mexico, settled mainly in the north-western part of the Estado de *Mexico state* and north-eastern part of *Michoacán* State. The largest concentration of *Mazahuas (people)* is found in the municipalities of San Felipe del Progreso and San Jose del Rincon, both in Estado de México, near Toluca. People speak their own dialect also referred as *Mazahua*.
Milpa	Term is derived from the Nahuatl word (mi-li= field and pa= to) usually meaning a field. In general terms, it is a piece of land dedicated to cultivation (mainly maize). Milpa term could also be referred to maize plants.
Pulque	A traditional and popular fermented alcoholic drink made from maguey plants. It has been a basic part of people's nutrition and cultural in rural areas of central Mexico.

Sangradera A mild-field earth bund dug by land users to reduce run-off and then divert water flow outside the maize field (*solar* or *milpa*. Its name is derived from *sangre* (blood) and could be translated as a “blood drain”, referring to draining the water. It is part of the LaDC technologies analysed in this thesis.

Solar It is a home garden located next to land user’s homestead, part of this piece of land is dedicated to cultivation, mainly of maize intercropped with beans and pumpkins or other plants.

Tope Tied- ridges constructed by land users in order to reduce run-off and harvesting sediment and water within maize fields (*solar* or *milpa*). Farmers do not use ploughing in when tope is adopted. It is part of the LaDC technologies analysed in this thesis.

References

AGUILAR, J., QUINTANAR, E., ILLSLEY, C. & GOMEZ, T. (eds.) 2000. *Incentives to Peasant creativity and research for conservation and efficient management of biodiversity in the centre mountain region of the State of Guerrero, Mexico. UNDP*

ALEMNEH, D., ELIEHO, S., PIUS, Y. & FRED, H. 1997. *Land degradation in Tanzania: Perception from the village,* Washington DC, World Bank

ALEXANDER, R. T. 2003. Introduction: Haciendas and Agrarian Change in Rural Mesoamerica. *Ethnohistory,* 50**,** 3-14.

ALLPORT, G. W. 1955. *Becoming: Basic considerations for a psychology of personality,* New Haven, Yale University Press.

AMERICAN HERITAGE 2005. *American Heritage Science Dictionary. ,* Boston USA, Houghton Mifflin Company.

AMSALU, A. & DE GRAAFF, J. 2006. Farmers' Views of Soil Erosion Problems and their Conservation Knowledge at Beressa Watershed, Central Highlands of Ethiopia. *Agriculture and Human Values,* 23**,** 99-108.

AMSALU, A. T. 2006. *Caring for the land: best practices in soil and water conservation in Beressa watershed, highlands of Ethiopia.* Wageningen University

AMSALU, A. T. & DE GRAAFF, J. 2007. Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian Highland watershed. *Ecological Economics* 61**,** 294-302.

ANAYA-GARDUNO, M. 2003. La Desertificacion en Mexico:Lineamientos Estrategicos para su Prevencion y Control. *Dialogo Internacional sobre Politicas en Materia de VUlnerabilidad al Cambio Climatico.* Zacatecas, Mexico.

ANIM, F. D. 1999. A note on the adoption of soil conservation measures in the northern province of South Africa. *Journal of Agricultural Economics,* 50**,** 336-345.

ANTLE, J. M., STOORVOGEL, J. J., CRISSMAN, C., BOWEN, W. & YANGGEN, D. 2003. The Tradeoff Analysis Approach: Lessons from Ecuador and Peru. *Quarterly Journal of International Agriculture,* 42**,** 189-206.

ARAYA, B. & ADJAYE, J. 2001. Adoption of farm level soil conservation practices in Eritrea. *Indian Journal of Agricultural Economics,* 56**,** 239-252.

ARRIAGA, C. M., PEDRAZA-FUENTES, A. M. E. G., NAVA-BERNAL, E. G., CHAVEZ-MEJIA, M. C. & CASTELAN-ORTEGA, O. A. 2005. Livestock Agrodiversity of Mazahua Smallholder Campesino Systems in the Highlands of Central Mexico. *Human Ecology,* 33**,** 821-845.

ASERCA (APOYOS Y SERVICIOS A LA COMERCIALIZACION AGROPECUARIA). 2010. http://www.aserca.gob.mx/artman/publish/article_183.asp [Online]. Mexico: ASERCA. [Accessed 2010].

ASSIES, W. 2008. Land Tenure and Tenure Regimes in Mexico: An Overview. *Journal of Agrarian change,* 8**,** 33-63.

BAIDU-FORSON, J. 1999. Factors influencing adoption of land-enhancing technology in the Sahel: lessons from a case study in Niger. *Agricultural Economics,* 20**,** 231-239.

BARRACLOUGH, S. 1995. Social dimensions of desertification: a review of key issues. *In:* STILES, D. (ed.) *Social aspects of sustainable dryland management.* Chichester: Wiley.

BARRERA-BASSOLS, N. & ZINCK, A. 2003. 'Land moves and Behaves': Indigenous discourse on sustainable land management in Pichataro, Patzcuaro basin, Mexico. *Geografiska Annaler,* 3-4**,** 229-245.

BARRERA-BASSOLS, N., ZINCK, J. A. & VAN RANST, E. 2006. Symbolism, knowledge and management of soil and land resources in indigenous communities: Ethnopedology at global, regional and local scales. *CATENA,* 65**,** 118-137.

BATEMAN, I. & WILLIS, K. G. 1999. *Valuing environmental preferences: theory and practice of the contingent valuation method in the US, EU and Developing countries,* Oxford, New York, Oxford university press.

BECERRA, A. 1998. Conservación de Suelos y Desarrollo Sustentable, ¿Utopía o Posibilidad en México? Soil Conservation and Sustainable Development, Utopia or Possibility in Mexico? *Departamento de Suelos, Universidad Autonoma Chapingo*.

BEKELE, W. & DRAKE, L. 2003. Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area. *Ecological Economics,* 46**,** 437-451.

BELLON, M. 2001. *Participatory Research Methods for Technology Evaluation: A Manual for Scientist Working with Farmers* Mexico City, International Maize and Wheat Improvement Center (CIMMYT).

BESHAH, T. 2003. Understanding farmers: explaining soil and water conservation in Konso, Wolaita and Wello, Ethiopia *In:* TROPICAL RESOURCE MANAGEMENT PAPERS (ed.). Wageningen, Netherlands: Wageningen University and Research Centre.

BISHOP, I. D., STOCK, C. & WILLIAMS, K. J. 2009. Using virtual environments and agent models in multi-criteria decision-making. *Land Use Policy,* 26**,** 87-94.

BLAIKIE, P. 1985. *The political ecology of soil erosion in developing countries,* England, Longman [Reprinted by Pearson Education in 2000].

BLAIKIE, P. 2001. Social nature and environmental policy in the South: Views from Verandah and Veld. Chapter 7. *In:* CASTREE, N. & BRAUN, B. (eds.) *Social nature: Theory, practice and politics.* London: Blackwells.

BLAIKIE, P. & BROOKFIELD, H. 1987. *Land degradation and Society,* London, Methuen.

BLANCO-MACIAS, G. 1969. Realizaciones y perspectivas en la conservación del suelo en México. *In:* INSTITUTO MEXICANOS DE RECURSOS NATURALES RENOVABLES, A. C. (ed.) *Mesas Redondas sobre utilización y conservación del suelo en México.* Mexico, D.F: Colegio de Posgraduados

BLANQUEL, M. & HERNÁNDEZ, R. 1999. San Felipe del Progreso. Monografía municipal. *In:* GOBIERNO DEL ESTADO DE MEXICO (ed.). Mexico: AMECROM.

BROOKFIELD, H., PADOCH, C., PARSON, H. & STOCKING, M. 2002. *Cultivating biodiversity: Understanding, analysing and using agricultural diversity,* London, ITDG publishing [in association with United Nations University, United Nations Environment Programme and the Global Environment Facility]

BROWN, K., ADGER, N. & TOMPKINS, E. 2002. *Making Waves: Integrating Coastal Conservation and Development,* London, Earthscan.

CAMPBELL, D. & BERRY, L. 2003. *Land degradation in Mexico: its extent and impact* [Online]. Available: http://fao.org/Ag/AGL/swlwpnr/reports/y_lm/z_mx/mx_doc/mxtx511.doc [Accessed 2006].

CARNEY, D. 1999. *Counting-assets. A framework for understanding sustainable rural livelihoods* [Online]. Available: http://www.odi.org.index.html [Accessed 2004].

CARTNER, R. 1988. Raising annoying questions: Why values should be built into decision-making. *CIPA publication,* 105.

CASTREE, N. 2001. Chapter 1 Socializing nature: Theory, practice and politics. *In:* CASTREE, N. & BRAUN, B. (eds.) *Social nature: Theory, practice and politics* London: Blackwells.

CASTREE, N. & BRAUN, B. 1998. The Construction Of Nature And The Nature Of Construction: Analytical And Political Tools For Building Survival Futures. *In:* CASTREE, B. B. A. N. (ed.) *Remaking Realities: Nature at the Millennium.* London: Routledge.

CHARLTON, T. H. 2003. On Agrarian Landholdings in Post-Conquest Rural Mesoamerica. *Ethnohistory,* 50**,** 221-230.

CHAVEZ, C., NAVA, B., VELAZQUEZ, L., MIRELES, P., NAVA, Y., PEDRAZA, M., GARCÍA, B., RUIZ, K., ARRIAGA, C. 2002. Management of Agrodiversity and Sustainable Campesino Agriculture on the Hillslopes of the Highlands of Central Mexico Second Stage. *Report for the Project People, Land and Environmental Change (PLEC)/United Nation University.* Toluca: Universidad Autónoma del Estado de Mexico.

CHÁVEZ, M., M. C. 1998. Etnobotánica de San Jerónimo Boncheté, México. *Universidad Autónoma del Estado de México*.

CHÁVEZ, M., MA. C. 2000. Análisis del solar familiar campesino como sitio deexperimentación e innovación. Caso de estudio: San Felipe del Progreso, estado de México. *Universidad Autónoma del Estado de México,* 60.

CHAVEZ, M., NAVA, G. & ARRIAGA, C. 1998. Agrodiversity, Management and Sustainable Agriculture in the Hill Slopes of the Highlands of Central Mexico. Final Report. Report for the Project People, Land and Environmental Change/United Nations University. *CICA and Universidad Autonoma del Estado de Mexico*.

CLARK, R., DURON, G. & STOCKING, M. 1998. Biophysical Assessment of Soil Erosion and Conservation. Evaluation Workshop: Bolivia. *Overseas Development Group and University of East Anglia*.

CLAWSON, D. L. & HOY, D. R. 1979. Nealtican, Mexico: A Peasant Community That Rejected the Green Revolution *American Journal of Economics and Sociology,* 38**,** 371-387.

CONAFOR 2007. Programa Nacional de Acción contra la Degradación de las Tierras y Mitigación de los Efectos de la Sequía 2007-2030. Comision Nacional Forestal.

CONAZA 1993. Plan de accion para combatir la desestificacion en Mexico [PACD-Mexico]. DF: Comision nacional de zonas aridas. Secretaria de Desarrollo Social

CONAZA. 2010. *Comision Nacional de Zonas Aridas* [Online]. Available: www.conaza.gob.mx [Accessed 2010].

COOK, S. & BORAH, W. 1963. *The Indian population of Central Mexico,* Berkeley, University of California Press.

COTLER, H. & ORTEGA-LARROCEA, M. P. 2006. Effects of land use on soil erosion in a tropical dry forest ecosystem, Chamela watershed, Mexico. *Catena,* 65**,** 107-117.

COXHEAD, I. & JAYASURIYA, S. 1994. Technical change in Agriculture and land degradation in developing countries: A general equilibrium. *Land economics,* February 70**,** 20-37.

CRESWELL, J. W. 1998. *Qualitative Inquiry and Research Design: Choosing Among Five Traditions,* Thousand Oaks, CA, SAGE.

CRITCHLEY, W. R. S. & MUTUNGA, K. 2003. Local innovation in a global context: documenting farmer initiatives in land husbandry through WOCAT. *Land degradation and Development,* 14**,** 143-162.

CRITCHLEY, W. R. S., REIJ, C. & WILLCOCKS, T. J. 1994. Indigenous solid and water conservation: a review of the state of knowledge and prospects for building on traditions. *Land degradation & Rehabilitation,* 5**,** 293-314.

DAHLBERG, A. 1994. *Contesting views and changing paradigms. The Land Degradation debate in Southern Africa,* Stockholm, Sweden, Nordiska Afrikainstitutet.

DAHLIN, B. H., T. BEACH, S. LUZZADDER-BEACH, D. HIXSON, S. HUTSON, A. MAGNONI, E. MANSEL, AND D.E. MAZEAU. 2005. Reconstructing agricultural self-sufficiency in Chunchucmil, Yucatan, Mexico. *Ancient Mesoamerica,* 16**,** 229-247.

DE GRAAFF, J., AMSALU, A., BODNA´ R , B., KESSLER, A., POSTHUMUS, H. & TENGE, A. 2008. Factors influencing adoption and continued use of long-term soil and water conservation measures in five developing countries *Applied Geography* 28**,** 271- 280.

DE ITA, A. 2005. *Mexico: Impacts of demarcation and titling by PROCEDE on agrarian conflicts and land concentration* [Online]. Centro de Estudios para el Cambio en el Campo Mexicano (CECCAM); LRAN. Available: http://www.landaction.org/display.php?article=336 [Accessed 7 July 2008].

DEMERITT, D. 1998. Science social constructivism and nature. *In:* BRAUN, B. A. C., N (ed.) *Remaking Reality: Nature at the Millennium.* London: Routledge.

DFID 1999. Sustainable livelihoods guidance sheets. *Department for international development (DFID)*.

DFID 2004. On measures taken to support the implementation of the United Nations Convention to combat desertification with a particular focus on affected developing country parties in Africa. *Department for International Development (DFID)*.

DICTIONARY, O. 2011. Oxford Dictionary. *In:* PRESS (ed.) *Oxford Dictionary.*

DIRECCION DE PROTECCION CIVIL. 1998. *Mapa del estado de Mexico en Contexto con el Atlas Nacional de Riesgo* [Online]. Toluca: Gobierno del Estado de Mexico. Available: http://www.edomexico.gob.mx [Accessed 2005].

DUMANSKI, J. 1997. Criteria and indicators for land quality and sustainable land management. *ITC Journal*

EDWARDS-JONES, G. 2006. Modelling farmer decision-making: concepts, progress and challenges. *Animal Science* 82**,** 783-790.

ELLIS, F. 2000. *Rural livelihoods and diversity in developing countries,* Oxford, Oxford University Press.

ENDFIELD, G. H. 1998. Lands, Livestock and the Law: Territorial Conflicts in Colonial West Central Mexico[a]. *Colonial Latin American Review,* 7**,** 205.

ENDFIELD, G. H. & O'HARA, S. L. 1999. Perception or deception? Land degradation in post-conquest Michoacán, west central México. *Land Degradation & Development,* 10**,** 383-398.

ERENSTEIN, O. 1999. *The economics of soil conservation in developing countries: The case of crop residue mulching.* PhD, Wageningen University.

ESWARAN, H., LAL, R. & REICH, P. F. 2001. Land degradation: an overview. *In:* BRIDGES, E. M., HANNAM, I. D., L.R. OLDEMAN, F.W.T. PENING DE VRIES, S.J. SCHERR & SOMPATPANIT, S. (eds.) *Response to land degradation [Proc. 2nd. International Conference on Land Degradation and Desertification, Khon Kaen, Thailand].* New Delhi: Oxford Press.

ETZIONI, A. 1967. Mixed-Scanning: A "Third" Approach to Decision-Making. *Public Administration Review,* 27**,** 385-392.

EVANS, S. 1990. The productivity of maguey terrace agriculture in Central Mexico during the Aztec Period. *Latin America Antiquity,* 1**,** 117-132.

FAO 1995. Sustainability issues in agricultural and rural development policies. Trainer's Manual, Volume 1. Rome: FAO.

FAO 1998. Terminology for Integrated Resources Planning and Management. *In:* UN FAO (FOOD AND AGRICULTURE ORGANIZATION) (ed.) *Land Degradation Assessment in Drylands (LADA) program.* Rome: FAO.

FAO. 2004. *Land degradation assessment in Drylands* [Online]. Rome. Available: http://ftp.fao.org/agl/agll/docs/lada.pdf [Accessed 2004].

FEAGIN, J., ORUM, A. & SJOBERG, G. 1991. *A case for case study,* Chapel Hill, NC., University of North Carolina Press.

FIELD, A. 2000. *Discovering statistics using SPSS for Windows,* London, Sage.

FRANCO-CARRASCO, J. 1969. Realizaciones y perspectivas en la conservacion del suelo en Mexico. *In:* INSTITUTO MEXICANOS DE RECURSOS NATURALES RENOVABLES, A. C. (ed.) *Mesas redondas sobre la utilizacion y conservacion del suelo en Mexico.* Mexico, D.F: Colegio de Posgraduados

GANZEL, B. 2007. *The Mexican Agricultural Program* [Online]. Lincon Available: http://www.livinghistoryfarm.org/farminginthe50s/crops_14.html [Accessed 18 August 2007].

GARCIA, B. & RUIZ., K. 2001. *Evolucion de Antrosuelos, Caso de Studio Barrio la Era, San Pablo Tlachichilpa, San Felipe del Progreso [Evolution of Anthrosoils, case study: Sector La Era, San Pablo Tlachichilpa, San Felipe del Progreso]. .* Thesis B.A, Facultad de Geografia.Universidad Autonoma del Estado de Mexico.

GARCIA, F. B. 2002. *Local soil conservation technologies and their role within farmers' rural livelihoods. A case study from the highlands of Central Mexico.* M.Sc. thesis, University of East Anglia.

GEBREMEDHIN, B. & SWINTON, S. 2003. Investment in soil conservation in Northern Ethiopia: the role of land tenure security and public programs. *Agricultural Economics,* 29**,** 69-84.

GEF 2005. Achieving the Millennium Development Goals. A GEF progress report. Washington, D.C.: Global Environment Facility.

GHIMIRE, K. & PIMBERT, M. (eds.) 1997. *Social Change & Conservation,* London: Earthscan.

GIAMPIETRO, M. 1997. Socioeconomic pressure, demographic pressure, environmental loading and technological changes in agriculture. *Agriculture, Ecosystems & Environment,* 65**,** 201-229.

GICHUKI, F., KODITUWAKKUA, D., NGUYEN-KHOAC, S. & HOANHA, C. T. 2009. Cross-scale trade-offs and synergies in aquaculture, water quality and environment: research issues and policy implications. *Water Policy,* 11 S. 1**,** 1-12.

GIDDENS, A. 1984. *The Constitution of Society. Outline of the Theory of Structuration,* Cambridge, Policy Press.

GISLADOTTIR, G. & STOCKING, M. 2005. Land degradation control and its global environmental benefits *Land Degradation and Development,* 16**,** 99-112.

GOOGLE EARTH (2008). San Pablo Tlalchichilpa aerial views [Online software]. Google Earth [Accessed 2008]

GONZALEZ, D., ARRIAGA-JORDAN, C. & SANCHEZ, V. 1996. The role of cattle and sheep in campesino (peasant) production systems in the highlands of central Mexico. *In:* DENT, J., MCGREGOR, M. & SIBBALD, A. (eds.) *Third international symposium on livestock farming systems.* Wageningen, EAAP Publication.

GONZÁLEZ JÁCOME, A. 2004. The ecological basis of the indigenous Nahuatl agriculture in the sixteenth century. *Agriculture and Human Values,* 21**,** 221-231.

GRIMBLE, R. & LAIDLAW, M. 2002. Biodiversity management and local livelihoods: Rio plus 10. *ODI Natural Resource Perspectives,* No. 73.

GROOT, J. C. J., ROSSING, W. A. H., TICHIT, M., TURPIN, N., JELLEMA, A., BAUDRY, J., VERBURG, P. H., DOYEN, L. & VAN DE VEN, G. W. J. 2009. On the contribution of modelling to multifunctional agriculture: Learning from comparisons. *Journal of Environmental Management* 90**,** 147-160.

GRUBE, J. W., MAYBETON, D. M. & BALL-ROKEACH, S. J. 1994. Inducing change in values, attitudes, and behaviors: Belief system theory and the method of value self-confrontation. *Journal of Social Issues,* 50**,** 153-173.

GUERRERO, A. 2000. *Autodiagnostico del Manejo del Solares en La Purisima Concepcion Mayorazgo, San Felipe del Progreso.* Thesis B.A., Facultad de Geografia. Universidad Autonoma del Estado de Mexico.

GUIJT, I. 1998 *Participatory Monitoring and Impact Assessment of Sustainable Agriculture Initiatives: An Introduction to the Key Elements. SARL Discussion Paper No.1,* London, IIED.

HAENN, N. 2006. The changing and enduring ejido: a state and regional examination of Mexico's land tenure counter-reforms. *Land Use Policy,* 23**,** 136-146.

HAGMANN, J. & MURWIRA, K. 1996. Indigenous soil and water conservation in Southern Zimbabwe. *In:* REIJ, C., SCOONES I. & TOULMIN., C. (eds.) *Sustaining the soil: indigenous soil and water conservation in Africa.* London: Earthscan.

HAGOS, F., PENDER, J. & NEGA, G. 1999. Land degradation in the Highlands of Tigray and strategies for sustainable land management. *Socioeconomic and Policy Research Working Paper,* 25**,** 73.

HAMMAD, A. A. & BORRENSEN, T. 2006. Socioeconomic factors affecting farmers' perceptions of land degradation and stonewall terraces in Central Palestine. *Environmental Management,* 37**,** 380-394.

HENGSDIJK, H., MEIJERINK, G. W. & MOSUGU, M. E. 2005. Modelling the effect of three soil and water conservation practices in Tigray, Ethiopia. *Agriculture, Ecosystems & Environment,* 105**,** 29-40.

HERWEG, K., STEINER, K. & SLAATS, J. 1998. Sustainable land management: guidelines for impact monitoring. Working documents for public discussion toolkit. *Sustainable land management workbook.* Bern: Centre for Development and Environment.

HOLDEN, S. & YOHANNES, H. 2002. Land redistribution, tenure insecurity, and intensity of production: A study of farm households in southern Ethiopia. *Land Economics,* 78**,** 573-590.

HUDSON, P. F. & ALCANTARA-AYALA, I. 2006. Ancient and modern perspectives on land degradation. *CATENA,* 65**,** 102-106.

HURNI, H. 2000. Assessing sustainable land management (SLM). *Agriculture, Ecosystems & Environment,* 81**,** 83-92.

IDB. 2010. *Procampo enters a Decisive phase in Mexico.* [Online]. Inter-American Development Bank. Available: http://www.iadb.org/en/topics/development-effectiveness/procampo-enters-a-decisive-phase-in-mexico,1263.html [Accessed 2010].

INEGI 1991. *XI Censo General de Población y Vivienda.Tabuladores Básicos,* Mexico, INEGI.

INEGI 2005. *Conteo de Poblacion y Vivienda.,* Mexico, INEGI.

INNIS, D. 1997. *Intercropping and Scientific Basis of Traditional Agriculture,* London, Intermediate Technology Publication.

JEWSBURY, L. 2001. *Rural Livelihoods and wild plants: a study of the Sabiny People of Easter Uganda and their reliance on Mount Elgon National Park.* M.Sc., University of East Anglia.

JONES, G. A. & WARD, P. M. 1998. Privatizing the commons: reforming the ejido and urban development in Mexico. *International Journal of Urban and Regional Research,* 22**,** 76-93.

JONES, S. 2002a. A framework for understanding on-farm environmental degradation and constraints to the adoption of soil conservation measures: Case studies from Highland Tanzania and Thailand. *World Development* 30**,** 1607-1620.

JONES, S. 2002b. Social Constructionism and the Environment: Through the Quagmire. *Global Environmental Change,* 12**,** 247-251.

KALIBA, A. R. M., FEATHERSTONE, A. M. & NORMAN, D. W. 1997. A stall-feeding management for improved cattle in semiarid central Tanzania: factors influencing adoption. *Agricultural Economics,* 17**,** 133-146.

KAMAR, M. 2001. Role of Kenyan Women's Groups in Community Based Soil And Water Conservation: A Case Study. *In:* STOTT, D. E., MOHTAR, R. H. & STEINHARDT, G. C. (eds.) *Sustaining the global farm (selected papers from the10th International Soil Conservation Organization Meeting held in May 24-29, 1999).* Purdue University and the USDA-ARS National Soil Erosion Research Laboratory.

KATZ, F. 1958. The Evolution of Aztec Society. *Past and Present***,** 14-25.

KEENEY, R. L. & RAIFFA, H. 1993. *Decisions with multiple objectives: Preferences and value tradeoffs,* Cambridge, Cambridge University Press.

KERR, J. & PENDER, J. 2005. Farmers' perceptions of soil erosion and its consequences in India's semiarid tropics. *Land Degradation and Development,* 16**,** 257-271.

KESSLER, A. 2006a. *Moving people - towards collective action in soil and water conservation: experiences from the Bolivian mountain valleys.* PhD thesis, Wageningen University.

KESSLER, C. A. 2006. Decisive key-factors influencing farm households' soil and water conservation investments. *Applied Geography,* 26**,** 40-60.

KIOME, R. & STOCKING, M. 1995. Rationality of farmer's perception of soil erosion- the effectiveness of soil conservation in semi-arid Kenya. *Global Environmental Change,* 5**,** 281-295.

KNOWLER, D. J. 2004. The economics of soil productivity: local, national and global perspectives. *Land Degradation & Development,* 15**,** 543-561.

LADA. 2008 Land *Degradation Assessment in Dryland.* [Online]. Available: http://www.fao.org/nr/lada/ [Accessed December 2008].

LAMBIN, E. F., DOWNING, T. E., KERVEN, C., KLEIDON, A., LEEMANS, R., LÜDEKE, M., PRINCE, S. D. & XUE, Y. 2002. The interplay between international and local processes affecting desertification. *In:* REYNOLDS, J. F. & STAFFORD-SMITH, D. M. (eds.) *Global desertification: Do humans cause deserts?* Berlin: Dahlem University press.

LAPAR, A. & PANDEY, S. 1999. Adoption of soil conservation: The case of the Philippines uplands. *Agricultural Economics,* 21**,** 241-256.

LESTRELIN, G. & GIORDANO, M. 2007. Upland development policy, livelihood change and land degradation: interactions from a Laotian village. *Land Degradation & Development,* 18**,** 55-76.

LITTLE, D. 1991. *Varieties of Social Explanation: An Introduction to the Philosophy of Social Science,* Oxford, Westview Press.

LU, C. H. & VAN ITTERSUM, M. K. 2003. A trade-off analysis of policy objectives for ansai, the Loess Plateau of China. *Agriculture, ecosystems and environment* 102**,** 235-246.

LU, Y. 2001. *Soil Conservation for Sustainable Land Use: A Decision-Support Model for The Loess Plateau China.* Thesis PhD School of Development Studies, University of East Anglia.

LYNNE, G. & SHONKWILER, J. 1988. Attitudes and farmer conservation behavior. *American Journal of Agricultural Economics,* 70**,** 12-19.

MALLAWAARACHNI, T. 2001. Conflicts and value trade-offs in the management of common property: insights from land use studies in the Australian Sugar Industry. *Inaugural Pacific Regional Meeting of the International Association for the Study of Common Property*.

MANGISONI, J. & PHIRI, G. 1996. New perspectives on local conservation techniques: a case study from Malawi. *In:* REIJ, C., SCOONES I. & TOULMIN., C. (eds.) *Sustaining the soil: indigenous soil and water conservation in Africa.* London: Earthscan.

MARIANOV, V., SNYDER, S. & REVELLE, C. 2004. Trading off species protection and timber production in forests managed for multiple objectives. *Environment and Planning B: Planning and Design,* 31**,** 847-862.

MAYBERY, D., CRASE, L. & GULLIFER, C. 2005. Categorising farming values as economic, conservation and lifestyle. *Journal of Economic Psychology,* 26**,** 59-72.

MCALLISTER, D. M. 1982. *Evaluation in environmental planning: assessing environment,* London, M.I.T. Press.

MCNEELY, J. 1988. Economics and biological diversity: developing and using conservation of nature and natural resources. *IUCN*, 11-36.

MEA. 2005. *Millennium Ecosystem Assessment* [Online]. Available: http://www.maweb.org/en/index.aspx [Accessed December 2010].

MIKKELSEN, B. 1995. *Methods for Sustainable Development Work and Research, A Guide for practitioners,* London, Sage Publications.

MIRANDA-DIAS, C. Year. Sustainable Development: The Anthropocentric Epistemology. *In:* RIO 02 - World Climate & Energy Event,, January 6-11, 2002. 201-206.

MOOR, G. 1996. Tenure security and productivity in the Zimbabwean small farm sector: implications for South Africa. *Department of Agricultural Economics. University of Natal: Pietermaritzburg*.

MORRIS, S., CARLETTO, C., HODDINOTT, J., & CHRISTIAENSEN, L. 2000. Validity of Rapid Estimates of Household wealth and income for health surveys in Rural Africa. *Journal of Epidemiology and Community Health,* 54**,** 381-387.

MUSALI, P. K. 2008. *Rethinking participatory natural resource management in the Kigezi highlands, Western Uganda: a resilience-building approach.* PhD, University of East Anglia.

NAVA, Y. 1999. *El Solar Familiar Campesino en La Purisima Concepcion Mayorazgo [The Campesino housegarden in the Purisima Conception Mayorazgo].* Thesis B.A., Facultad de Antropologia. Universidad Autonoma del Estado de Mexico.

NAVA-BERNAL, E. G. 2003. *Local maize varieties in Central Mexico: their management and contribution to campesinos' livelihoods.* PhD Thesis, University of East Anglia.

NIEMEIJER, D. & MAZZUCATO, V. 2000. *Rethinking soil and water conservation in a changing society. A case study in Eastern Burkina Faso.* PhD thesis, Wageningen University.

NUIJTEN, M. 2003. *Power, community and the state: the political anthropology of organisation in Mexico. Anthropology, culture and society,* London, Pluto Press.

NYSSEN, J., POESEN, J. & DECKERS, J. 2009. Land degradation and soil and water conservation in tropical highlands. *Soil and Tillage Research,* 103**,** 197-202.

OBA, G., SJAASTDA, E. & ROBA, H. G. 2008. Framework for Participatory Assessments and Implementation of Global Environmental Conventions at The Community Level. *Land Degradation & Development,* 19**,** 65-76.

ÖHLMÉR, B., OLSON, K. & B., B. 1998. Understanding farmers' decision making processes and improving managerial assistance. *Agricultural Economics***,** 273-290.

OKOBA, B. & DE GRAAFF, J. 2005. Farmers' Knowledge and Perceptions of Soil Erosion and Conservation Measures in the Central Highlands, Kenya. *Land Degradation & Development***,** 475-487.

OKOBA, B. O. & STERK, G. 2006. Farmers' identification of erosion indicators and related erosion damage in the Central Highlands of Kenya. *Catena* 65**,** 292 - 301.

O'RIORDAN, T. 2000. *Environmental science for environmental management,* Harlow, UK, Prentice-Hall & Pearson Education.

ORTIZ-VILLANUEVA, B. 1969. Realizaciones y perspectivas en la conservacion del suelo en Mexico. *In:* INSTITUTO MEXICANOS DE RECURSOS NATURALES RENOVABLES, A. C. (ed.) *Mesas redondas sobre la utilizacion y conservacion del suelo en Mexico.* Mexico, D.F: Colegio de Posgraduados

OVIEDO 1969. Realizaciones y perspectivas en la conservacion del suelo en Mexico. *In:* INSTITUTO MEXICANOS DE RECURSOS NATURALES RENOVABLES, A. C. (ed.) *Mesas redondas sobre la utilizacion y conservacion del suelo en Mexico.* Mexico, D.F: Colegio de Posgraduados

PAGIOLA, S. 1999. The global environmental benefits of land degradation control on agricultural land. Global Overlays Program. . *World Bank Environment Paper 16.* Washington, DC: The World Bank.

PAUDEL, G. & THAPA, G. 2004. Impact of social, institutional and ecological factors on land management practices in mountain watershed of Nepal. *Applied Geography* 24**,** 35-55.

PEARCE, D. & TUNER, R. K. 1990. *Economic natural resources and the environment,* Hemel Hempstead, Harvester Wheatsheaf.

POSEY, D. 1999. *Cultural and spiritual values of biodiversity,* London, Intermediate technology.

POSTHUMUS, H. 2005. *Adoption of terraces in the Peruvian Andes.* PhD thesis, Wageningen University

RANSOM, J. K., PAUDYAL, K. & ADHIKARI, K. 2003. Adoption of improved maize varieties in the hills of Nepal. *Agricultural Economics,* 29**,** 299-305.

REIJ, C., SCOONES I. & TOULMIN, C. (eds.) 1996. *Sustaining the soil: indigenous soil and water conservation in Africa* London: Earthscan.

REYNOLDS, F., STAFFORD-SMITH, D. M. & LAMBIN, E. 2003. Do Humans Cause Deserts? An Old Problem through the Lens of a New Framework. *Proceedings of the VIIth International Rangelands Congress.* Durban, South Africa.

RIGBY, D., HOWLETT, D., & WOODHOUSE, P. 2000. A review of indicators of agricultural and rural livelihood sustainability' *Sustainability Indicators for Natural Resource Management and Policy Series.* University of Manchester: IDPM.

ROBBINS, P. F., ABEL, N., JIANG, H., MORTIMORE, M., MULLIGAN, M., ORKIN, G. S. & STAFFORD SMITH, D. 2002. Desertification at the community scale: Sustaining dynamic human-environment systems. *Global Desertification: Do Humans Cause Deserts?* Berlin: Dahlem University Press.

ROBSON, C. 1993. *Real World Research. A Resource for Social Scientists and Practitioner Researchers,* London, Blackwell Publications.

ROCCAS, S., SAVIG, L., SCHWARTZ, S. H. & KNAFO, A. 2002. The big five personality factors and personal values. *Personality and Social Psychology Bullentin,* 28**,** 789-801.

ROMERO FRIZZY, L. 1991. La agricultura en la epoca colonial *In:* T, R.-R. (ed.) *La agricultura en tierras mexicanas desde sus origenes hasta nuestros dias.* Mexico D.F: Grijalbo.

ROMO-SANTOS, J. Year. Modulo 1: Desarrollo Rural Sustentable. *In:* SECRETARIA DE AGRICULTURA, G., DESARROLLO RURAL, PESCA Y ALIMENTACION (SAGARPA), ed. Taller: Uso, Manejo y Conservacion del Suelo, Agua y Vegetacion, 2005 Mexico, D.F.: SAGARPA.

RUIZ-ARRANZ, M., DAVIS, B., STAMPINI, M., WINTERS, P. & HANDA, S. 2002. More Calories or More Diversity? An econometric evaluation of the impact of the PROGRESA and PROCAMPO transfer programmes on food security in rural Mexico. *Agricultural and Development Economics Division of the Food and Agriculture Organization of the United Nations (FAO - ESA) Working Papers.*

RYAN, R. L., ERICKSON, D. L. & DE YOUNG, R. 2003. Farmers' motivations for adopting conservation practices along riparian zones in a mid-western agricultural watershed. *Journal of Environmental Planning and Management,* 46**,** 19-37.

SADOULET, E., DE JANVRY, A. & DAVIS, B. 2001. Cash transfer programs with income multipliers: PROCAMPO in Mexico. *In:* Food Consumption and Nutrition Division. (ed.) *FCND DISCUSSION PAPER NO. 99.* Washington, DC International Food Policy Research Institute.

SAGARPA. 2008. *Tabla de equivalencia de ganado mayor y menor* [Online]. Mexico: SAGARPA. Available: www.sagarpa.gob.mx [Accessed January 2008].

SAÏDOU, A. 2006. Converging strategies by farmers and scientists to improve soil fertility and enhance crop production in Benin_Tropical resource management *Wageningen University and Research Centre,* 84.

SAMBODO, L. 2007. *The decision making processes of semi-commercial farmers: a case study of technology adoption in Indonesia.* PhD thesis PhD Thesis, Lincoln University.

SANCHEZ-COLON, S. 2007. *Evaluation of human induced soil degradation in Mexico,* Mexico, SEMARNAT.

SÁNCHEZ-TOVAR, S. A., SALAZAR-ZAZUETA, A., MENA-INIESTA, B. & DURÁN-DE-BAZÚA, C. 2004. Viscoamylographic Studies on Zea Mays [Mexican White Tuxpeño Maize] Partial Gelatinization with Calcium Hydroxide. *Starch - Stärke,* 56**,** 526-534.

SATTLER, C. & NAGEL, U. 2010. Factors affecting farmers' acceptance of conservation measures - A case study from north-eastern Germany. *Land Use Policy***,** 70–77.

SCHERR, S. & YADAV, S. 1996. Land degradation in the developing world. Issues and policy options for 2020. *Food, Agriculture, and the Environment* Discussion Paper 14**,** 37.

SCHERR, S. & YADAV, S. 1997. Land degradation in the developing world; issues and policy options for 2020, 2020 Vision Policy Brief No.44. Washington, D.C.: International Food Policy Research Institute.

SCHOLES, B. & VON MALTITZ, G. P. 2007. Quantifying tradeoffs between sustainable land management and other environmental concerns. *United Nations Environment Program.* Nairobi.

SCHWILCH, G., BACHMANN, F. & LINIGER, H. 2009. Appraising and selecting conservation measures to mitigate desertification and land degradation based on stakeholder participation and global best practices. *Land Degradation & Development,* 20**,** 308-326.

SEARLE, J. R. 1995. *The Construction of Social Reality,* London, Allen Lane, the Penguin Press.

SEMARNAT. 2002. *Informe de la Situación del Medio Ambiente en México.* [Online]. Mexico: SEMARNAT. Available: http://www.semarnat.gob.mx/wps/portal/.cmd/cs/.ce/155/.s/4696/_s.155/4691 [Accessed 2004].

SERRAT, O. 2008. The sustainable livelihoods approach: Knowledge solutions. Asian development bank (ADB).

SHATISH, S. 2004. *Understanding the Case Study Approach.* [Online]. National University of Singapore. Available: http://www.comp.nus.edu.sg/~sath/CS4250CaseStudy.doc [Accessed 2004].

SHIVELY, G. E. 1999. Risks and Returns from Soil Conservation: Evidence From, Low-Income Farms In The Philippines. *Agricultural Economics,* 21.

SMITH, M. E. 1986. The Role of Social Stratification in the Aztec Empire: A View From the Provinces. *American Anthropologist,* 88**,** 70-91.

SMITH, M. E. & PRICE, J. T. 1994. Aztec-Period Agricultural Terraces in Morelos, Mexico: Evidence for Household-Level Agricultural Intensification. *Journal of Field Archaeology,* 21**,** 169-179.

SOMMER, R., WALL, P. C. & GOVAERTS, B. 2007. Model-based assessment of maize cropping under conventional and conservation agriculture in Highland Mexico. *Soil and Tillage Research,* 94**,** 83-100.

SOUSTELLE, J. 1993. *La Familia Otomi-Pama del Mexico Central [The Otomi-pame family of Central Mexico],* Mexico, Fondo de Cultura Internacional.

SOY, S. 1997. *The Case Study as a Research Method.* [Online]. Texas: University of Texas. Available: http://www.gslis.utexas.edu/~ssoy/usesusers/l391d1b.htm. [Accessed 2004].

STAKE, E. R. 1994. Case studies. *In:* N. DENZIN & LINCOLN, Y. (eds.) *Handbook of qualitative research.* Thousand Oaks, CA: SAGE.

STAKE, R. E. 1995. *The art of case study research,* Thousand Oaks, CA, Sage Publications.

STILES, D. 1995. An overview of desertification and dryland degradation. *In:* D.STILES (ed.) *Social aspects of sustainable dryland management.* Chichester: John Wiley.

STOCKING, M. 2002a. Land degradation. *International Encyclopaedia of the Social and Behavioral Sciences,* 2002**,** 8242-8247.

STOCKING, M. 2002b. Agrodiversity, environmental protection and sustaining rural livelihoods: The global view. *In:* BROOKFIELD, H., PADOCH, C., PARSON, H., STOCKING, M. (EDS.) (ed.) *Cultivating Biodiversity, Understanding, Analysing and Using Agricultural Diversity* London: ITDG

STOCKING, M., HELLEMAN, H. & WHITE, R. 2005. *Renewable natural resources management for mountain communities,* Kathmandu, International Centre for Integrated Mountain Development.

STOCKING, M. & MURNAGHAN, N. 2003. *Manual para la evaluación de campo de la degradación de la tierra[Translation of Handbook for the Field Assessment of Land Degradation. Earthscan, London]* Madrid, Mundi-Prensa Libros.

TELLIS, W. 1997. *Application of a Case Study Methodology. The Qualitative Report 3 volume 3* [Online]. Available: (http://www.nova.edu/ssss/QR/QR3-3/tellis2.html) [Accessed 2004].

TENGE, A. J., DE GRAAFF, J. & HELLA, J. P. 2004. Social and economic factors affecting the adoption of soil and water conservation in West Usambara highlands, Tanzania. *Land Degradation & Development,* 15**,** 99-114.

TENGE, A. J. M. 2005. *Participatory appraisal for farm level soil and water conservation planning in West Usambara highlands, Tanzania.* PhD, Wageningen University.

THRUPP, L. A. 1997. Linking biodiversity and agriculture: Challenges and opportunities for sustainable food security. *World Resources Institute. Washington*.

TITTONELL, P., VAN WIJK, M. T., RUFINO, M. C., VRUGT, J. A. & GILLER, K. E. 2007. Analysing trade-offs in resource and labour allocation by smallholder farmers using inverse modelling techniques: A case-study from Kakamega district, western Kenya *AGRICULTURAL SYSTEMS,* 95**,** 76-95.

TRIPP, R. 1996. Biodiversity and modern crop varieties: shapering the debate. . *Agriculture and humans values,* 13**,** 48-63.

TURNER, R., BATEMAN, I. & PEARCE, D. 1994. *Environmental Economics: an Elementary Introduction,* London, Harvester Wheatsheaf

UNDP 2003. The global challenge: goals and targets. *Millennium Development Goals.* United Nations Development Programme.

UNDP 2010. Evaluation of UNDP contribution to environmental management for poverty reduction: the poverty-environment nexus. United States: United Nations Development Programme.

VAN DETH, J. W. & SCARBROUGH, E. 1995. The concept of values. *In:* VAN DETH, J. W. &. SCARBROUGH, E. (ed.) *The impact of Values: Beliefs in Government.* Oxford: Oxford University Press.

WALTON, S., GAMA CASTRO, J. E. & PALACIOS MAYORGA, S. 1998. Surface Water Erosion in the Mazahuan municipal, San Felipe del Progreso, in the State of Mexico. *Centro de Investigacion en Ciencias Agropecuarias*.

WEBER, U., BARON, J. & GRAHAM, L. 2001. *Conflicting and tradeoffs in decision making,* Cambridge, Cambridge university press.

WHITMORE, T. M. & TURNER, B. 1992. Landscapes of Cultivation in Mesoamerica on the Eve of the Conquest. *Annals of the Association of American Geographers,* 82**,** 402-425.

WIGGERING, H., DALCHOW, C., GLEMNITZ, M., HELMING, K., MÜLLER, K., SCHULTZ, A., STACHOW, U. & ZANDER, P. 2006. Indicators for multifunctional land use--Linking socio-economic requirements with landscape potentials. *Ecological Indicators,* 6**,** 238-249.

WILKEN, G. 1987. *Good Farmers: Traditional agricultural resource management in Mexico and Central America,* Berkeley, University of California Press

WILLIAMS, B. J. 1972. Tepetate in the Valley of Mexico. *Annals of the Association of American Geographers,* 62**,** 618-626.

WILSHUSEN, P. 2002. Reinventing a Square Wheel: Critique of A Resurgent “Protection Paradigm" International Biodiversity Conservation *Society and Natural Resources,* 15**,** 17-40.

WILSON, K. A., CARWARDINE, J. & POSSINGHAM, H. P. 2009. Setting Conservation Priorities. *Annals of the New York Academy of Sciences,* 1162**,** 237-264.

WINEGARDNER, K. E. 2002. *The case study method of scholarly research* [Online]. University of Southern California. Available: http://www.tgsa.edu/online/cybrary/case1.html [Accessed 2004].

WOCAT (WORLD OVERVIEW OF CONSERVATION APPROACHES AND TECHNOLOGIES) 2007. *Where the land is greener- case studies and analysis of soil and water conservation initiatives worldwide,* Wageningen, WOCAT/CTA.

WOLF, S. A. & ALLEN, T. F. H. 1995. Recasting alternative agriculture as a management model: The value of adept scaling. *Ecological Economics,* 12**,** 5-12.

WORLD BANK. 2004. *Data collection methods. Poverty net* [Online]. Available: http://www.worldbank.org/poverty/impact/methods/datacoll.htm [Accessed 2004].

WSSD 2002. Report of the World Summit on Sustainable Development. South Africa: United Nations.

WUENSCH, K. L. 2009. *Binary Logistic Regression with PASW/SPSS* [Online]. Available: http://core.ecu.edu/psyc/wuenschk/SPSS/SPSS-MV.htm [Accessed 2005,2006, 2009].

YIN, R. 1984. *Case study research: Design and methods,* Beverly Hills, CA, SAGE.

YIN, R. 1994. *Case study research: Design and methods,* Beverly Hills, CA, Sage Publishing.

YOUNG, O. 2002. The institutional dimension of environmental change: Fit, interplay and scale. . Cambridge: The MIT Press.

YUNEZ-NAUDE, A. 2003. The Dismantling of CONASUPO, a Mexican State Trader in Agriculture. *The World Economy,* 26**,** 97-122.

ZIMMERER, K. S. 1993. Soil erosion and labor shortages in the Andes with special reference to Bolivia, 1953-1991: Implications for "conservation-with-development". *World Development,* 21**,** 1659-1675.

ZURIA, I. & GATES, J. E. 2006. Vegetated field margins in Mexico: their History, Structure and Function, and Management. *Human Ecology,* 34**,** 53-77.

Appendix

Appendix III.1 Household Survey

Location (landscape)____
Location (local)____
Name (family)____
Family Details

Relation	Age	Place of work	Education	Languages	Responsibilities
Father					
Wife					
Child 1					
Child 2					
Child 3					
Child 4					
Child 5					
Child 6					
Child 7					
Child 8					
Child 9					
Child 10					
Others					

How many plots of land do you own?
____

	1 Solar	2	3	4	5
Plot's Location (Local Mazahua) i.e.Teneria, Bombaro etc.					
Type of soil (local name/Mazahua)					
Soil characteristics according to farmer (productive, not good, colour, texture)					
Plot size (Hectares)					

	1 Solar	2	3	4	5
Main Crops					
Seeding No. *cuartillos* or kilos					
Harvest No of Tons					
Reasons for growing these crops (to sell or for self consumption)					
Other crops (oats, broad beans, beans, pumpkin, spinach)					
Reasons for growing these crops					
Erosion perception by the farmer					
On whose name is the land title?					
Which one of your plots give you enough to eat?					
What do you do with the production of other plots					
How much do you get for your harvest?					

LDCT	1 Solar	2 Milpa	3 Milpa	4 Milpa	5 Milpa
Who do you take care of your land?					
Do you cultivate it?					
Does it have ditch?					
Does it have stone wall?					
Does it have Boundary vegetation?					
Does it have surcos?					
Is it level?					
Does it have arena/pumice?					
Does it have manure?					
Does it have fertillizer					
Does it have infilling gullies					
Others					

How many livestock you have?
[ ] Turkeys [ ] Donkey [ ] Horses [ ] Mare [ ] Male mule [ ] Mules [ ] Cows
[ ] Oxes [ ] Sheep [ ] Hens [ ] Roosters [ ] others

What services & equipment do you have?

[ ] Electricity [ ] Water [ ] Water pump
[ ] Gas [ ] Water Tank

If you get water supply, how often do you get it?

[ ] Everyday [ ] Every two weeks
[ ] Every week [ ] Every month

Is there a road near by?

[ ] Your house [ ] Your milpas

Is there a lane near by?

[ ] Your house [ ] Your milpas

How many rooms does your house have?

[ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] More

What is your house build of?____

Does you house has any of the following;

[ ] Concrete floor [ ] Kitchen [ ] Latrine
[ ] Stable

Which of the items below do you currently own?

[ ] Car [ ] TV [ ] Radio [ ] Telephone

What of the following tools do you currently own?
[ ] Pick [ ] Shovel [ ] Wheelbarrow [ ] Grub hoe [ ] Bucket[ ] Other

Do you have draft animals? [ ] Yes [ ] No

Do you hire draft animals? [ ] Yes [ ] No

If you hire draft animals, how much do you pay ?

[ ] Between 50 and 100 pesos
[ ] Between 100 and 200 pesos
[ ] more than 200 pesos
In how many fields do you work like "yuntero"?
[ ] in a day
[ ] in a month
[ ] in a season
Do you hire your services to cultivate or in any other agricultural activity?

[ ] Cultivating
[ ] Hire my services in other agricultural activities such as harvest

If you hire your services how much do you charge? ________________________________

How much do you earn?
___________ in one day___________ in one moth___________ in one year

What do you collect from communal lands?

[ ] Fruit [ ] Firewood [ ] Arena –pumice sand [ ] Other
Specify ____
What do you collect from your lands?

[ ] Fruit [ ] Flowers [ ] Qualities-wild edible weed [ ] Other
Specify
____
_____

What do you usually eat?

[ ]Tortillas [ ] chillies/salsa [ ] Meat [ ] Vegetables [ ] Other

Specify ____
Agricultural activities

When do you do?

Land preparation ______________ seeding _______________ harvest__________

What is the participation of women in taking care of the land and the agricultural activities?

Would you like to get help from your wife to look after the land?
[ ] yes [ ] No

If yes, Why?____

In the past have you met a woman who looked after her land? (For example, to carry soil for her land)
[ ] yes [ ] No

If yes, do you know why she did it?
____

Who looks after the flowers and cooking herbs at your home?
____

Can you say why?
____

At home, what herbs do you have?
[ ] Cooking Which herbs?______________________
[ ] Medicinal Which herbs?______________________
[ ] Adornment Which herbs?______________________

If you have herbs at home, how did you get them?

[ ] They are wild [ ] Some body gave them to you [ ] You bought them

Do your children or grandchildren help to look after your land?

[ ] yes, [ ] No, how many of them? [ ] ,

If they help, how do they help?
____

If they do not help because they have other work, do they contribute with money to buy manure or fertilizer? [ ] yes, [ ] No

Can you get help from your community (family or church community) in time of trouble? [ ] yes, [ ] No

If somebody is ill, who helps to do the work that otherwise that person would do?____

If you have ever lost the harvest product, why did you loose it?_______________

If you have ever lost your harvest product, what did you lived on? And how did you obtain new resources to cultivate again?
____

Do you believe that from what you spend to cultivate is there a?
[ ] Loss or [ ] Gain

If there is a loss, why do you keep cultivating?____

Do you receive support from any of the following:

[ ] PROCAMPO, What type of support?
____
[ ] INSEN, What type of support?__________________________________
[ ] CICA, What type of support?__________________________________
[ ] SEMARNAT, What type of support?
____
[ ] EDOMEX, What type of support?
____
[ ] OPORTUNIDADES, What type of support?
____

Which do you consider has been one of the more difficult situations you have been in and why?
____
Who taught you how too look after your land?
[ ] Parents [ ] Husband or Wife [ ] Others [ ] Nobody
Do you believe your land better or worse quality?
[ ] Better [ ] Worse

When you first acquired your land,
How much did you cultivate?_______________________
How much do you harvest?_____________________
If the production of your land is better now, what are the reasons?________
What technique do you prefer and why? ____
Have you changed any technique for another? (for example vegetation instead of wall stone)
____
In your community, who do you think looks after their land? And would you like you land to be like that?
____
If you have not looked after your land , can you say why?
____
How do you see your land (adjective)________________________________
From your pots of land, which ones do you like the most and why?

Do you intend to continue looking after those plots of land? ?
[ ] yes, [ ] No, [ ] Not sure
could you say why?_______________________________________
Why do you seed more than two plots of land if you can get enough food production from one or two?
____
Why do you seed your plots and look after them? (to inherit something good to your children , for pleasure, by custom, because of your religion, for money?)____
What would happen if you do not cultivate your land?
____
The fact that your land is private property has to do with the way you look after them? [ ] More [ ] Less
What technique to look after the land would you recommend and why?
____

Appendix III.2 Matrix of Multiple Values

Technology/ Values Please write the number you think is appropriate to each column 4=very good 3=good 2=no value, neutral 1=negative, not good 0=very bad ST=short term LT=long term		Natural					Human					Physical					Financial					Social				
		Humidity (soil moisture)	Fertility	Topsoil	Capture of sediments	Area (increase or decrease)	Labour needed (no. person)	Quality of labour (age, gender)	Maintenance (labour needed)	Skills /knowledge required ado.	Impacts on other activities	Accessibility of fields	Manageability of land	Tools needed for adoption	Accessibility to land (e.g. road)	Material needed	Impacts on production	Savings (kind or money)	Income source	Economic land value	Money needed for adoption	Aesthetic	Customs/traditions	Recognition in the community	Personal incentives (linked to land)	Networks
Name of technology adopted	ST	4	2	4	4	2						4	4	4	4	4						4	2	4	4	3
	LT	4	2	4	4	2						4	4	4	4	4						3	2	3	3	4
Name of technology adopted	ST	4	4	4	3	2						4	4	3	4	3						4	3	4	3	2
	LT	4	4	4	3	2						4	4	2	4	3						4	3	4	4	2
Name of technology adopted	ST	4	4	2	2	2						2	2	2	2	2						4	1	3	4	4
	LT	4	4	2	2	2						2	2	2	2	1						3	1	4	4	4
Name of technology adopted	ST	3	3	4	4	2						4	4	4	2	3						3	3	3	1	1
	LT	3	3	4	4	2						4	4	4	2	3						3	3	3	1	2
Name of technology NO adopted	ST	2	2	2	4	1						2	2	0	2	4						4	4	4	3	3
	LT	2	2	3	4	1						2	2	1	2	4						4	3	4	2	3
Name of technology NO adopted	ST	2	2	2	4	2						1	2	4	2	2						2	4	3	3	2
	LT	2	2	2	2	2						1	2	4	2	2						2	3	2	2	2

Appendix IV.1

Labour Weights per Age and Sex

Age category	Age group	Male	Female
1	8-15	0.50	0.25
2	16-18	1.00	0.50
3	19-30	1.00	0.75
4	31-50	1.00	0.75
5	51-65	1.00	0.50
6	>65	0.75	0.25

Appendix IV.2 Wealth Proxy

Taking into consideration the local view of wealth in SPT, a wealth score is created as a proxy for households' wealth which is based on three assets:

1) Total land area (weighted by soil types' productivity),
2) Livestock (in tropical livestock units) and
3) Total production (in ton).

Some comments regarding the way in which these assets are converted to score should be noted. Firstly, total area of land (in hectares) is weighted by soil types' productivity. Land holding value is not based only on the quantity of land farmers own but also the type of soil, as it is not the same wealth owning a hectare of productive land than a hectare of wasteland. The weights are established according to differences in productivity within soil types. *Colorada Pejo* y *Polvillo* soils present similar productivity, then, a weight of 1 was given to these three soils which represent same total area. A weight of 1.4 was given to *Arena* and *Tepetate* soils as their productivity was greater by around 40% more than the last soils types. The total area of these two soils is multiplied by 1.4 generating the total area weighted. *Negra* soil type shows an increase in mean productivity by around 60% in comparison to the less productive soils. Thus, a weight of 1.6 is used to obtain total area weighted.

Secondly, livestock data is transformed to Tropical livestock units (TLU) by using parameters applied by the Mexican government (SAGARPA, 2008)[134]. This is in order to estimate a total TLU per households. According to SAGARPA (accessed in January, 2008) a head of bovine or equine was equivalent to 1.0 and a head of sheep was equivalent to 0.14 (SAGARPA, 2008). Poultry is not included as it is temporal and morbidity changes every year.

Thirdly, total production of maize per household is used as it represents food security and access to cash flow when selling excess of production of maize.

The total area weighted (ha), livestock (total TLU) and total Production (ton) are converted to scores to be able to sum them up by modifying the formula used by Brown et al (2002)[135]. This means that the wealthiest household would have a total score of 15.

$$X_{score} = \frac{X - X_{min}}{X_{max} - X_{min}} * 5$$

Where:

X score = score of asset

X= value of asset per households

X_{min}= minimum value of assets in the sample

[134] A head of bovine or equide was equivalent to 1.0 and a head of sheep was equivalent to 0.14 (SAGARPA, 2008). Poultry is not included as it is temporal and morbidity changes every year.

[135] The formula used number 5 as the maximum score per assets (any number could be used instead of 5 as in the original formula that is 100, the results did not vary).

The minimum and maximum values used in the formula to create assets' score were: for area (0.04 / 4.0); for TLU (0.00/10.30) and; for production (0.10/ 6.0). These values are excluding outliers in the sample.
The minimum score of household wealth in SPT was 0.2 (the poorest household) and the maximum was 14.3 (the richest households). After considering the mean value of wealth scores and the frequencies of cases, three household wealth categories are established: Poor (0 -4.0 total score); Medium (4.01-10.0 total score) and Rich (> 10.01 score).

Attribute	Min value	Max value
Area (ha)	0.04	10.00
Livestock units	0.00	13.00
Labour index	0.25	5.75
Productivity (ton)	0.30	20.35
Productivity (ton/ha)	0.30	10.00

Attribute	Weight	
Area (ha)	Same 0-10	
Livestock capital	(Livestock unit*10) /max value	
Labour capital	(Livestock unit*10) /max value	
Productivity capital (ton)	(Livestock unit*10) /max value	
Area Categories capital	Score	Ha
	0	< 0.25
	1	0.50
	2	0.75
	3	1.00
	4	1.25
	5	1.50
	6	1.75
	7	2.00
	8	2.50
	9	3.00- 4.00
	10	>5.00

	Min value	Max value
Total Capitals index (area categories)	2.30	24.30
Total Capitals Index	1.83	21.64
Total capital index	Wealth scores	Category
0.00-5.00	1	Very poor
5.01-10.01	2	Poor
10.01-15.00	3	Medium
15.01-20.00	4	Rich
>20.01	5	Very rich

		area		production		livestock		
		score	real value	score	real value	score	real value	score
		4		6		10.3		
SPT	Poor	0.7	0.56	0.6	0.72	1.1	2.266	**2.4**
	Medium	2.2	1.76	2.3	2.76	2	4.12	**6.5**
	Rich	4.6	3.68	4.6	5.52	3.1	6.386	**12.3**
Era	Poor	0.8	0.64	0.6	0.72	1.3	2.678	**2.7**
	Medium	2.4	1.92	2.4	2.88	2.2	4.532	**7**
	Rich	4.7	3.76	4.4	5.28	3.8	7.828	**12.9**
Centro	Poor	0.6	0.48	0.5	0.6	0.9	1.854	**2**
	Medium	1.8	1.44	2.2	2.64	1.6	3.296	**5.6**
	Rich	4.5	3.6	5	6	1.3	2.678	**10.8**

Appendix V.1 Correlation of Technologies

	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	T 11	T 12	T 13	T 14	T 15	T 16	T 17
T1																	
T2	0.4**																
T3	0.3**	0.2**															
T4	0.4**	0.4**	0.3**														
T5	0.4**	0.4**	0.4**	0.8**													
T6	0.2**	0.3**	0.2**	0.3**	0.4**												
T7	0.2**	0.2**	0.2**	0.6**	0.5**	0.3**											
T8	--	0.2**	0.2**	0.3**	0.2**	0.2**	0.3**										
T9	0.3**	0.3**	0.2**	0.3**	0.3**	0.3**	0.3**	0.2**									
T10	0.1*	0.3**	0.2**	0.3**	0.3**	0.2**	0.2**	0.1*	0.2**								
T11	0.2**	0.3**	0.2**	0.3**	0.2**	0.2**	0.3**	--	0.3**	0.3**							
T12	0.1*	--	0.1**	--	--	--	--	--	0.1*	--	0.2**						
T13	--	0.2**	--	0.1*	0.1*	0.2**	--	--	--	--	0.2**	--					
T14	0.3**	0.2**	0.2**	0.4**	0.4**	0.2**	0.5**	0.3**	0.3**	0.4**	0.3**	0.2**	--				
T15	--	0.1*	0.1*	0.2**	0.2**	0.2**	0.2**	0.1*	--	--	0.2**	--	0.5**	--			
T16	0.2**	--	0.3**	0.1*	0.2**	--	--	0.2**	--	0.2**	0.1*	--	--	0.2**	--		
T17	-0.2**	-0.2**	--	-0.1*	--	-0.2**	--	--	--	--	-0.2**	0.2**	-0.4**	-0.1*	-0.4**	--	--

**

Correlation is significant at the 0.01 level (2- tailed)
* Correlation is significant at the 0.05 level (2- tailed)

Appendix V.2

Statistical Results –Differences In Adoption of Technologies Between Solar And Milpa LUT

ADOPTION OF LAND CONSERVATION TECHNOLOGIES BETWEEN SOLAR AND MILPA IN SPT

LaDC Technologies	**Chi-Square (Difference in technologies between solar and milpa in SPT)** X^2	**Sig.**	**Z value**
1. Incorporation of pumice*	19.994	.000	**3.995**
2. Manure	69.896	.000	**10.917**
3. Mulching	17.898	.000	**3.885**
4. Weeding*	43.384	.000	**7.093**
5. Reinstating of sediments *	31.853	.000	**5.862**
6. Ditches	21.107	.000	**5.375**
7. Holes*	31.313	.000	**5.975**
8. Sangradera	3.894	.034	**1.920**
9. Boundary vegetation	23.794	.000	**5.622**
10. Stone walls*	11.508	.001	**3.244**
11. Intercropping*	58.163	.000	**9.548**
12. Crop rotation*	6.342	.008	**-2.693**
13. Furrow Design	2.664	**.080**	**1.875**
14. Infilling gullies*	8.159	.003	**2.789**
15. Fertiliser	1.398	**.162**	**1.261**
16. Tope*	0.653	**.262**	**0.784**
17. Fallow	14.615	.000	**-4.700**

ADOPTION OF LAND CONSERVATION TECHNOLOGIES

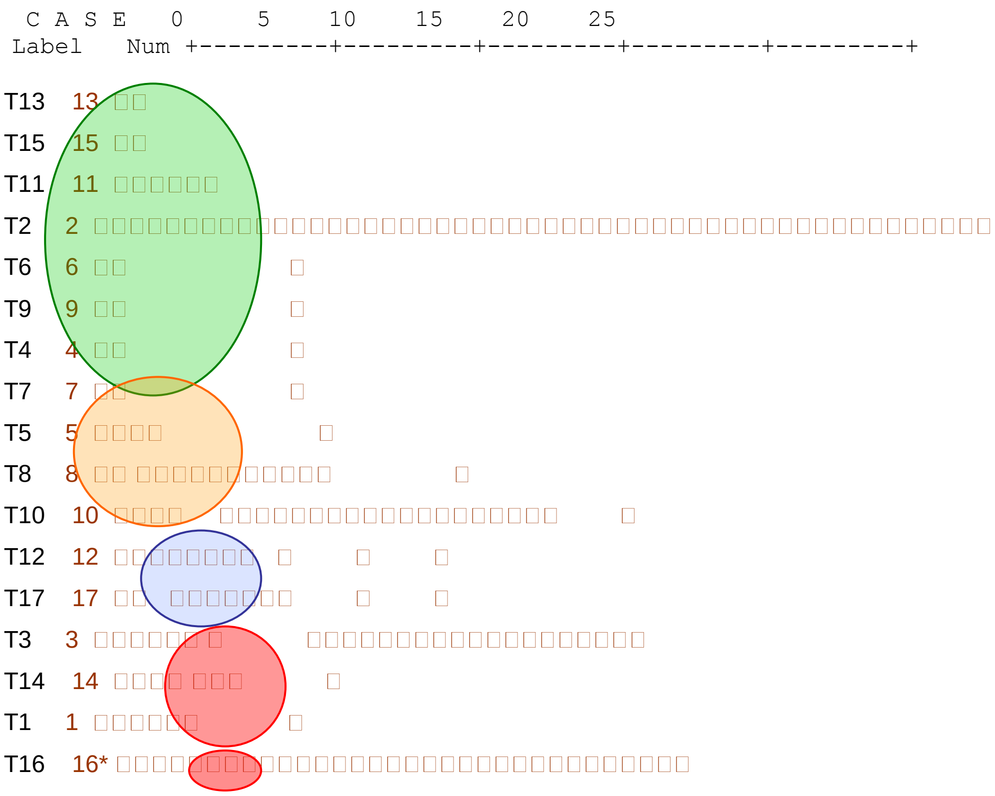
LaDC Technologies	**Solar** % of units with adopted technologies		**Z value**	**Milpa** % of units with adopted technologies		**Zvalue**
	La Era	Centro		La Era	Centro	
1. Incorporation of pumice*	67	17	5.792	26	9	3.087
2. Manure	94	83	1.850	36	44	-1.064
3. Canuela*	39	22	1.906	15	2	3.650
4. Weeding*	83	52	3.484	30	25	0.664
5. Reinstating of sediments *	78	46	3.465	33	18	2.265
6. Ditches	91	85	0.902	64	58	0.740
7. Holes*	81	54	2.999	40	22	2.565
8. Sangradera	41	28	1.324	27	18	1.289
9. Boundary vegetation	89	80	1.167	56	60	-0.617
10. Stone walls*	48	24	2.617	25	4	4.758
11. Intercropping*	91	83	1.189	51	15	5.653
12. Crop rotation*	24	13	1.442	39	18	3.115
13. Furrow Design	91	93	-0.510	92	78	2.138
14. Infilling gullies*	69	11	7.381	34	5	5.581
15. Fertiliser	100	93	1.791	94	89	0.911
16. Tope*	26	4	3.231	17	2	4.096
17. Fallow	6	4	0.279	21	25	-0.604

Appendix V.3

****** H I E R A R C H I C A L C L U S T E R A N A L Y S I S ******

Dendrogram using Ward Method

Rescaled Distance Cluster Combine



* Dendrogram using 7 factors (Households' mean values of: productivity, distance of plots, soil diversity, religion, age and no. equines heads

Appendix VI.1 (a)

Comparing means from 5x5 sample size and MV (total sample size)

(a) t-Test: Paired Two Sample for Means

	Adopters		Non-adopters	
	5x5	**MV**	**5x5**	**MV**
	Variable 1	*Variable 2*	*Variable 1*	*Variable 2*
Mean	20.341	20.285	11.506	10.757
Variance	68.749	71.970	62.166	62.699
Observations	17	17	17	17
Pearson Correlation	0.991		0.964	
Hypothesized Mean Difference	0.000		0	
df	16		16	
t Stat	0.198		1.453	
P(T<=t) one-tail	0.423		0.083	
t Critical one-tail	1.746		1.746	
P(T<=t) two-tail	**0.845**		**0.166**	
t Critical two-tail	2.120		2.120	

Appendix VI.1 (b)

T-test per criteria between meanof 5x5 and mv

1)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	networks_mean	**.7686**	**17**	**.57885**	**.14039**
	networks_meaVn	**.7609**	**17**	**.54122**	**.13127**

		N	Correlation	Sig.
Pair 1	networks_mean & networks_meaVn	**17**	**.973**	**.000**

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	networks_mean networks_meaVn	**-.00774**	**.13458**	**.03264**	**-.06145**	**.07693**	**.237**	**16**	**.816**

2)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	fertility_mean	**.7235**	**17**	**.76529**	**.18561**
	fertility_meanV	**.7432**	**17**	**.71902**	**.17439**

		N	Correlation	Sig.
Pair 1	fertility_mean & fertility_meanV	**17**	**.994**	**.000**

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	fertility_mean – fertility_meanV	**-1.96386E-2**	**.09570**	**.02321**	**-.06884**	**.02957**	**-.846**	**16**	**.410**

3)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	topsoil_mean	**.7176**	**17**	**.77236**	**.18733**
	topsoil_meanV	**.6771**	**17**	**.77427**	**.18779**

		N	Correlation	Sig.
Pair 1	topsoil_mean & topsoil_meanV	**17**	**.991**	**.000**

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	topsoil_mean - topsoil_meanV	**.04051**	**.10548**	**.02558**	**-.01372**	**.09475**	**1.584**	**16**	**.133**

4)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	captureofsediments_mean	**1.1059**	**17**	**.88845**	**.21548**
	captureofsedimentsMV_mean	**1.0632**	**17**	**.85023**	**.20621**

		N	Correlation	Sig.
Pair 1	captureofsediments_mean & captureofsedimentsMV_mean	**17**	**.995**	**.000**

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	captureofsediments_mean – captureofsedimentsMV_mean	**.04264**	**.09558**	**.02318**	**-.00650**	**.09178**	**1.839**	**16**	**.084**

5)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	area_mean	**-.0627**	**17**	**.61462**	**.14907**
	area_meanMV	**-.0631**	**17**	**.62998**	**.15279**

	N	Correlation	Sig.
Pair 1 area_mean & area_meanMV	**17**	**.990**	**.000**

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	area_mean - area_meanMV	.00034	.08790	.02132	-.04486	.04553	.016	16	.988

6)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	labouradoptionno.person_mean	.4490	17	.65417	.15866
	labouradoptionMVno.person_mean	.4435	17	.59478	.14425

		N	Correlation	Sig.
Pair 1	labouradoptionno.person_mean & labouradoptionMVno.person_mean	17	.939	.000

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	labouradoptionno.person_mean - labouradoptionMVno.person_mean	.00554	.22516	.05461	-.11023	.12130	.101	16	.920

7)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Qualityoflabour_mean	.3725	17	.98758	.23952
	QualityoflabourMV_mean	.3997	17	.96074	.23301

		N	Correlation	Sig.
Pair 1	Qualityoflabour_mean & QualityoflabourMV_mean	17	.980	.000

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Qualityoflabour_mean - QualityoflabourMV_mean	-2.71048E-2	.19461	.04720	-.12716	.07295	-.574	16	.574

8)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	maintenancelabour_mean	.4588	17	.56796	.13775
	maintenancelabourMV_mean	.5054	17	.46136	.11190

		N	Correlation	Sig.
A	maintenancelabour_mean & maintenancelabourMV_mean	17	.978	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	maintenancelabour_mean - maintenancelabourMV_mean	**-4.65735E-2**	**.15055**	**.03651**	**-.12398**	**.03083**	**-1.276**	**16**	**.220**

9)**Paired Samples Statistics**

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	skillsknowledgeadoption_mean	**.1255**	**17**	**.83902**	**.20349**
	skillsknowledgeadoptionMV_mean	**.2080**	**17**	**.89526**	**.21713**

		N	Correlation	Sig.
Pair 1	skillsknowledgeadoption_mean & skillsknowledgeadoptionMV_mean	**17**	**.976**	**.000**

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	skillsknowledgeadoption_mean - skillsknowledgeadoptionMV_mean	**-8.25464E-2**	**.19928**	**.04833**	**-.18501**	**.01992**	**-1.708**	**16**	**.107**

10)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	impactsonotheractivities_mean	**.4882**	**17**	**.71579**	**.17360**
	impactsonotheractivitiesMV_mean	**.4432**	**17**	**.63508**	**.15403**

		N	Correlation	Sig.
Pair 1	impactsonotheractivities_mean & impactsonotheractivitiesMV_mean	**17**	**.937**	**.000**

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	impactsonotheractivities_mean - impactsonotheractivitiesMV_mean	**.04500**	**.25240**	**.06122**	**-.08477**	**.17477**	**.735**	**16**	**.473**

11)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	accesibilityofland_mean	**.2725**	**17**	**.69274**	**.16802**
	AccesibilityoflandMV_mean	**.2706**	**17**	**.67134**	**.16282**

		N	Correlation	Sig.
Pair 1	accesibilityofland_mean & accesibilityoflandMV_mean	**17**	**.972**	**.000**

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	accesibilityofland_mean accesibilityoflandMV_mean	.00199	.16350	.03965	-.08207	.08606	.050	16	.961

12)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	manageabilityofland_mean	.6471	17	.80477	.19518
	manageabilityoflandMV_mean	.6336	17	.77323	.18754

		N	Correlation	Sig.
Pair 1	manageabilityofland_mean & manageabilityoflandMV_mean	17	.991	.000

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	manageabilityofland_mean manageabilityoflandMV_mean	.01341	.11243	.02727	-.04440	.07122	.492	16	.630

13)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Toolsneededforadoption_mean	1.1980	17	.51404	.12467
	ToolsneededforadoptionMV_mean	1.1316	17	.48891	.11858

		N	Correlation	Sig.
Pair 1	Toolsneededforadoption_mean & ToolsneededforadoptionMV_mean	17	.956	.000

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Toolsneededforadoption_mean ToolsneededforadoptionMV_mean	.06645	.15164	.03678	-.01152	.14442	1.807	16	.090

14)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	accessibilitytoland_mean	.1569	17	.34334	.08327
	accessibilitytolandMV_mean	.1765	17	.35278	.08556

		N	Correlation	Sig.
Pair 1	accessibilitytoland_mean & accessibilitytolandMV_mean	17	.960	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	accessibilitytoland_mean - accessibilitytolandMV_mean	**-1.96529E-2**	**.09831**	**.02384**	**-.07020**	**.03089**	**-.824**	**16**	**.422**

15)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	materialneeded_mean	**.7078**	**17**	**.67067**	**.16266**
	materialneededMV_mean	**.7161**	**17**	**.66925**	**.16232**

		N	Correlation	Sig.
Pair 1	materialneeded_mean & materialneededMV_mean	**17**	**.951**	**.000**

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	materialneeded_mean - materialneededMV_mean	**-8.25288E-3**	**.21011**	**.05096**	**-.11628**	**.09977**	**-.162**	**16**	**.873**

16)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	impactsonproduction_mean	**.9373**	**17**	**.85699**	**.20785**
	impactsonproductionMV_mean	**.9046**	**17**	**.88373**	**.21434**

		N	Correlation	Sig.
Pair 1	impactsonproduction_mean & impactsonproductionMV_mean	**17**	**.991**	**.000**

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	impactsonproduction_mean - impactsonproductioMVn_mean	**.03269**	**.12093**	**.02933**	**-.02949**	**.09487**	**1.115**	**16**	**.282**

17)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	savingskindormoney_mean	**.7353**	**17**	**.58943**	**.14296**
	savingskindormoneyMV_mean	**.7371**	**17**	**.52800**	**.12806**

		N	Correlation	Sig.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair	savingskindormoney_mean	**.7353**	**17**	**.58943**	**.14296**

		N	Correlation	Sig.
Pair 1	savingskindormoney_mean & savingskindormoneyMV_mean	**17**	**.977**	**.000**

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	savingskindormoney_mean savingskindormoneyMV_mean	**-1.79806E-3**	**.13436**	**.03259**	**-.07088**	**.06729**	**-.055**	**16**	**.957**

18)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	incomesource_mean	**.1882**	**17**	**.42409**	**.10286**
	incomesourceMV_mean	**.1937**	**17**	**.42822**	**.10386**

		N	Correlation	Sig.
Pair 1	incomesource_mean & incomesourceMV_mean	**17**	**.973**	**.000**

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	incomesource_mean incomesourceMV_mean	**-5.42946E-3**	**.09847**	**.02388**	**-.05606**	**.04520**	**-.227**	**16**	**.823**

19)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	eco.landvalue_mean	**.6118**	**17**	**.68637**	**.16647**
	eco.landvalueMV_mean	**.6063**	**17**	**.68100**	**.16517**

		N	Correlation	Sig.
Pair 1	eco.landvalue_mean & eco.landvalueMV_mean	**17**	**.993**	**.000**

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	eco.landvalue_mean eco.landvalueMV_mean	**-.00549**	**.08267**	**.02005**	**-.03702**	**.04799**	**.274**	**16**	**.788**

20)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	moneyadoption_mean	**.1431**	**17**	**.67944**	**.16479**
	moneyadoptionMV_mean	**.1662**	**17**	**.66391**	**.16102**

		N	Correlation	Sig.
Pair 1	moneyadoption_mean & moneyadoptionMV_mean	**17**	**.950**	**.000**

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	moneyadoption_mean - moneyadoptionMV_mean	**-2.30288E-2**	**.21366**	**.05182**	**-.13288**	**.08683**	**-.444**	**16**	**.663**

21)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	aesthetic_mean	**1.1510**	**17**	**.71094**	**.17243**
	aestheticMV_mean	**1.0989**	**17**	**.73411**	**.17805**

		N	Correlation	Sig.
Pair 1	aesthetic_mean & aestheticMV_mean	**17**	**.988**	**.000**

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	aesthetic_mean - aestheticMV_mean	**.05211**	**.11434**	**.02773**	**-.00668**	**.11090**	**1.879**	**16**	**.079**

22)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	customstraditionsMV_mean	**1.1309**	**17**	**.88459**	**.21455**
	customstraditions_mean	**1.2000**	**17**	**.92938**	**.22541**

		N	Correlation	Sig.
Pair 1	customstraditions_mean MV& customstraditions_mean	**17**	**.977**	**.000**

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	customstraditionsMV_mean - customstraditions_mean	**-6.90678E-2**	**.19811**	**.04805**	**-.17093**	**.03279**	**-1.437**	**16**	**.170**

23)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	recognitionMV_mean	**1.1717**	**17**	**.71917**	**.17443**
	recognition_mean	**1.1922**	**17**	**.71662**	**.17381**

		N	Correlation	Sig.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair	recognitionMV_mean	**1.1717**	**17**	**.71917**	**.17443**

		N	Correlation	Sig.
Pair 1	recognitionMV_mean & recognition_mean	**17**	**.992**	**.000**

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	recognitionMV_Mean recognition_mean	**-2.04913E-2**	**.09229**	**.02238**	**-.06794**	**.02696**	**-.915**	**16**	**.374**

24)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Personalincentivestoland	**1.0953**	**17**	**.59882**	**.14524**
	personalincentivestolandMV_mean	**1.1255**	**17**	**.63950**	**.15510**

		N	Correlation	Sig.
Pair 1	Personalincentivestoland & personalincentivestolandMV_mean	**17**	**.960**	**.000**

Paired Samples Test

		Statistics							
		Paired Differences							
					95% Confidence Interval of the Difference				
Pairs		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Personalincentivestoland personalincentivestolandMV_mean	**-3.02280E-2**	**.18007**	**.04367**	**-.12281**	**.06236**	**-.692**	**16**	**.499**

25)

Paired Samples Statistics

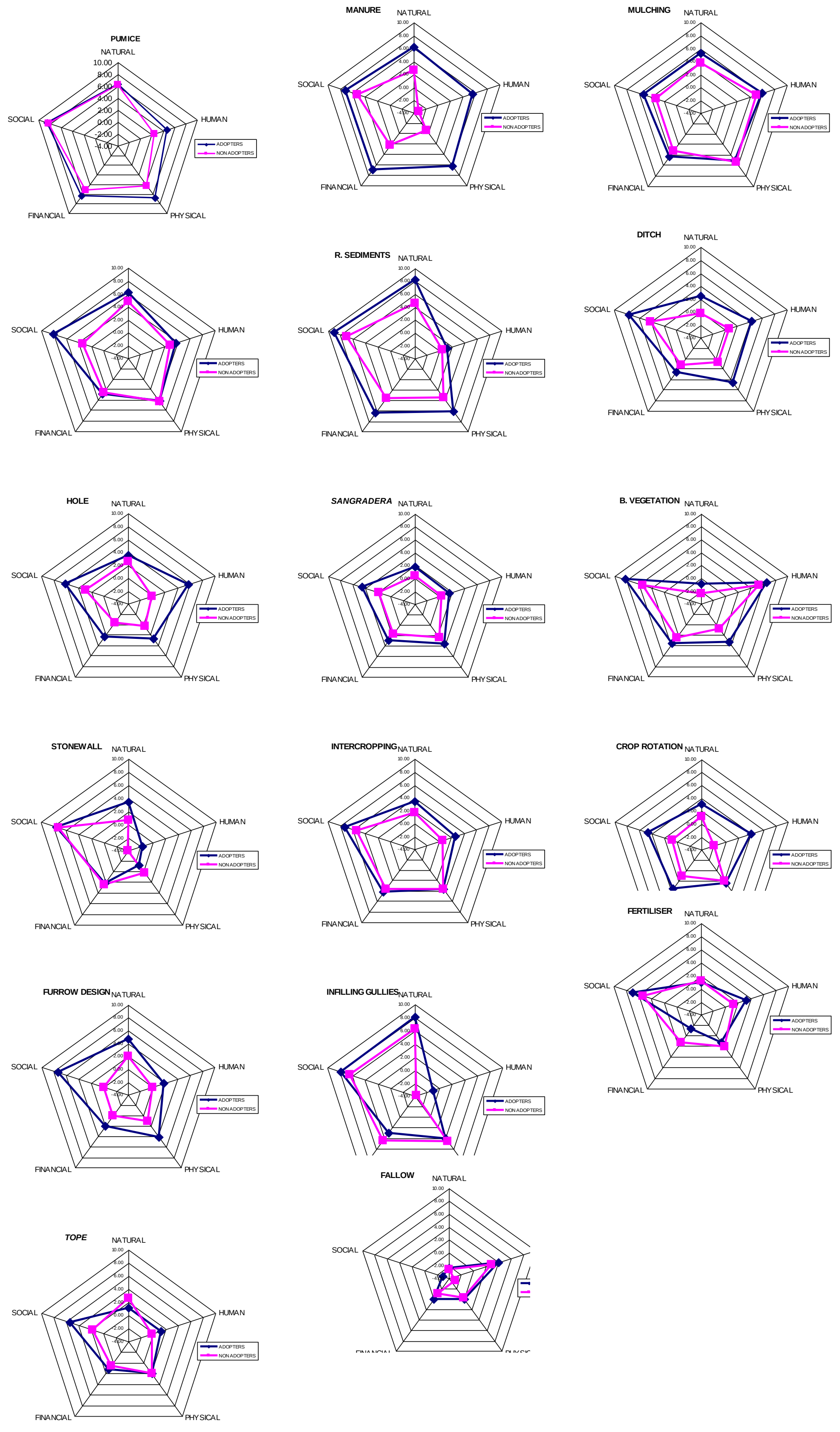
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	networks_mean	**.7686**	**17**	**.57885**	**.14039**
	networks_meaVn	**.7609**	**17**	**.54122**	**.13127**

		N	Correlation	Sig.
Pair 1	networks_mean & networks_meaVn	**17**	**.973**	**.000**

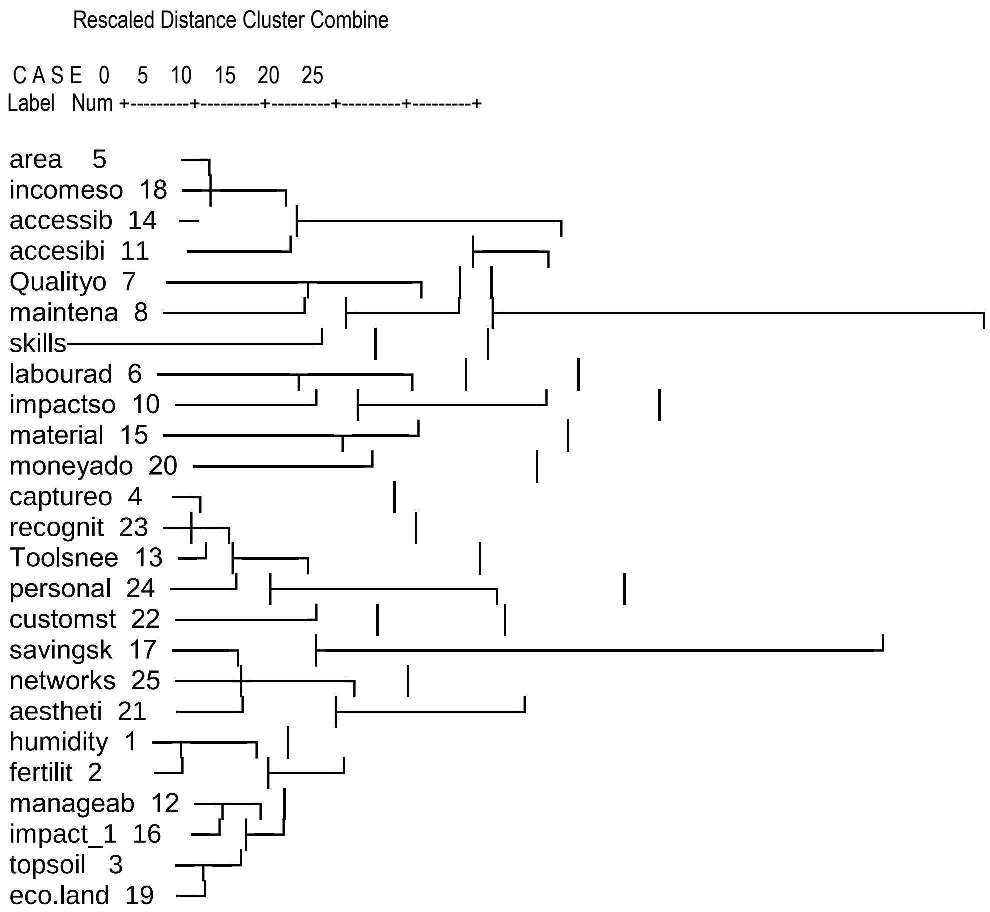
Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	networks_mean networks_meaVn	**-.00774**	**.13458**	**.03264**	**-.06145**	**.07693**	**.237**	**16**	**.816**

Appendix VI.2



Appendix VI.3



Appendix VI.4

Kruskal-Wallis Tests Results Difference Of Indicators Across Clusters

Ranks

	cluster of technologies	N	Mean Rank
humidity	1	106	103.08
	2	36	104.15
	3	25	74.16
	4	56	150.81
	Total	223	
fertility	1	106	109.87
	2	36	99.56
	3	25	101.88
	4	56	128.55
	Total	223	
topsoil	1	106	108.82
	2	36	111.29
	3	25	44.64
	4	56	148.55
	Total	223	
capture of sediments	1	106	105.53
	2	36	143.60
	3	25	30.32
	4	56	140.39
	Total	223	
area	1	106	91.63
	2	36	95.46
	3	25	137.06
	4	56	150.01
	Total	223	
labour-adoption(no. person)	1	106	118.09
	2	36	106.72
	3	25	109.92
	4	56	104.79
	Total	223	
Quality of labour/time	1	106	131.53
	2	36	59.56
	3	25	109.36
	4	56	109.93
	Total	223	
maintenance(labour)	1	106	104.51
	2	36	112.01
	3	25	104.52
	4	56	129.51
	Total	223	

adoption	2	36	60.88
	3	25	95.30
	4	56	124.88
	Total	223	
impacts on other activities	1	106	115.25
	2	36	100.46
	3	25	139.56
	4	56	100.96
	Total	223	
accessibility of land	1	106	93.90
	2	36	115.64
	3	25	104.06
	4	56	147.46
	Total	223	
manageability of land	1	106	100.21
	2	36	120.99
	3	25	64.34
	4	56	149.81
	Total	223	
Tools needed for adoption	1	106	114.25
	2	36	123.21
	3	25	47.74
	4	56	129.22
	Total	223	
accessibility to land	1	106	118.30
	2	36	87.40
	3	25	112.52
	4	56	115.65
	Total	223	
material needed	1	106	122.42
	2	36	92.85
	3	25	105.54
	4	56	107.46
	Total	223	
impacts on production	1	106	107.17
	2	36	116.78
	3	25	64.86
	4	56	139.11
	Total	223	

Ranks

	cluster of technologies	N	Mean Rank
skills/knowledge-	1	106	126.50

Ranks

	cluster of technologies	N	Mean Rank
savings(kind or money)	1	106	111.86
	2	36	99.50
	3	25	135.20
	4	56	109.94
	Total	223	
income source	1	106	117.62
	2	36	100.15
	3	25	109.24
	4	56	110.21
	Total	223	
eco.land value	1	106	94.37
	2	36	141.83
	3	25	71.28
	4	56	144.38
	Total	223	
money-adoption	1	106	111.63
	2	36	118.12
	3	25	94.58
	4	56	116.54
	Total	223	
aesthetic	1	106	114.34
	2	36	120.14
	3	25	76.42
	4	56	118.21
	Total	223	
customs/traditions	1	106	127.58
	2	36	126.04
	3	25	34.52
	4	56	108.06
	Total	223	

Recognition	1	106	116.49
	2	36	122.76
	3	25	35.30
	4	56	130.82
	Total	223	
personal incentives to land	1	106	118.24
	2	36	129.21
	3	25	48.28
	4	56	117.58
	Total	223	
networks	1	106	114.75
	2	36	112.53
	3	25	83.88
	4	56	119.02
	Total	223	

Appendix VI.5

Mann-Whitney results adopters and non adopters differences among clusters

Ranks[a]

	adopti12	N	Mean Rank	Sum of Ranks
humidity	1	61	61.11	3727.50
	2	45	43.19	1943.50
	Total	106		
fertility	1	61	57.35	3498.50
	2	45	48.28	2172.50
	Total	106		
topsoil	1	61	59.90	3654.00
	2	45	44.82	2017.00
	Total	106		
capture of sediments	1	61	60.51	3691.00
	2	45	44.00	1980.00
	Total	106		
area	1	61	56.80	3465.00
	2	45	49.02	2206.00
	Total	106		
labour-adoption(no. person)	1	61	61.38	3744.00
	2	45	42.82	1927.00
	Total	106		
Quality of labour/time	1	61	57.37	3499.50
	2	45	48.26	2171.50
	Total	106		
maintenance(labour)	1	61	60.44	3687.00
	2	45	44.09	1984.00
	Total	106		
skills/knowledge-adoption	1	61	54.32	3313.50
	2	45	52.39	2357.50
	Total	106		
impacts on other activities	1	61	62.93	3839.00
	2	45	40.71	1832.00
	Total	106		
accessibility of land	1	61	57.41	3502.00
	2	45	48.20	2169.00
	Total	106		
manageability of land	1	61	57.48	3506.00
	2	45	48.11	2165.00
	Total	106		
Tools needed for adoption	1	61	59.14	3607.50
	2	45	45.86	2063.50
	Total	106		
accessibility to land	1	61	58.19	3549.50
	2	45	47.14	2121.50
	Total	106		
material needed	1	61	62.00	3782.00
	2	45	41.98	1889.00
	Total	106		
impacts on production	1	61	54.34	3315.00
	2	45	52.36	2356.00
	Total	106		
savings(kind or money)	1	61	55.30	3373.00
	2	45	51.07	2298.00
	Total	106		
income source	1	61	53.20	3245.50
	2	45	53.90	2425.50
	Total	106		
eco.land value	1	61	54.50	3324.50
	2	45	52.14	2346.50
	Total	106		
money-adoption	1	61	61.66	3761.00
	2	45	42.44	1910.00
	Total	106		
aesthetic	1	61	62.42	3807.50
	2	45	41.41	1863.50
	Total	106		
customs/traditions	1	61	61.07	3725.00
	2	45	43.24	1946.00
	Total	106		
recognition	1	61	63.98	3902.50
	2	45	39.30	1768.50
	Total	106		
personal incentives to land	1	61	62.52	3813.50
	2	45	41.28	1857.50
	Total	106		
networks	1	61	57.11	3484.00
	2	45	48.60	2187.00
	Total	106		

a. cluster of technologies = 1.00

Ranks[a]

	adopti12	N	Mean Rank	Sum of Ranks
humidity	1	16	25.03	400.50
	2	20	13.28	265.50
	Total	36		
fertility	1	16	20.69	331.00
	2	20	16.75	335.00
	Total	36		
topsoil	1	16	20.72	331.50
	2	20	16.72	334.50
	Total	36		

capture of sediments	1	16	21.00	336.00
	2	20	16.50	330.00
	Total	36		
area	1	16	19.94	319.00
	2	20	17.35	347.00
	Total	36		
labour-adoption(no. person)	1	16	20.88	334.00
	2	20	16.60	332.00
	Total	36		
Quality of labour/time	1	16	18.06	289.00
	2	20	18.85	377.00
	Total	36		
maintenance(labour)	1	16	22.81	365.00
	2	20	15.05	301.00
	Total	36		
skills/knowledge-adoption	1	16	16.06	257.00
	2	20	20.45	409.00
	Total	36		
impacts on other activities	1	16	24.72	395.50
	2	20	13.52	270.50
	Total	36		
accessibility of land	1	16	22.62	362.00
	2	20	15.20	304.00
	Total	36		
manageability of land	1	16	18.06	289.00
	2	20	18.85	377.00
	Total	36		
Tools needed for adoption	1	16	20.50	328.00
	2	20	16.90	338.00
	Total	36		
accessibility to land	1	16	17.09	273.50
	2	20	19.62	392.50
	Total	36		
material needed	1	16	18.75	300.00
	2	20	18.30	366.00
	Total	36		
impacts on production	1	16	20.00	320.00
	2	20	17.30	346.00
	Total	36		
savings(kind or money)	1	16	20.91	334.50
	2	20	16.58	331.50
	Total	36		
income source	1	16	17.50	280.00
	2	20	19.30	386.00
	Total	36		
eco.land value	1	16	18.03	288.50
	2	20	18.88	377.50
	Total	36		
money-adoption	1	16	22.53	360.50
	2	20	15.28	305.50
	Total	36		
aesthetic	1	16	20.09	321.50
	2	20	17.22	344.50
	Total	36		
customs/traditions	1	16	20.97	335.50
	2	20	16.52	330.50
	Total	36		
recognition	1	16	20.31	325.00
	2	20	17.05	341.00
	Total	36		
personal incentives to land	1	16	22.19	355.00
	2	20	15.55	311.00
	Total	36		
networks	1	16	17.88	286.00
	2	20	19.00	380.00
	Total	36		

a. cluster of technologies = 2.00

Ranks[a]

	adopti12	N	Mean Rank	Sum of Ranks
humidity	1	11	14.05	154.50
	2	14	12.18	170.50
	Total	25		
fertility	1	11	15.59	171.50
	2	14	10.96	153.50
	Total	25		
topsoil	1	11	13.64	150.00
	2	14	12.50	175.00
	Total	25		
capture of sediments	1	11	14.18	156.00
	2	14	12.07	169.00
	Total	25		
area	1	11	13.36	147.00
	2	14	12.71	178.00
	Total	25		
labour-adoption(no. person)	1	11	15.18	167.00
	2	14	11.29	158.00
	Total	25		
Quality of labour/time	1	11	15.36	169.00
	2	14	11.14	156.00
	Total	25		
maintenance(labour)	1	11	14.55	160.00
	2	14	11.79	165.00
	Total	25		
skills/knowledge-adoption	1	11	16.50	181.50
	2	14	10.25	143.50
	Total	25		
impacts on other activities	1	11	14.73	162.00
	2	14	11.64	163.00

	Total	25		
accessibility of land	1	11	12.82	141.00
	2	14	13.14	184.00
	Total	25		
manageability of land	1	11	13.05	143.50
	2	14	12.96	181.50
	Total	25		
Tools needed for adoption	1	11	13.55	149.00
	2	14	12.57	176.00
	Total	25		
accessibility to land	1	11	13.14	144.50
	2	14	12.89	180.50
	Total	25		
material needed	1	11	14.55	160.00
	2	14	11.79	165.00
	Total	25		
impacts on production	1	11	14.09	155.00
	2	14	12.14	170.00
	Total	25		
savings(kind or money)	1	11	15.18	167.00
	2	14	11.29	158.00
	Total	25		
income source	1	11	14.77	162.50
	2	14	11.61	162.50
	Total	25		
eco.land value	1	11	13.91	153.00
	2	14	12.29	172.00
	Total	25		
money-adoption	1	11	13.27	146.00
	2	14	12.79	179.00
	Total	25		
aesthetic	1	11	15.36	169.00
	2	14	11.14	156.00
	Total	25		
customs/traditions	1	11	16.09	177.00
	2	14	10.57	148.00
	Total	25		
recognition	1	11	14.55	160.00
	2	14	11.79	165.00
	Total	25		
personal incentives to land	1	11	16.27	179.00
	2	14	10.43	146.00
	Total	25		
networks	1	11	13.95	153.50
	2	14	12.25	171.50
	Total	25		

a. cluster of technologies = 3.00

Ranks[a]

	adopti12	N	Mean Rank	Sum of Ranks
humidity	1	32	30.88	988.00
	2	24	25.33	608.00
	Total	56		
fertility	1	32	29.33	938.50
	2	24	27.40	657.50
	Total	56		
topsoil	1	32	31.69	1014.00
	2	24	24.25	582.00
	Total	56		
capture of sediments	1	32	29.94	958.00
	2	24	26.58	638.00
	Total	56		
area	1	32	31.41	1005.00
	2	24	24.62	591.00
	Total	56		
labour-adoption(no. person)	1	32	32.16	1029.00
	2	24	23.62	567.00
	Total	56		
Quality of labour/time	1	32	29.22	935.00
	2	24	27.54	661.00
	Total	56		
maintenance(labour)	1	32	33.67	1077.50
	2	24	21.60	518.50
	Total	56		
skills/knowledge-adoption	1	32	26.03	833.00
	2	24	31.79	763.00
	Total	56		
impacts on other activities	1	32	32.09	1027.00
	2	24	23.71	569.00
	Total	56		
accessibility of land	1	32	31.89	1020.50
	2	24	23.98	575.50
	Total	56		
manageability of land	1	32	30.98	991.50
	2	24	25.19	604.50
	Total	56		
Tools needed for adoption	1	32	29.00	928.00
	2	24	27.83	668.00
	Total	56		
accessibility to land	1	32	28.25	904.00
	2	24	28.83	692.00
	Total	56		
material needed	1	32	28.25	904.00
	2	24	28.83	692.00
	Total	56		
impacts on production	1	32	30.38	972.00
	2	24	26.00	624.00
	Total	56		
savings(kind or money)	1	32	29.42	941.50

	2	24	27.27	654.50
	Total	56		
income source	1	32	27.14	868.50
	2	24	30.31	727.50
	Total	56		
eco.land value	1	32	31.45	1006.50
	2	24	24.56	589.50
	Total	56		
money-adoption	1	32	28.92	925.50
	2	24	27.94	670.50
	Total	56		
aesthetic	1	32	31.97	1023.00
	2	24	23.88	573.00
	Total	56		
customs/traditions	1	32	28.62	916.00
	2	24	28.33	680.00
	Total	56		
recognition	1	32	30.98	991.50

	2	24	25.19	604.50
	Total	56		
personal incentives to land	1	32	32.34	1035.00
	2	24	23.38	561.00
	Total	56		
networks	1	32	31.48	1007.50
	2	24	24.52	588.50
	Total	56		

a. cluster of technologies = 4.00

Appendix VI.6.

Adopters and Non Adopters Differences among Clusters

	c1	c1non	c2	c2non	c3	c3non	c4	c4no
	Variable 1	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*
Mean	0.868	0.408	0.776	0.396	0.356	-0.100	1.024	0.724
Variance	0.251	0.182	0.659	0.445	0.276	0.239167	0.240	0.248
Observations	25	25	25	25	25	25	25	25
Pearson Correlation	0.812		0.786		0.785		0.773	
Hypothesized Mean Difference	0		0		0		0	
df	24		24		24		24	
t Stat	**7.851**		**3.781**		**6.821**		**4.506**	
P(T<=t) one-tail	0.000		0.000		0.000		0.000	
t Critical one-tail	1.711		1.711		1.711		1.711	
P(T<=t) two-tail	**0.000**		**0.001**		**0.000**		**0.000**	
t Critical two-tail	2.064		2.064		2.064		2.064	

Appendix VI.7

Gender

a)

t-test sex clusters t-Test: Paired Two Sample for Means

	c1m	c1f	c2m	c2f	c3m	c3f	c4m	c4f
	Variable 1	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*
Mean	0.674	0.668	0.649	0.462	0.103	0.105	0.954	0.831
Variance	0.303	0.151	0.553	0.421	0.331	0.173	0.223	0.266
Observations	25	25	25	25	25	25	25	25
Pearson Correlation	0.847		0.896		0.832		0.737	
Hypothesized Mean Difference	0		0		0		0	
df	24		24		24		24	
t Stat	0.103		2.820		-0.020		1.703	
P(T<=t) one-tail	**0.459**		**0.005**		**0.492**		**0.0508**	
t Critical one-tail	1.711		1.711		1.711		1.711	
P(T<=t) two-tail	**0.919**		**0.009**		**0.984**		**0.102**	
t Critical two-tail	2.064		2.064		2.064		2.064	

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	c1m - c1f	**.00622**	**.30240**	**.06048**	**-.11861**	**.13104**	**.103**	**24**	**.919**
Pair 2	c2m - c2f	**.18667**	**.33096**	**.06619**	**.05005**	**.32328**	**2.820**	**24**	**.009**
Pair 3	c3m - c3f	**-.00128**	**.32524**	**.06505**	**-.13553**	**.13297**	**-.020**	**24**	**.984**
Pair 4	c4m - c4f	**.12263**	**.36015**	**.07203**	**-.02603**	**.27129**	**1.703**	**24**	**.102**

b) Mann-Whitney test gender per clusters
Significant different indicators according to gender per cluster[136]

Higher Mean Rank given by	**C1** (Men n=49, Women n=57)	**C2** (Men n=18, Women n=18)	**C3** (Men n=12, Women n=13)	**C4** (Men n=25, Women n=31)
Men (n=104)	Material needed Aesthetic Personal Inc. Networks	Capture sed. Imp other act. Personal inc.	_____	Maintenance Money network
Women (n=119)	Quality of labour Maintenance Manageability Accessibility to land	____	_____	____

Source: The author's field data

136 Indicators are located in the group in which higher mean ranks are found

Ranks[a]	Sex	N	Mean Rank	Sum of Ranks
humidity	1	49	52.18	2557.00
	2	57	54.63	3114.00
	Total	106		
fertility	1	49	55.19	2704.50
	2	57	52.04	2966.50
	Total	106		
topsoil	1	49	54.70	2680.50
	2	57	52.46	2990.50
	Total	106		
capture of sediments	1	49	58.05	2844.50
	2	57	49.59	2826.50
	Total	106		
area	1	49	51.87	2541.50
	2	57	54.90	3129.50
	Total	106		
labour-adoption(no. person)	1	49	54.05	2648.50
	2	57	53.03	3022.50
	Total	106		
Quality of labour/time	1	49	47.88	2346.00
	2	57	58.33	3325.00
	Total	106		
maintenance(labour)	1	49	46.81	2293.50
	2	57	59.25	3377.50
	Total	106		
skills/knowledge-adoption	1	49	50.02	2451.00
	2	57	56.49	3220.00
	Total	106		
impacts on other activities	1	49	53.88	2640.00
	2	57	53.18	3031.00
	Total	106		
accessibility of land	1	49	49.26	2413.50
	2	57	57.15	3257.50
	Total	106		
manageability of land	1	49	48.50	2376.50
	2	57	57.80	3294.50
	Total	106		
Tools needed for adoption	1	49	55.34	2711.50
	2	57	51.92	2959.50
	Total	106		
accessibility to land	1	49	47.01	2303.50
	2	57	59.08	3367.50
	Total	106		
material needed	1	49	60.10	2945.00
	2	57	47.82	2726.00
	Total	106		
impacts on production	1	49	52.29	2562.00
	2	57	54.54	3109.00
	Total	106		
savings(kind or money)	1	49	56.13	2750.50
	2	57	51.24	2920.50
	Total	106		
income source	1	49	54.57	2674.00
	2	57	52.58	2997.00
	Total	106		
eco.land value	1	49	50.46	2472.50
	2	57	56.11	3198.50
	Total	106		
money-adoption	1	49	53.90	2641.00
	2	57	53.16	3030.00
	Total	106		
aesthetic	1	49	60.89	2983.50
	2	57	47.15	2687.50
	Total	106		
customs/traditions	1	49	55.43	2716.00
	2	57	51.84	2955.00
	Total	106		
recognition	1	49	57.36	2810.50
	2	57	50.18	2860.50
	Total	106		
personal incentives to land	1	49	58.50	2866.50
	2	57	49.20	2804.50
	Total	106		
networks	1	49	62.48	3061.50
	2	57	45.78	2609.50
	Total	106		

a. cluster of technologies = 1.00

Ranks[a]	Sex	N	Mean Rank	Sum of Ranks
humidity	1	18	19.36	348.50
	2	18	17.64	317.50
	Total	36		
fertility	1	18	17.61	317.00
	2	18	19.39	349.00
	Total	36		
topsoil	1	18	20.69	372.50
	2	18	16.31	293.50
	Total	36		
capture of sediments	1	18	20.94	377.00
	2	18	16.06	289.00
	Total	36		
area	1	18	17.92	322.50

	2	18	19.08	343.50
	Total	36		
labour-adoption(no. person)	1	18	21.06	379.00
	2	18	15.94	287.00
	Total	36		
Quality of labour/time	1	18	18.31	329.50
	2	18	18.69	336.50
	Total	36		
maintenance(labour)	1	18	21.19	381.50
	2	18	15.81	284.50
	Total	36		
skills/knowledge-adoption	1	18	17.72	319.00
	2	18	19.28	347.00
	Total	36		
impacts on other activities	1	18	22.28	401.00
	2	18	14.72	265.00
	Total	36		
accessibility of land	1	18	20.39	367.00
	2	18	16.61	299.00
	Total	36		
manageability of land	1	18	19.42	349.50
	2	18	17.58	316.50
	Total	36		
Tools needed for adoption	1	18	18.56	334.00
	2	18	18.44	332.00
	Total	36		
accessibility to land	1	18	16.67	300.00
	2	18	20.33	366.00
	Total	36		
material needed	1	18	18.39	331.00
	2	18	18.61	335.00
	Total	36		
impacts on production	1	18	19.78	356.00
	2	18	17.22	310.00
	Total	36		
savings(kind or money)	1	18	20.03	360.50
	2	18	16.97	305.50
	Total	36		
income source	1	18	17.50	315.00
	2	18	19.50	351.00
	Total	36		
eco.land value	1	18	19.67	354.00
	2	18	17.33	312.00
	Total	36		
money-adoption	1	18	20.00	360.00
	2	18	17.00	306.00
	Total	36		
aesthetic	1	18	19.64	353.50
	2	18	17.36	312.50
	Total	36		
customs/traditions	1	18	18.53	333.50
	2	18	18.47	332.50
	Total	36		
recognition	1	18	18.03	324.50
	2	18	18.97	341.50
	Total	36		
personal incentives to land	1	18	21.83	393.00
	2	18	15.17	273.00
	Total	36		
networks	1	18	20.64	371.50
	2	18	16.36	294.50
	Total	36		

a. cluster of technologies = 2.00

Ranks[a]

	adopti12	N	Mean Rank	Sum of Ranks
humidity	1	11	14.05	154.50
	2	14	12.18	170.50
	Total	25		
fertility	1	11	15.59	171.50
	2	14	10.96	153.50
	Total	25		
topsoil	1	11	13.64	150.00
	2	14	12.50	175.00
	Total	25		
capture of sediments	1	11	14.18	156.00
	2	14	12.07	169.00
	Total	25		
area	1	11	13.36	147.00
	2	14	12.71	178.00
	Total	25		
labour-adoption(no. person)	1	11	15.18	167.00
	2	14	11.29	158.00
	Total	25		
Quality of labour/time	1	11	15.36	169.00
	2	14	11.14	156.00
	Total	25		
maintenance(labour)	1	11	14.55	160.00
	2	14	11.79	165.00
	Total	25		
skills/knowledge-adoption	1	11	16.50	181.50
	2	14	10.25	143.50
	Total	25		
impacts on other activities	1	11	14.73	162.00
	2	14	11.64	163.00
	Total	25		
accessibility of land	1	11	12.82	141.00
	2	14	13.14	184.00
	Total	25		

manageability of land	1	11	13.05	143.50
	2	14	12.96	181.50
	Total	25		
Tools needed for adoption	1	11	13.55	149.00
	2	14	12.57	176.00
	Total	25		
accessibility to land	1	11	13.14	144.50
	2	14	12.89	180.50
	Total	25		
material needed	1	11	14.55	160.00
	2	14	11.79	165.00
	Total	25		
impacts on production	1	11	14.09	155.00
	2	14	12.14	170.00
	Total	25		
savings(kind or money)	1	11	15.18	167.00
	2	14	11.29	158.00
	Total	25		
income source	1	11	14.77	162.50
	2	14	11.61	162.50
	Total	25		
eco.land value	1	11	13.91	153.00
	2	14	12.29	172.00
	Total	25		
money-adoption	1	11	13.27	146.00
	2	14	12.79	179.00
	Total	25		
aesthetic	1	11	15.36	169.00
	2	14	11.14	156.00
	Total	25		
customs/traditions	1	11	16.09	177.00
	2	14	10.57	148.00
	Total	25		
recognition	1	11	14.55	160.00
	2	14	11.79	165.00
	Total	25		
personal incentives to land	1	11	16.27	179.00
	2	14	10.43	146.00
	Total	25		
networks	1	11	13.95	153.50
	2	14	12.25	171.50
	Total	25		

a. cluster of technologies = 3.00

Ranks[a]

	adopti12	N	Mean Rank	Sum of Ranks
humidity	1	32	30.88	988.00
	2	24	25.33	608.00
	Total	56		
fertility	1	32	29.33	938.50
	2	24	27.40	657.50
	Total	56		
topsoil	1	32	31.69	1014.00
	2	24	24.25	582.00
	Total	56		
capture of sediments	1	32	29.94	958.00
	2	24	26.58	638.00
	Total	56		
area	1	32	31.41	1005.00
	2	24	24.62	591.00
	Total	56		
labour-adoption(no. person)	1	32	32.16	1029.00
	2	24	23.62	567.00
	Total	56		
Quality of labour/time	1	32	29.22	935.00
	2	24	27.54	661.00
	Total	56		
maintenance(labour)	1	32	33.67	1077.50
	2	24	21.60	518.50
	Total	56		
skills/knowledge-adoption	1	32	26.03	833.00
	2	24	31.79	763.00
	Total	56		
impacts on other activities	1	32	32.09	1027.00
	2	24	23.71	569.00
	Total	56		
accessibility of land	1	32	31.89	1020.50
	2	24	23.98	575.50
	Total	56		
manageability of land	1	32	30.98	991.50
	2	24	25.19	604.50
	Total	56		
Tools needed for adoption	1	32	29.00	928.00
	2	24	27.83	668.00
	Total	56		
accessibility to land	1	32	28.25	904.00
	2	24	28.83	692.00
	Total	56		
material needed	1	32	28.25	904.00
	2	24	28.83	692.00
	Total	56		
impacts on production	1	32	30.38	972.00
	2	24	26.00	624.00
	Total	56		
savings(kind or money)	1	32	29.42	941.50
	2	24	27.27	654.50
	Total	56		
income source	1	32	27.14	868.50
	2	24	30.31	727.50

	Total	56		
eco.land value	1	32	31.45	1006.50
	2	24	24.56	589.50
	Total	56		
money-adoption	1	32	28.92	925.50
	2	24	27.94	670.50
	Total	56		
aesthetic	1	32	31.97	1023.00
	2	24	23.88	573.00
	Total	56		
customs/traditions	1	32	28.62	916.00
	2	24	28.33	680.00
	Total	56		
recognition	1	32	30.98	991.50
	2	24	25.19	604.50
	Total	56		
personal incentives to land	1	32	32.34	1035.00
	2	24	23.38	561.00
	Total	56		
networks	1	32	31.48	1007.50
	2	24	24.52	588.50
	Total	56		

a. cluster of technologies = 4.00

Appendix VI.8

Age t-test results Kruskal-Wallis test

Household head age groups and significant different indicators by technology clusters[137]

Household heads Age group Higher mean rank by	C1 (Young=24, Mature=55, Old=27)	C2 (Young=8, Mature=18, Old=10)	C3 (Young=2, Mature=12, Old=8)	C4 (Young=14, Mature=30, Old=12)
Young 18-40 (n=51)	Area Quality of labour Access. to land	I. Source	Acces. to land	Income source
Mature 41-60 (n=115)	______	______	______	______
Old >60 (n=57)	______	Skills	Area Maintenance Tools Material	______

Source: The author's field data

137 Indicators are located in the groups in which higher mean ranks are found. This is in order to highlight the groups which have the highest mean rank in comparison with the other groups. Indicators are significantly different across all groups.

a. Technology Clusters = Standard

Ranks[a]

	age groups category	N	Mean Rank
Humidity	18-40 years	24	51.60
	41-60 years	55	54.34
	>60 years	27	53.48
	Total	106	
fertility	18-40 years	24	50.00
	41-60 years	55	55.19
	>60 years	27	53.17
	Total	106	
topsoil	18-40 years	24	49.71
	41-60 years	55	53.45
	>60 years	27	56.96
	Total	106	
capture of sediments	18-40 years	24	49.08
	41-60 years	55	51.23
	>60 years	27	62.06
	Total	106	
area	18-40 years	24	64.23
	41-60 years	55	51.28
	>60 years	27	48.48
	Total	106	
labour-adoption(no.person)	18-40 years	24	51.44
	41-60 years	55	51.15
	>60 years	27	60.13
	Total	106	
Quality of labour/time	18-40 years	24	65.17
	41-60 years	55	50.34
	>60 years	27	49.57
	Total	106	
maintenance(labour)	18-40 years	24	59.62
	41-60 years	55	55.57
	>60 years	27	43.83
	Total	106	
skills/knowledge-adoption	18-40 years	24	58.27
	41-60 years	55	48.25
	>60 years	27	59.96
	Total	106	
impacts on other activities	18-40 years	24	57.08
	41-60 years	55	53.27
	>60 years	27	50.78
	Total	106	
accesibility of land	18-40 years	24	58.62
	41-60 years	55	54.45
	>60 years	27	47.00
	Total	106	
manageability of land	18-40 years	24	51.85
	41-60 years	55	55.96
	>60 years	27	49.94
	Total	106	
Tools needed for adoption	18-40 years	24	51.79
	41-60 years	55	54.36
	>60 years	27	53.26
	Total	106	
accessibility to land	18-40 years	24	64.04
	41-60 years	55	52.85
	>60 years	27	45.46
	Total	106	
material needed	18-40 years	24	51.04
	41-60 years	55	52.68
	>60 years	27	57.35
	Total	106	
impacts on production	18-40 years	24	50.83
	41-60 years	55	54.44
	>60 years	27	53.96
	Total	106	
savings(kind or money)	18-40 years	24	58.27
	41-60 years	55	50.25
	>60 years	27	55.87
	Total	106	
income source	18-40 years	24	57.77
	41-60 years	55	53.59
	>60 years	27	49.52
	Total	106	
eco.land value	18-40 years	24	50.52
	41-60 years	55	55.97
	>60 years	27	51.11
	Total	106	
money-adoption	18-40 years	24	53.58
	41-60 years	55	50.82
	>60 years	27	58.89
	Total	106	
aesthetic	18-40 years	24	52.44
	41-60 years	55	51.50
	>60 years	27	58.52
	Total	106	
customs/traditions	18-40 years	24	56.75
	41-60 years	55	52.04
	>60 years	27	53.59
	Total	106	
recognition	18-40 years	24	46.83
	41-60 years	55	55.54
	>60 years	27	55.28
	Total	106	
personal incentives to land	18-40 years	24	52.21
	41-60 years	55	50.99
	>60 years	27	59.76
	Total	106	
networks	18-40 years	24	63.92
	41-60 years	55	51.25
	>60 years	27	48.83
	Total	106	

a. Technology Clusters = Sediment management

Ranks[a]

	age groups category	N	Mean Rank
Humidity	18-40 years	8	18.88
	41-60 years	18	18.39
	>60 years	10	18.40
	Total	36	
fertility	18-40 years	8	20.88
	41-60 years	18	17.61
	>60 years	10	18.20
	Total	36	
topsoil	18-40 years	8	18.62
	41-60 years	18	17.44
	>60 years	10	20.30
	Total	36	
capture of sediments	18-40 years	8	15.81
	41-60 years	18	20.14
	>60 years	10	17.70
	Total	36	
area	18-40 years	8	21.56
	41-60 years	18	18.81
	>60 years	10	15.50
	Total	36	
labour-adoption(no.person)	18-40 years	8	18.94
	41-60 years	18	18.58
	>60 years	10	18.00
	Total	36	
Quality of labour/time	18-40 years	8	24.31
	41-60 years	18	16.67
	>60 years	10	17.15
	Total	36	
maintenance(labour)	18-40 years	8	17.94
	41-60 years	18	17.78
	>60 years	10	20.25
	Total	36	
skills/knowledge-adoption	18-40 years	8	20.88
	41-60 years	18	15.06
	>60 years	10	22.80
	Total	36	
impacts on other activities	18-40 years	8	15.88
	41-60 years	18	17.17
	>60 years	10	23.00
	Total	36	
accesibility of land	18-40 years	8	15.88
	41-60 years	18	20.67
	>60 years	10	16.70
	Total	36	
manageability of land	18-40 years	8	21.31
	41-60 years	18	17.72
	>60 years	10	17.65
	Total	36	
Tools needed for adoption	18-40 years	8	21.50
	41-60 years	18	17.92
	>60 years	10	17.15
	Total	36	
accessibility to land	18-40 years	8	20.44
	41-60 years	18	17.47
	>60 years	10	18.80
	Total	36	
material needed	18-40 years	8	24.06
	41-60 years	18	18.06
	>60 years	10	14.85
	Total	36	
impacts on production	18-40 years	8	22.12
	41-60 years	18	17.22
	>60 years	10	17.90
	Total	36	
savings(kind or money)	18-40 years	8	19.62
	41-60 years	18	17.42
	>60 years	10	19.55
	Total	36	
income source	18-40 years	8	22.00
	41-60 years	18	17.50
	>60 years	10	17.50
	Total	36	
eco.land value	18-40 years	8	22.81
	41-60 years	18	16.28
	>60 years	10	19.05
	Total	36	
money-adoption	18-40 years	8	14.38
	41-60 years	18	20.67
	>60 years	10	17.90
	Total	36	
aesthetic	18-40 years	8	18.19
	41-60 years	18	18.97
	>60 years	10	17.90
	Total	36	
customs/traditions	18-40 years	8	14.12
	41-60 years	18	19.39
	>60 years	10	20.40
	Total	36	
recognition	18-40 years	8	16.06
	41-60 years	18	20.53
	>60 years	10	16.80
	Total	36	
personal incentives to land	18-40 years	8	16.75
	41-60 years	18	18.00
	>60 years	10	20.80
	Total	36	
networks	18-40 years	8	22.31
	41-60 years	18	18.14
	>60 years	10	16.10
	Total	36	

a. Technology Clusters = Labour/area

Ranks[a]

	age groups category	N	Mean Rank
Humidity	18-40 years	5	18.00
	41-60 years	12	12.17
	>60 years	8	11.12
	Total	25	
fertility	18-40 years	5	15.80
	41-60 years	12	12.25
	>60 years	8	12.38
	Total	25	
topsoil	18-40 years	5	15.60
	41-60 years	12	13.00
	>60 years	8	11.38
	Total	25	
capture of sediments	18-40 years	5	14.60
	41-60 years	12	12.29
	>60 years	8	13.06
	Total	25	
area	18-40 years	5	13.80
	41-60 years	12	11.00
	>60 years	8	15.50
	Total	25	
labour-adoption(no.person)	18-40 years	5	12.80
	41-60 years	12	13.33
	>60 years	8	12.62
	Total	25	
Quality of labour/time	18-40 years	5	10.20
	41-60 years	12	12.00
	>60 years	8	16.25
	Total	25	
maintenance(labour)	18-40 years	5	11.70
	41-60 years	12	10.42
	>60 years	8	17.69
	Total	25	
skills/knowledge-adoption	18-40 years	5	15.80
	41-60 years	12	11.29
	>60 years	8	13.81
	Total	25	
impacts on other activities	18-40 years	5	10.40
	41-60 years	12	13.50
	>60 years	8	13.88
	Total	25	
accesibility of land	18-40 years	5	13.60
	41-60 years	12	11.83
	>60 years	8	14.38
	Total	25	
manageability of land	18-40 years	5	15.20
	41-60 years	12	11.75
	>60 years	8	13.50
	Total	25	
Tools needed for adoption	18-40 years	5	12.40
	41-60 years	12	11.00
	>60 years	8	16.38
	Total	25	
accessibility to land	18-40 years	5	17.00
	41-60 years	12	12.00
	>60 years	8	12.00
	Total	25	
material needed	18-40 years	5	13.90
	41-60 years	12	9.71
	>60 years	8	17.38
	Total	25	
impacts on production	18-40 years	5	12.20
	41-60 years	12	11.38
	>60 years	8	15.94
	Total	25	
savings(kind or money)	18-40 years	5	14.50
	41-60 years	12	11.67
	>60 years	8	14.06
	Total	25	
income source	18-40 years	5	15.40
	41-60 years	12	11.92
	>60 years	8	13.12
	Total	25	
eco.land value	18-40 years	5	12.10
	41-60 years	12	11.33
	>60 years	8	16.06
	Total	25	
money-adoption	18-40 years	5	10.70
	41-60 years	12	11.42
	>60 years	8	16.81
	Total	25	
aesthetic	18-40 years	5	13.20
	41-60 years	12	12.42
	>60 years	8	13.75
	Total	25	
customs/traditions	18-40 years	5	16.30
	41-60 years	12	11.54
	>60 years	8	13.12
	Total	25	
recognition	18-40 years	5	15.00
	41-60 years	12	12.58
	>60 years	8	12.38
	Total	25	
personal incentives to land	18-40 years	5	14.20
	41-60 years	12	13.62
	>60 years	8	11.31
	Total	25	
networks	18-40 years	5	16.70
	41-60 years	12	12.88
	>60 years	8	10.88
	Total	25	

a. Technology Clusters = Intensive investment

Ranks[a]

	age groups category	N	Mean Rank
Humidity	18-40 years	**14**	**30.00**
	41-60 years	**30**	**28.00**
	>60 years	**12**	**28.00**
	Total	**56**	
fertility	18-40 years	**14**	**32.18**
	41-60 years	**30**	**28.13**
	>60 years	**12**	**25.12**
	Total	**56**	
topsoil	18-40 years	**14**	**26.36**
	41-60 years	**30**	**29.22**
	>60 years	**12**	**29.21**
	Total	**56**	
capture of sediments	18-40 years	**14**	**26.93**
	41-60 years	**30**	**30.83**
	>60 years	**12**	**24.50**
	Total	**56**	
area	18-40 years	**14**	**30.21**
	41-60 years	**30**	**27.68**
	>60 years	**12**	**28.54**
	Total	**56**	
labour-adoption(no.person)	18-40 years	**14**	**23.07**
	41-60 years	**30**	**30.23**
	>60 years	**12**	**30.50**
	Total	**56**	
Quality of labour/time	18-40 years	**14**	**29.14**
	41-60 years	**30**	**30.47**
	>60 years	**12**	**22.83**
	Total	**56**	
maintenance(labour)	18-40 years	**14**	**23.46**
	41-60 years	**30**	**29.47**
	>60 years	**12**	**31.96**
	Total	**56**	
skills/knowledge-adoption	18-40 years	**14**	**33.39**
	41-60 years	**30**	**27.00**
	>60 years	**12**	**26.54**
	Total	**56**	
impacts on other activities	18-40 years	**14**	**22.32**
	41-60 years	**30**	**32.23**
	>60 years	**12**	**26.38**
	Total	**56**	
accesibility of land	18-40 years	**14**	**25.29**
	41-60 years	**30**	**30.60**
	>60 years	**12**	**27.00**
	Total	**56**	
manageability of land	18-40 years	**14**	**27.64**
	41-60 years	**30**	**30.68**
	>60 years	**12**	**24.04**
	Total	**56**	
Tools needed for adoption	18-40 years	**14**	**27.07**
	41-60 years	**30**	**31.12**
	>60 years	**12**	**23.62**
	Total	**56**	
accessibility to land	18-40 years	**14**	**31.54**
	41-60 years	**30**	**27.10**
	>60 years	**12**	**28.46**
	Total	**56**	
material needed	18-40 years	**14**	**26.68**
	41-60 years	**30**	**29.35**
	>60 years	**12**	**28.50**
	Total	**56**	
impacts on production	18-40 years	**14**	**30.57**
	41-60 years	**30**	**30.47**
	>60 years	**12**	**21.17**
	Total	**56**	
savings(kind or money)	18-40 years	**14**	**32.21**
	41-60 years	**30**	**27.48**
	>60 years	**12**	**26.71**
	Total	**56**	
income source	18-40 years	**14**	**34.75**
	41-60 years	**30**	**27.18**
	>60 years	**12**	**24.50**
	Total	**56**	
eco.land value	18-40 years	**14**	**27.96**
	41-60 years	**30**	**31.30**
	>60 years	**12**	**22.12**
	Total	**56**	
money-adoption	18-40 years	**14**	**24.29**
	41-60 years	**30**	**29.37**
	>60 years	**12**	**31.25**
	Total	**56**	
aesthetic	18-40 years	**14**	**30.50**
	41-60 years	**30**	**29.25**
	>60 years	**12**	**24.29**
	Total	**56**	
customs/traditions	18-40 years	**14**	**27.50**
	41-60 years	**30**	**28.67**
	>60 years	**12**	**29.25**
	Total	**56**	
recognition	18-40 years	**14**	**25.86**
	41-60 years	**30**	**29.67**
	>60 years	**12**	**28.67**
	Total	**56**	
personal incentives to land	18-40 years	**14**	**24.61**
	41-60 years	**30**	**30.72**
	>60 years	**12**	**27.50**
	Total	**56**	
networks	18-40 years	**14**	**30.57**
	41-60 years	**30**	**27.35**
	>60 years	**12**	**28.96**
	Total	**56**	

Appendix VI.9

Religion Results t-test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	C1CAT	.6444	25	.44401	.08880
	C1PRO	.6846	25	.46899	.09380
Pair 2	C2CAT	.6356	25	.71400	.14280
	C2PRO	.5289	25	.71638	.14328
Pair 3	C3CAT	.5867	25	.57959	.11592
	C3PRO	.0382	25	.49614	.09923
Pair 4	C4CAT	.9250	25	.55287	.11057
	C4PRO	.8700	25	.45081	.09016

Religion results Mann-Whitney test

Statistically significant different indicators according to farmers' religion per technology clusters[138]

Religion Higher mean rank by	C1 (Protestant n=70, Catholic n=36)	C2 (Protestant n=27, Catholic n=9)	C3 (Protestant n=22, Catholic n=3)	C4 (Protestant n=40, Catholic n=16)
Protestant (n=159)	Topsoil Eco. Value land Recognition Personal inc.	Money	———	———
Catholic (n=54)	Inc. Source	Skills/know. Eco.value land	Skills/know. Customs Personal inc.	Imp. Production Savings I. Source Networks*

Source: field data

[138] Indicators are located in the groups in which the highest mean ranks are found per cluster. This is in order to highlight the groups as indicators are significantly different across all groups.

a. Technology Clusters = Standard

Ranks[a]

	Religion	N	Mean Rank	Sum of Ranks
Humidity	Catholic	36	50.71	1825.50
	Protestant	70	54.94	3845.50
	Total	106		
fertility	Catholic	36	49.56	1784.00
	Protestant	70	55.53	3887.00
	Total	106		
topsoil	Catholic	36	47.11	1696.00
	Protestant	70	56.79	3975.00
	Total	106		
capture of sediments	Catholic	36	51.38	1849.50
	Protestant	70	54.59	3821.50
	Total	106		
area	Catholic	36	58.69	2113.00
	Protestant	70	50.83	3558.00
	Total	106		
labour-adoption(no.person)	Catholic	36	47.71	1717.50
	Protestant	70	56.48	3953.50
	Total	106		
Quality of labour/time	Catholic	36	57.60	2073.50
	Protestant	70	51.39	3597.50
	Total	106		
maintenance(labour)	Catholic	36	49.76	1791.50
	Protestant	70	55.42	3879.50
	Total	106		
skills/knowledge-adoption	Catholic	36	55.10	1983.50
	Protestant	70	52.68	3687.50
	Total	106		
impacts on other activities	Catholic	36	48.97	1763.00
	Protestant	70	55.83	3908.00
	Total	106		
accesibility of land	Catholic	36	55.31	1991.00
	Protestant	70	52.57	3680.00
	Total	106		
manageability of land	Catholic	36	52.46	1888.50
	Protestant	70	54.04	3782.50
	Total	106		
Tools needed for adoption	Catholic	36	54.88	1975.50
	Protestant	70	52.79	3695.50
	Total	106		
accessibility to land	Catholic	36	55.53	1999.00
	Protestant	70	52.46	3672.00
	Total	106		
material needed	Catholic	36	53.18	1914.50
	Protestant	70	53.66	3756.50
	Total	106		
impacts on production	Catholic	36	52.35	1884.50
	Protestant	70	54.09	3786.50
	Total	106		
savings(kind or money)	Catholic	36	55.85	2010.50
	Protestant	70	52.29	3660.50
	Total	106		
income source	Catholic	36	63.00	2268.00
	Protestant	70	48.61	3403.00
	Total	106		
eco.land value	Catholic	36	46.25	1665.00
	Protestant	70	57.23	4006.00
	Total	106		
money-adoption	Catholic	36	49.85	1794.50
	Protestant	70	55.38	3876.50
	Total	106		
aesthetic	Catholic	36	52.67	1896.00
	Protestant	70	53.93	3775.00
	Total	106		
customs/traditions	Catholic	36	55.65	2003.50
	Protestant	70	52.39	3667.50
	Total	106		
recognition	Catholic	36	46.22	1664.00
	Protestant	70	57.24	4007.00
	Total	106		
personal incentives to land	Catholic	36	46.00	1656.00
	Protestant	70	57.36	4015.00
	Total	106		
networks	Catholic	36	56.88	2047.50
	Protestant	70	51.76	3623.50
	Total	106		

. Technology Clusters = Sediment management

Ranks[a]

	Religion	N	Mean Rank	Sum of Ranks
Humidity	Catholic	9	18.39	165.50
	Protestant	27	18.54	500.50
	Total	36		
fertility	Catholic	9	19.17	172.50
	Protestant	27	18.28	493.50
	Total	36		
topsoil	Catholic	9	18.94	170.50
	Protestant	27	18.35	495.50
	Total	36		
capture of sediments	Catholic	9	18.39	165.50
	Protestant	27	18.54	500.50
	Total	36		
area	Catholic	9	20.50	184.50
	Protestant	27	17.83	481.50
	Total	36		
labour-adoption(no.person)	Catholic	9	16.67	150.00
	Protestant	27	19.11	516.00
	Total	36		
Quality of labour/time	Catholic	9	22.22	200.00
	Protestant	27	17.26	466.00
	Total	36		
maintenance(labour)	Catholic	9	16.61	149.50
	Protestant	27	19.13	516.50
	Total	36		
skills/knowledge-adoption	Catholic	9	25.78	232.00
	Protestant	27	16.07	434.00
	Total	36		
impacts on other activities	Catholic	9	17.67	159.00
	Protestant	27	18.78	507.00
	Total	36		
accesibility of land	Catholic	9	15.28	137.50
	Protestant	27	19.57	528.50

	Total	36		
manageability of land	Catholic	9	20.39	183.50
	Protestant	27	17.87	482.50
	Total	36		
Tools needed for adoption	Catholic	9	19.56	176.00
	Protestant	27	18.15	490.00
	Total	36		
accessibility to land	Catholic	9	19.00	171.00
	Protestant	27	18.33	495.00
	Total	36		
material needed	Catholic	9	20.94	188.50
	Protestant	27	17.69	477.50
	Total	36		
impacts on production	Catholic	9	22.94	206.50
	Protestant	27	17.02	459.50
	Total	36		
savings(kind or money)	Catholic	9	20.22	182.00
	Protestant	27	17.93	484.00
	Total	36		
income source	Catholic	9	21.50	193.50
	Protestant	27	17.50	472.50
	Total	36		
eco.land value	Catholic	9	24.78	223.00
	Protestant	27	16.41	443.00
	Total	36		
money-adoption	Catholic	9	11.50	103.50
	Protestant	27	20.83	562.50
	Total	36		
aesthetic	Catholic	9	19.00	171.00
	Protestant	27	18.33	495.00
	Total	36		
customs/traditions	Catholic	9	19.39	174.50
	Protestant	27	18.20	491.50
	Total	36		
recognition	Catholic	9	18.67	168.00
	Protestant	27	18.44	498.00
	Total	36		
personal incentives to land	Catholic	9	21.67	195.00
	Protestant	27	17.44	471.00
	Total	36		
networks	Catholic	9	20.83	187.50
	Protestant	27	17.72	478.50
	Total	36		

a. Technology Clusters = Labour/area

Ranks[a]

	Religion	N	Mean Rank	Sum of Ranks
Humidity	Catholic	3	14.33	43.00
	Protestant	22	12.82	282.00
	Total	25		
fertility	Catholic	3	16.00	48.00
	Protestant	22	12.59	277.00
	Total	25		
topsoil	Catholic	3	14.00	42.00
	Protestant	22	12.86	283.00
	Total	25		
capture of sediments	Catholic	3	15.17	45.50
	Protestant	22	12.70	279.50
	Total	25		
area	Catholic	3	15.67	47.00
	Protestant	22	12.64	278.00
	Total	25		
labour-adoption(no.person)	Catholic	3	15.00	45.00
	Protestant	22	12.73	280.00
	Total	25		
labour/time	Catholic	3	17.00	51.00
	Protestant	22	12.45	274.00
	Total	25		
maintenance(labour)	Catholic	3	13.83	41.50
	Protestant	22	12.89	283.50
	Total	25		
skills/knowledge-adoption	Catholic	3	21.00	63.00
	Protestant	22	11.91	262.00
	Total	25		
impacts on other activities	Catholic	3	13.33	40.00
	Protestant	22	12.95	285.00
	Total	25		
accesibility of land	Catholic	3	12.17	36.50
	Protestant	22	13.11	288.50
	Total	25		
manageability of land	Catholic	3	15.83	47.50
	Protestant	22	12.61	277.50
	Total	25		
Tools needed for adoption	Catholic	3	14.00	42.00
	Protestant	22	12.86	283.00
	Total	25		
accessibility to land	Catholic	3	16.17	48.50
	Protestant	22	12.57	276.50
	Total	25		
material needed	Catholic	3	19.00	57.00
	Protestant	22	12.18	268.00
	Total	25		
impacts on production	Catholic	3	12.33	37.00
	Protestant	22	13.09	288.00
	Total	25		
savings(kind or money)	Catholic	3	16.83	50.50
	Protestant	22	12.48	274.50
	Total	25		
income source	Catholic	3	17.83	53.50
	Protestant	22	12.34	271.50
	Total	25		
eco.land value	Catholic	3	14.17	42.50
	Protestant	22	12.84	282.50
	Total	25		
money-adoption	Catholic	3	12.67	38.00
	Protestant	22	13.05	287.00
	Total	25		
aesthetic	Catholic	3	12.33	37.00
	Protestant	22	13.09	288.00
	Total	25		
customs/traditions	Catholic	3	21.17	63.50
	Protestant	22	11.89	261.50
	Total	25		
recognition	Catholic	3	16.67	50.00

	Protestant	22	12.50	275.00
	Total	25		
personal incentives to land	Catholic	3	20.17	60.50
	Protestant	22	12.02	264.50
	Total	25		
networks	Catholic	3	17.33	52.00
	Protestant	22	12.41	273.00
	Total	25		

a. Technology Clusters = Intensive investment

Ranks[a]

	Religion	N	Mean Rank	Sum of Ranks
Humidity	Catholic	16	30.50	488.00
	Protestant	40	27.70	1108.00
	Total	56		
fertility	Catholic	16	28.16	450.50
	Protestant	40	28.64	1145.50
	Total	56		
topsoil	Catholic	16	26.72	427.50
	Protestant	40	29.21	1168.50
	Total	56		
capture of sediments	Catholic	16	30.50	488.00
	Protestant	40	27.70	1108.00
	Total	56		
area	Catholic	16	30.94	495.00
	Protestant	40	27.52	1101.00
	Total	56		
labour-adoption(no.person)	Catholic	16	26.00	416.00
	Protestant	40	29.50	1180.00
	Total	56		
Quality of labour/time	Catholic	16	30.69	491.00
	Protestant	40	27.62	1105.00
	Total	56		
maintenance(labour)	Catholic	16	27.75	444.00
	Protestant	40	28.80	1152.00
	Total	56		
skills/knowledge-adoption	Catholic	16	26.53	424.50
	Protestant	40	29.29	1171.50
	Total	56		
impacts on other activities	Catholic	16	27.56	441.00
	Protestant	40	28.88	1155.00
	Total	56		
accesibility of land	Catholic	16	29.31	469.00
	Protestant	40	28.18	1127.00
	Total	56		
manageability of land	Catholic	16	30.00	480.00
	Protestant	40	27.90	1116.00
	Total	56		
Tools needed for adoption	Catholic	16	29.00	464.00
	Protestant	40	28.30	1132.00
	Total	56		
accessibility to land	Catholic	16	27.28	436.50
	Protestant	40	28.99	1159.50
	Total	56		
material needed	Catholic	16	31.28	500.50
	Protestant	40	27.39	1095.50
	Total	56		
impacts on production	Catholic	16	34.69	555.00
	Protestant	40	26.02	1041.00
	Total	56		
savings(kind or money)	Catholic	16	33.41	534.50
	Protestant	40	26.54	1061.50
	Total	56		
income source	Catholic	16	31.62	506.00
	Protestant	40	27.25	1090.00
	Total	56		
eco.land value	Catholic	16	32.34	517.50
	Protestant	40	26.96	1078.50
	Total	56		
money-adoption	Catholic	16	24.38	390.00
	Protestant	40	30.15	1206.00
	Total	56		
aesthetic	Catholic	16	30.53	488.50
	Protestant	40	27.69	1107.50
	Total	56		
customs/traditions	Catholic	16	28.69	459.00
	Protestant	40	28.42	1137.00
	Total	56		
recognition	Catholic	16	25.28	404.50
	Protestant	40	29.79	1191.50
	Total	56		
personal incentives to land	Catholic	16	32.41	518.50
	Protestant	40	26.94	1077.50
	Total	56		
networks	Catholic	16	32.94	527.00
	Protestant	40	26.72	1069.00
	Total	56		

Appendix VI.10

Wealth results t-test

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	C1P - C1M	-.00405	.30293	.06059	-.12910	.12099	-.067	24	.947
Pair 2	C1P - C1R	.11974	.26089	.05218	.01205	.22743	2.295	24	.031
Pair 3	C1M - C1R	.12380	.28603	.05721	.00573	.24187	2.164	24	.041
Pair 4	C2P - C2M	.26631	.42588	.08518	.09052	.44210	3.127	24	.005
Pair 5	C2P - C2R	.05955	.43044	.08609	-.11813	.23722	.692	24	.496
Pair 6	C2M - C2R	-.20676	.38657	.07731	-.36633	-.04719	-2.674	24	.013
Pair 7	C3P - C3M	.24264	.40416	.08083	.07581	.40947	3.002	24	.006
Pair 8	C3P - C3R	.07771	.42173	.08435	-.09637	.25180	.921	24	.366
Pair 9	C3M - C3R	-.16492	.56997	.11399	-.40019	.07035	-1.447	24	.161
Pair 10	C4P - C4M	.04514	.27763	.05553	-.06946	.15974	.813	24	.424
Pair 11	C4P - C4R	.06800	.43304	.08661	-.11075	.24675	.785	24	.440
Pair 12	C4M - C4R	.02286	.40989	.08198	-.14634	.19205	.279	24	.783

Wealth results Mann-Whitney test

Statistically significant different indicators according to wealth categories per technology clusters[139]

Wealth Higher mean rank by	**C1** (Poor n=39, Med n=43, Rich n=24)	**C2** (Poor n=11, Med n=17, Rich n=8)	**C3** (Poor n=7, Med n=13, Rich n=5)	**C4** (Poor n=20, Med n=28, Rich n=8)
Poor (n=77)	Quality of labour	Income Source	Access. to land	______
Medium (n=101)	Material Personal inc.	______	______	______
Rich (n=45)	Networks	_____	Personal inc.	Networks

[139] **Indicators are located in the groups in which the highest mean ranks are found per cluster. This is in order to highlight the groups as indicators are significantly different across all groups.**

a. Technology Clusters = Standard

Ranks[a]

	Wealth Category	N	Mean Rank
Humidity	Poor	39	53.31
	Medium	43	58.31
	Rich	24	45.19
	Total	106	
fertility	Poor	39	50.73
	Medium	43	54.17
	Rich	24	56.79
	Total	106	
topsoil	Poor	39	50.59
	Medium	43	58.33
	Rich	24	49.58
	Total	106	
capture of sediments	Poor	39	50.26
	Medium	43	55.99
	Rich	24	54.31
	Total	106	
area	Poor	39	59.64
	Medium	43	51.63
	Rich	24	46.88
	Total	106	
labour-adoption(no.person)	Poor	39	49.19
	Medium	43	60.79
	Rich	24	47.44
	Total	106	
Quality of labour/time	Poor	39	61.99
	Medium	43	50.74
	Rich	24	44.65
	Total	106	
maintenance(labour)	Poor	39	57.88
	Medium	43	51.69
	Rich	24	49.62
	Total	106	
skills/knowledge-adoption	Poor	39	57.51
	Medium	43	52.69
	Rich	24	48.44
	Total	106	
impacts on other activities	Poor	39	50.85
	Medium	43	56.90
	Rich	24	51.73
	Total	106	
accesibility of land	Poor	39	57.13
	Medium	43	48.83
	Rich	24	55.98
	Total	106	
manageability of land	Poor	39	56.15
	Medium	43	51.60
	Rich	24	52.58
	Total	106	
Tools needed for adoption	Poor	39	55.63
	Medium	43	53.72
	Rich	24	49.65
	Total	106	
accessibility to land	Poor	39	59.17
	Medium	43	48.99
	Rich	24	52.38
	Total	106	
material needed	Poor	39	49.95
	Medium	43	62.16
	Rich	24	43.75
	Total	106	
impacts on production	Poor	39	52.08
	Medium	43	57.28
	Rich	24	49.04
	Total	106	
savings(kind or money)	Poor	39	53.33
	Medium	43	55.66
	Rich	24	49.90
	Total	106	
income source	Poor	39	58.79
	Medium	43	49.43
	Rich	24	52.19
	Total	106	
eco.land value	Poor	39	48.53
	Medium	43	56.64
	Rich	24	55.96
	Total	106	
money-adoption	Poor	39	51.06
	Medium	43	58.88
	Rich	24	47.81
	Total	106	
aesthetic	Poor	39	53.59
	Medium	43	53.51
	Rich	24	53.33
	Total	106	
customs/traditions	Poor	39	57.72
	Medium	43	49.29
	Rich	24	54.19
	Total	106	
recognition	Poor	39	47.91
	Medium	43	55.87
	Rich	24	58.33
	Total	106	
personal incentives to land	Poor	39	46.94
	Medium	43	60.08
	Rich	24	52.38
	Total	106	
networks	Poor	39	58.51
	Medium	43	44.47
	Rich	24	61.54
	Total	106	

a. Technology Clusters = Sediment management

Ranks[a]

	Wealth Category	N	Mean Rank
Humidity	Poor	11	18.32
	Medium	17	19.24
	Rich	8	17.19
	Total	36	
fertility	Poor	11	21.50
	Medium	17	16.35
	Rich	8	18.94
	Total	36	
topsoil	Poor	11	19.23
	Medium	17	17.35
	Rich	8	19.94
	Total	36	
capture of sediments	Poor	11	16.32
	Medium	17	19.97
	Rich	8	18.38
	Total	36	
area	Poor	11	19.18
	Medium	17	17.85
	Rich	8	18.94
	Total	36	
labour-adoption(no.person)	Poor	11	20.64
	Medium	17	15.76
	Rich	8	21.38
	Total	36	
Quality of labour/time	Poor	11	23.14
	Medium	17	15.62
	Rich	8	18.25
	Total	36	
maintenance(labour)	Poor	11	15.77
	Medium	17	20.29
	Rich	8	18.44
	Total	36	
skills/knowledge-adoption	Poor	11	22.09
	Medium	17	18.06
	Rich	8	14.50
	Total	36	
impacts on other activities	Poor	11	18.36
	Medium	17	16.97
	Rich	8	21.94
	Total	36	
accesibility of land	Poor	11	17.41
	Medium	17	18.09
	Rich	8	20.88
	Total	36	
manageability of land	Poor	11	22.64
	Medium	17	14.97
	Rich	8	20.31
	Total	36	
Tools needed for adoption	Poor	11	20.23
	Medium	17	17.85
	Rich	8	17.50
	Total	36	
accessibility to land	Poor	11	19.55
	Medium	17	18.41
	Rich	8	17.25
	Total	36	
material needed	Poor	11	21.00
	Medium	17	15.18
	Rich	8	22.12
	Total	36	
impacts on production	Poor	11	22.05
	Medium	17	17.15
	Rich	8	16.50
	Total	36	
savings(kind or money)	Poor	11	20.59
	Medium	17	15.59
	Rich	8	21.81
	Total	36	
income source	Poor	11	20.77
	Medium	17	17.50
	Rich	8	17.50
	Total	36	
eco.land value	Poor	11	23.27
	Medium	17	15.56
	Rich	8	18.19
	Total	36	
money-adoption	Poor	11	16.18
	Medium	17	18.06
	Rich	8	22.62
	Total	36	
aesthetic	Poor	11	19.00
	Medium	17	18.59
	Rich	8	17.62
	Total	36	
customs/traditions	Poor	11	16.68
	Medium	17	20.06
	Rich	8	17.69
	Total	36	
recognition	Poor	11	18.64
	Medium	17	18.59
	Rich	8	18.12
	Total	36	
personal incentives to land	Poor	11	19.00
	Medium	17	17.59
	Rich	8	19.75
	Total	36	
networks	Poor	11	22.77
	Medium	17	15.47
	Rich	8	19.06
	Total	36	

a. Technology Clusters = Labour/area

Ranks[a]

	Wealth Category	N	Mean Rank
Humidity	Poor	7	15.57
	Medium	13	11.92
	Rich	5	12.20
	Total	25	
fertility	Poor	7	14.86
	Medium	13	11.38
	Rich	5	14.60
	Total	25	
topsoil	Poor	7	14.57
	Medium	13	11.15
	Rich	5	15.60
	Total	25	
capture of sediments	Poor	7	13.50
	Medium	13	11.62
	Rich	5	15.90
	Total	25	
area	Poor	7	13.00
	Medium	13	13.77
	Rich	5	11.00
	Total	25	
labour-adoption(no.person)	Poor	7	13.64
	Medium	13	11.42
	Rich	5	16.20
	Total	25	
Quality of labour/time	Poor	7	13.14
	Medium	13	13.31
	Rich	5	12.00
	Total	25	
maintenance(labour)	Poor	7	12.43
	Medium	13	12.92
	Rich	5	14.00
	Total	25	
skills/knowledge-adoption	Poor	7	14.14
	Medium	13	14.15
	Rich	5	8.40
	Total	25	
impacts on other activities	Poor	7	11.00
	Medium	13	14.23
	Rich	5	12.60
	Total	25	
accesibility of land	Poor	7	13.29
	Medium	13	14.88
	Rich	5	7.70
	Total	25	
manageability of land	Poor	7	14.93
	Medium	13	11.85
	Rich	5	13.30
	Total	25	
Tools needed for adoption	Poor	7	13.43
	Medium	13	12.77
	Rich	5	13.00
	Total	25	
accessibility to land	Poor	7	15.57
	Medium	13	12.00
	Rich	5	12.00
	Total	25	
material needed	Poor	7	15.07
	Medium	13	12.46
	Rich	5	11.50
	Total	25	
impacts on production	Poor	7	12.14
	Medium	13	13.50
	Rich	5	12.90
	Total	25	
savings(kind or money)	Poor	7	14.71
	Medium	13	11.50
	Rich	5	14.50
	Total	25	
income source	Poor	7	14.29
	Medium	13	11.85
	Rich	5	14.20
	Total	25	
eco.land value	Poor	7	11.21
	Medium	13	14.31
	Rich	5	12.10
	Total	25	
money-adoption	Poor	7	12.71
	Medium	13	14.54
	Rich	5	9.40
	Total	25	
aesthetic	Poor	7	12.57
	Medium	13	12.08
	Rich	5	16.00
	Total	25	
customs/traditions	Poor	7	15.79
	Medium	13	11.12
	Rich	5	14.00
	Total	25	
recognition	Poor	7	14.29
	Medium	13	10.92
	Rich	5	16.60
	Total	25	
personal incentives to land	Poor	7	14.71
	Medium	13	10.19
	Rich	5	17.90
	Total	25	
networks	Poor	7	15.50
	Medium	13	10.19
	Rich	5	16.80
	Total	25	

a. Technology Clusters = Intensive investment

Ranks[a]

	Wealth Category	N	Mean Rank
Humidity	Poor	20	30.00
	Medium	28	27.86
	Rich	8	27.00
	Total	56	
fertility	Poor	20	32.85
	Medium	28	26.14
	Rich	8	25.88
	Total	56	
topsoil	Poor	20	27.78
	Medium	28	29.21
	Rich	8	27.81
	Total	56	
capture of sediments	Poor	20	28.80
	Medium	28	28.50
	Rich	8	27.75
	Total	56	
area	Poor	20	31.52
	Medium	28	27.62
	Rich	8	24.00
	Total	56	
labour-adoption(no.person)	Poor	20	27.15
	Medium	28	29.18
	Rich	8	29.50
	Total	56	
Quality of labour/time	Poor	20	28.30
	Medium	28	30.29
	Rich	8	22.75
	Total	56	
maintenance(labour)	Poor	20	25.82
	Medium	28	27.45
	Rich	8	38.88
	Total	56	
skills/knowledge-adoption	Poor	20	30.72
	Medium	28	27.36
	Rich	8	26.94
	Total	56	
impacts on other activities	Poor	20	25.22
	Medium	28	30.00
	Rich	8	31.44
	Total	56	
accesibility of land	Poor	20	29.70
	Medium	28	27.29
	Rich	8	29.75
	Total	56	
manageability of land	Poor	20	31.65
	Medium	28	27.59
	Rich	8	23.81
	Total	56	
Tools needed for adoption	Poor	20	26.35
	Medium	28	30.34
	Rich	8	27.44
	Total	56	
accessibility to land	Poor	20	28.85
	Medium	28	29.43
	Rich	8	24.38
	Total	56	
material needed	Poor	20	27.70
	Medium	28	29.12
	Rich	8	28.31
	Total	56	
impacts on production	Poor	20	32.40
	Medium	28	26.43
	Rich	8	26.00
	Total	56	
savings(kind or money)	Poor	20	31.40
	Medium	28	25.50
	Rich	8	31.75
	Total	56	
income source	Poor	20	31.68
	Medium	28	27.38
	Rich	8	24.50
	Total	56	
eco.land value	Poor	20	29.32
	Medium	28	27.05
	Rich	8	31.50
	Total	56	
money-adoption	Poor	20	25.85
	Medium	28	27.93
	Rich	8	37.12
	Total	56	
aesthetic	Poor	20	30.58
	Medium	28	28.30
	Rich	8	24.00
	Total	56	
customs/traditions	Poor	20	31.55
	Medium	28	26.07
	Rich	8	29.38
	Total	56	
recognition	Poor	20	27.20
	Medium	28	29.55
	Rich	8	28.06
	Total	56	
personal incentives to land	Poor	20	26.88
	Medium	28	31.88
	Rich	8	20.75
	Total	56	
networks	Poor	20	32.48
	Medium	28	23.73
	Rich	8	35.25
	Total	56	

Appendix VI.11

Education : results Mann-Whitney test

Education categories Higher mean rank by	C1 (Illiterate=43 Education= 63)	C2 (Illiterate=12 Education= 24)	C3 (Illiterate=13 Education=12)	C4 (Illiterate=25 Education= 31)
Illiterate (I)	Capture sed. Economic value aesthetic	Access. of land Customs Personal incentives	Money	Area Access. to land* Manageability Customs Recognition Personal inc. Networks
Primary incomplete to higher education			Humidity Income source Networks	

a. Technology Clusters = Standard

Ranks[a]

	Education	N	Mean Rank	Sum of Ranks
Humidity	iliterate	43	59.08	2540.50
	Primary incompleted/higher	63	49.69	3130.50
	Total	106		
fertility	iliterate	43	54.24	2332.50
	Primary incompleted/higher	63	52.99	3338.50
	Total	106		
topsoil	iliterate	43	58.24	2504.50
	Primary incompleted/higher	63	50.26	3166.50
	Total	106		
capture of sediments	iliterate	43	60.84	2616.00
	Primary incompleted/higher	63	48.49	3055.00
	Total	106		
area	iliterate	43	50.34	2164.50
	Primary incompleted/higher	63	55.66	3506.50
	Total	106		
labour-adoption(no.person)	iliterate	43	52.60	2262.00
	Primary incompleted/higher	63	54.11	3409.00
	Total	106		
Quality of labour/time	iliterate	43	54.63	2349.00
	Primary incompleted/higher	63	52.73	3322.00
	Total	106		
maintenance(labour)	iliterate	43	55.24	2375.50
	Primary incompleted/higher	63	52.31	3295.50
	Total	106		
skills/knowledge-adoption	iliterate	43	56.93	2448.00
	Primary incompleted/higher	63	51.16	3223.00
	Total	106		
impacts on other activities	iliterate	43	52.53	2259.00
	Primary incompleted/higher	63	54.16	3412.00
	Total	106		
accesibility of land	iliterate	43	49.08	2110.50
	Primary incompleted/higher	63	56.52	3560.50
	Total	106		
manageability of land	iliterate	43	57.43	2469.50
	Primary incompleted/higher	63	50.82	3201.50
	Total	106		
Tools needed for adoption	iliterate	43	56.64	2435.50
	Primary incompleted/higher	63	51.36	3235.50
	Total	106		
accessibility to land	iliterate	43	50.92	2189.50
	Primary incompleted/higher	63	55.26	3481.50
	Total	106		
material needed	iliterate	43	57.79	2485.00
	Primary incompleted/higher	63	50.57	3186.00
	Total	106		
impacts on production	iliterate	43	54.69	2351.50
	Primary incompleted/higher	63	52.69	3319.50
	Total	106		
savings(kind or money)	iliterate	43	52.53	2259.00
	Primary incompleted/higher	63	54.16	3412.00
	Total	106		
income source	iliterate	43	54.42	2340.00
	Primary incompleted/higher	63	52.87	3331.00
	Total	106		
eco.land value	iliterate	43	48.74	2096.00
	Primary incompleted/higher	63	56.75	3575.00
	Total	106		

money-adoption	iliterate	43	56.24	2418.50
	Primary incompleted/higher	63	51.63	3252.50
	Total	106		
aesthetic	iliterate	43	59.52	2559.50
	Primary incompleted/higher	63	49.39	3111.50
	Total	106		
customs/traditions	iliterate	43	53.72	2310.00
	Primary incompleted/higher	63	53.35	3361.00
	Total	106		
recognition	iliterate	43	56.87	2445.50
	Primary incompleted/higher	63	51.20	3225.50
	Total	106		
personal incentives to land	iliterate	43	52.03	2237.50
	Primary incompleted/higher	63	54.50	3433.50
	Total	106		
networks	iliterate	43	52.55	2259.50
	Primary incompleted/higher	63	54.15	3411.50
	Total	106		

a. Technology Clusters = Sediment management

Ranks[a]

	Education	N	Mean Rank	Sum of Ranks
Humidity	iliterate	12	19.83	238.00
	Primary incompleted/higher	24	17.83	428.00
	Total	36		
fertility	iliterate	12	21.08	253.00
	Primary incompleted/higher	24	17.21	413.00
	Total	36		
topsoil	iliterate	12	18.71	224.50
	Primary incompleted/higher	24	18.40	441.50
	Total	36		
capture of sediments	iliterate	12	20.33	244.00
	Primary incompleted/higher	24	17.58	422.00
	Total	36		
area	iliterate	12	17.79	213.50
	Primary incompleted/higher	24	18.85	452.50
	Total	36		
labour-adoption(no.person)	iliterate	12	21.62	259.50
	Primary incompleted/higher	24	16.94	406.50
	Total	36		
Quality of labour/time	iliterate	12	18.58	223.00
	Primary incompleted/higher	24	18.46	443.00
	Total	36		
maintenance(labour)	iliterate	12	18.04	216.50
	Primary incompleted/higher	24	18.73	449.50
	Total	36		
skills/knowledge-adoption	iliterate	12	21.17	254.00
	Primary incompleted/higher	24	17.17	412.00
	Total	36		
impacts on other activities	iliterate	12	20.67	248.00
	Primary incompleted/higher	24	17.42	418.00
	Total	36		
accesibility of land	iliterate	12	22.67	272.00
	Primary incompleted/higher	24	16.42	394.00
	Total	36		
manageability of land	iliterate	12	21.71	260.50
	Primary incompleted/higher	24	16.90	405.50
	Total	36		
Tools needed for adoption	iliterate	12	20.83	250.00
	Primary incompleted/higher	24	17.33	416.00
	Total	36		
accessibility to land	iliterate	12	18.38	220.50
	Primary incompleted/higher	24	18.56	445.50
	Total	36		
material needed	iliterate	12	19.38	232.50
	Primary incompleted/higher	24	18.06	433.50
	Total	36		
impacts on production	iliterate	12	20.83	250.00
	Primary incompleted/higher	24	17.33	416.00
	Total	36		
savings(kind or money)	iliterate	12	20.00	240.00
	Primary incompleted/higher	24	17.75	426.00
	Total	36		
income source	iliterate	12	17.50	210.00
	Primary incompleted/higher	24	19.00	456.00
	Total	36		
eco.land value	iliterate	12	18.33	220.00
	Primary incompleted/higher	24	18.58	446.00
	Total	36		
money-adoption	iliterate	12	22.38	268.50
	Primary incompleted/higher	24	16.56	397.50
	Total	36		
aesthetic	iliterate	12	20.75	249.00
	Primary incompleted/higher	24	17.38	417.00
	Total	36		

customs/traditions	iliterate	12	22.21	266.50
	Primary incompleted/higher	24	16.65	399.50
	Total	36		
recognition	iliterate	12	21.46	257.50
	Primary incompleted/higher	24	17.02	408.50
	Total	36		
personal incentives to land	iliterate	12	22.50	270.00
	Primary incompleted/higher	24	16.50	396.00
	Total	36		
networks	iliterate	12	20.25	243.00
	Primary incompleted/higher	24	17.62	423.00
	Total	36		

a. Technology Clusters = Labour/area

Ranks[a]

	Education	N	Mean Rank	Sum of Ranks
Humidity	iliterate	13	9.88	128.50
	Primary incompleted/higher	12	16.38	196.50
	Total	25		
fertility	iliterate	13	11.62	151.00
	Primary incompleted/higher	12	14.50	174.00
	Total	25		
topsoil	iliterate	13	11.54	150.00
	Primary incompleted/higher	12	14.58	175.00
	Total	25		
capture of sediments	iliterate	13	11.54	150.00
	Primary incompleted/higher	12	14.58	175.00
	Total	25		
area	iliterate	13	13.77	179.00
	Primary incompleted/higher	12	12.17	146.00
	Total	25		
labour-adoption(no.person)	iliterate	13	12.38	161.00
	Primary incompleted/higher	12	13.67	164.00
	Total	25		
Quality of labour/time	iliterate	13	14.92	194.00
	Primary incompleted/higher	12	10.92	131.00
	Total	25		
maintenance(labour)	iliterate	13	13.81	179.50
	Primary incompleted/higher	12	12.12	145.50
	Total	25		
skills/knowledge-adoption	iliterate	13	12.96	168.50
	Primary incompleted/higher	12	13.04	156.50
	Total	25		
impacts on other activities	iliterate	13	13.38	174.00
	Primary incompleted/higher	12	12.58	151.00
	Total	25		
accesibility of land	iliterate	13	13.58	176.50
	Primary incompleted/higher	12	12.38	148.50
	Total	25		
manageability of land	iliterate	13	13.23	172.00
	Primary incompleted/higher	12	12.75	153.00
	Total	25		
Tools needed for adoption	iliterate	13	13.69	178.00
	Primary incompleted/higher	12	12.25	147.00
	Total	25		
accessibility to land	iliterate	13	12.00	156.00
	Primary incompleted/higher	12	14.08	169.00
	Total	25		
material needed	iliterate	13	15.15	197.00
	Primary incompleted/higher	12	10.67	128.00
	Total	25		
impacts on production	iliterate	13	12.50	162.50
	Primary incompleted/higher	12	13.54	162.50
	Total	25		
savings(kind or money)	iliterate	13	13.08	170.00
	Primary incompleted/higher	12	12.92	155.00
	Total	25		
income source	iliterate	13	10.85	141.00
	Primary incompleted/higher	12	15.33	184.00
	Total	25		
eco.land value	iliterate	13	12.77	166.00
	Primary incompleted/higher	12	13.25	159.00
	Total	25		
money-adoption	iliterate	13	15.85	206.00
	Primary incompleted/higher	12	9.92	119.00
	Total	25		
aesthetic	iliterate	13	11.96	155.50
	Primary incompleted/higher	12	14.12	169.50
	Total	25		
customs/traditions	iliterate	13	12.81	166.50
	Primary incompleted/higher	12	13.21	158.50
	Total	25		
recognition	iliterate	13	11.00	143.00
	Primary incompleted/higher	12	15.17	182.00
	Total	25		

personal incentives to land	iliterate	13	13.00	169.00
	Primary incompleted/higher	12	13.00	156.00
	Total	25		
networks	iliterate	13	10.42	135.50
	Primary incompleted/higher	12	15.79	189.50
	Total	25		

a. Technology Clusters = Intensive investment

Ranks[a]

	Education	N	Mean Rank	Sum of Ranks
Humidity	iliterate	25	31.76	794.00
	Primary incompleted/higher	31	25.87	802.00
	Total	56		
fertility	iliterate	25	31.94	798.50
	Primary incompleted/higher	31	25.73	797.50
	Total	56		
topsoil	iliterate	25	30.56	764.00
	Primary incompleted/higher	31	26.84	832.00
	Total	56		
capture of sediments	iliterate	25	29.82	745.50
	Primary incompleted/higher	31	27.44	850.50
	Total	56		
area	iliterate	25	32.04	801.00
	Primary incompleted/higher	31	25.65	795.00
	Total	56		
labour-adoption(no.person)	iliterate	25	32.14	803.50
	Primary incompleted/higher	31	25.56	792.50
	Total	56		
Quality of labour/time	iliterate	25	25.54	638.50
	Primary incompleted/higher	31	30.89	957.50
	Total	56		
maintenance(labour)	iliterate	25	30.44	761.00
	Primary incompleted/higher	31	26.94	835.00
	Total	56		
skills/knowledge-adoption	iliterate	25	27.40	685.00
	Primary incompleted/higher	31	29.39	911.00
	Total	56		
impacts on other activities	iliterate	25	32.32	808.00
	Primary incompleted/higher	31	25.42	788.00
	Total	56		
accesibility of land	iliterate	25	33.74	843.50
	Primary incompleted/higher	31	24.27	752.50
	Total	56		
manageability of land	iliterate	25	33.96	849.00
	Primary incompleted/higher	31	24.10	747.00
	Total	56		
Tools needed for adoption	iliterate	25	27.44	686.00
	Primary incompleted/higher	31	29.35	910.00
	Total	56		
accessibility to land	iliterate	25	28.70	717.50
	Primary incompleted/higher	31	28.34	878.50
	Total	56		
material needed	iliterate	25	25.76	644.00
	Primary incompleted/higher	31	30.71	952.00
	Total	56		
impacts on production	iliterate	25	31.26	781.50
	Primary incompleted/higher	31	26.27	814.50
	Total	56		
savings(kind or money)	iliterate	25	29.72	743.00
	Primary incompleted/higher	31	27.52	853.00
	Total	56		
income source	iliterate	25	26.70	667.50
	Primary incompleted/higher	31	29.95	928.50
	Total	56		
eco.land value	iliterate	25	31.44	786.00
	Primary incompleted/higher	31	26.13	810.00
	Total	56		
money-adoption	iliterate	25	29.18	729.50
	Primary incompleted/higher	31	27.95	866.50
	Total	56		
aesthetic	iliterate	25	30.68	767.00
	Primary incompleted/higher	31	26.74	829.00
	Total	56		
customs/traditions	iliterate	25	33.58	839.50
	Primary incompleted/higher	31	24.40	756.50
	Total	56		
recognition	iliterate	25	32.22	805.50
	Primary incompleted/higher	31	25.50	790.50
	Total	56		
personal incentives to land	iliterate	25	32.52	813.00
	Primary incompleted/higher	31	25.26	783.00
	Total	56		
networks	iliterate	25	32.48	812.00
	Primary incompleted/higher	31	25.29	784.00

	Total	56

Appendix VII.12

Family type results Kruskall-Wallis

Family type Highest mean rank by	C1 (nuclear n=62, Extended n=29, solitary n=15)	C2 (nuclear n=17, Extended n=13, solitary n=6)	C3 (nuclear n=12, Extended n=8, solitary n=5)	C4 (nuclear n=39, Extended n=10, solitary n=7)
Nuclear	Access. to land	Material	Skills/knowledge	Labour needed Manageability Imp. production
Extended	Material	Maintenance Money		Money
Solitary/single	Capture sed.	Personal inc.	Maintenance Money Customs	

a. Technology Clusters = Standard

Ranks[a]

	Family Type	N	Mean Rank
Humidity	Nuclear	62	51.81
	Extended	29	52.40
	Solitary/single	15	62.63
	Total	106	
fertility	Nuclear	62	50.05
	Extended	29	58.50
	Solitary/single	15	58.10
	Total	106	
topsoil	Nuclear	62	53.22
	Extended	29	51.21
	Solitary/single	15	59.10
	Total	106	
capture of sediments	Nuclear	62	50.99
	Extended	29	46.72
	Solitary/single	15	76.97
	Total	106	
area	Nuclear	62	54.84
	Extended	29	55.10
	Solitary/single	15	44.87
	Total	106	
labour-adoption(no.person)	Nuclear	62	49.27
	Extended	29	62.60
	Solitary/single	15	53.40
	Total	106	
Quality of labour/time	Nuclear	62	55.56
	Extended	29	50.83
	Solitary/single	15	50.17
	Total	106	
maintenance(labour)	Nuclear	62	55.29
	Extended	29	53.47
	Solitary/single	15	46.17
	Total	106	
skills/knowledge-adoption	Nuclear	62	53.84
	Extended	29	51.03
	Solitary/single	15	56.87

	Total	106	
impacts on other activities	Nuclear	62	51.40
	Extended	29	62.38
	Solitary/single	15	45.03
	Total	106	
accesibility of land	Nuclear	62	57.38
	Extended	29	51.98
	Solitary/single	15	40.40
	Total	106	
manageability of land	Nuclear	62	56.10
	Extended	29	50.09
	Solitary/single	15	49.33
	Total	106	
Tools needed for adoption	Nuclear	62	56.19
	Extended	29	50.66
	Solitary/single	15	47.87
	Total	106	
accessibility to land	Nuclear	62	57.87
	Extended	29	52.22
	Solitary/single	15	37.90
	Total	106	
material needed	Nuclear	62	47.74
	Extended	29	61.62
	Solitary/single	15	61.60
	Total	106	
impacts on production	Nuclear	62	51.40
	Extended	29	58.00
	Solitary/single	15	53.47
	Total	106	
savings(kind or money)	Nuclear	62	54.52
	Extended	29	54.19
	Solitary/single	15	47.93
	Total	106	
income source	Nuclear	62	54.10
	Extended	29	52.81
	Solitary/single	15	52.37
	Total	106	
eco.land value	Nuclear	62	51.31
	Extended	29	59.95

	Solitary/single	15	50.10
	Total	106	
money-adoption	Nuclear	62	56.02
	Extended	29	49.95
	Solitary/single	15	49.97
	Total	106	
aesthetic	Nuclear	62	50.66
	Extended	29	59.72
	Solitary/single	15	53.20
	Total	106	
customs/traditions	Nuclear	62	54.51
	Extended	29	47.57
	Solitary/single	15	60.80
	Total	106	
recognition	Nuclear	62	52.27
	Extended	29	61.09
	Solitary/single	15	43.90
	Total	106	
personal incentives to land	Nuclear	62	51.19
	Extended	29	56.57
	Solitary/single	15	57.10
	Total	106	
networks	Nuclear	62	52.10
	Extended	29	59.36
	Solitary/single	15	47.97
	Total	106	

a. Technology Clusters = Sediment management

Ranks[a]

	Family Type	N	Mean Rank
Humidity	Nuclear	17	17.29
	Extended	13	20.77
	Solitary/single	6	17.00
	Total	36	
fertility	Nuclear	17	18.74
	Extended	13	18.08
	Solitary/single	6	18.75
	Total	36	
topsoil	Nuclear	17	18.15
	Extended	13	18.58
	Solitary/single	6	19.33
	Total	36	
capture of sediments	Nuclear	17	17.74
	Extended	13	19.88
	Solitary/single	6	17.67
	Total	36	
area	Nuclear	17	19.76
	Extended	13	18.23
	Solitary/single	6	15.50
	Total	36	
labour-adoption(no.person)	Nuclear	17	19.91
	Extended	13	18.81
	Solitary/single	6	13.83
	Total	36	
Quality of labour/time	Nuclear	17	21.21
	Extended	13	16.50
	Solitary/single	6	15.17
	Total	36	
maintenance(labour)	Nuclear	17	15.68
	Extended	13	26.88
	Solitary/single	6	8.33
	Total	36	
skills/knowledge-adoption	Nuclear	17	18.82
	Extended	13	16.23
	Solitary/single	6	22.50
	Total	36	
impacts on other activities	Nuclear	17	16.53
	Extended	13	21.19
	Solitary/single	6	18.25
	Total	36	
accesibility of land	Nuclear	17	16.68
	Extended	13	21.27
	Solitary/single	6	17.67
	Total	36	
manageability of land	Nuclear	17	20.21
	Extended	13	17.58
	Solitary/single	6	15.67
	Total	36	
Tools needed for adoption	Nuclear	17	19.41
	Extended	13	19.88
	Solitary/single	6	12.92
	Total	36	
accessibility to land	Nuclear	17	20.91
	Extended	13	17.54
	Solitary/single	6	13.75
	Total	36	
material needed	Nuclear	17	21.88
	Extended	13	19.38
	Solitary/single	6	7.00
	Total	36	
impacts on production	Nuclear	17	19.91
	Extended	13	19.58
	Solitary/single	6	12.17
	Total	36	
savings(kind or money)	Nuclear	17	20.12
	Extended	13	16.73
	Solitary/single	6	17.75
	Total	36	
income source	Nuclear	17	19.62
	Extended	13	17.50
	Solitary/single	6	17.50
	Total	36	
eco.land value	Nuclear	17	20.76
	Extended	13	14.42

	Solitary/single	6	20.92
	Total	36	
money-adoption	Nuclear	17	20.09
	Extended	13	20.58
	Solitary/single	6	9.50
	Total	36	
aesthetic	Nuclear	17	18.15
	Extended	13	19.12
	Solitary/single	6	18.17
	Total	36	
customs/traditions	Nuclear	17	18.18
	Extended	13	17.81
	Solitary/single	6	20.92
	Total	36	
recognition	Nuclear	17	18.59
	Extended	13	19.38
	Solitary/single	6	16.33
	Total	36	
personal incentives to land	Nuclear	17	15.47
	Extended	13	19.46
	Solitary/single	6	25.00
	Total	36	
networks	Nuclear	17	21.32
	Extended	13	17.19
	Solitary/single	6	13.33
	Total	36	

a. Technology Clusters = Labour/area

Ranks[a]

	Family Type	N	Mean Rank
Humidity	Nuclear	12	12.17
	Extended	8	14.75
	Solitary/single	5	12.20
	Total	25	
fertility	Nuclear	12	12.71
	Extended	8	12.12
	Solitary/single	5	15.10
	Total	25	
topsoil	Nuclear	12	12.00
	Extended	8	12.88
	Solitary/single	5	15.60
	Total	25	
capture of sediments	Nuclear	12	11.17
	Extended	8	13.88
	Solitary/single	5	16.00
	Total	25	
area	Nuclear	12	13.17
	Extended	8	11.00
	Solitary/single	5	15.80
	Total	25	
labour-adoption(no.person)	Nuclear	12	14.00
	Extended	8	12.62
	Solitary/single	5	11.20
	Total	25	
Quality of labour/time	Nuclear	12	14.00
	Extended	8	11.50
	Solitary/single	5	13.00
	Total	25	
maintenance(labour)	Nuclear	12	11.75
	Extended	8	10.50
	Solitary/single	5	20.00
	Total	25	
skills/knowledge-adoption	Nuclear	12	16.62
	Extended	8	10.00
	Solitary/single	5	9.10
	Total	25	
impacts on other activities	Nuclear	12	13.92
	Extended	8	14.00
	Solitary/single	5	9.20
	Total	25	
accesibility of land	Nuclear	12	11.83
	Extended	8	11.75
	Solitary/single	5	17.80
	Total	25	
manageability of land	Nuclear	12	12.54
	Extended	8	10.94
	Solitary/single	5	17.40
	Total	25	
Tools needed for adoption	Nuclear	12	12.00
	Extended	8	11.88
	Solitary/single	5	17.20
	Total	25	
accessibility to land	Nuclear	12	14.08
	Extended	8	12.00
	Solitary/single	5	12.00
	Total	25	
material needed	Nuclear	12	13.67
	Extended	8	10.75
	Solitary/single	5	15.00
	Total	25	
impacts on production	Nuclear	12	12.17
	Extended	8	11.06
	Solitary/single	5	18.10
	Total	25	
savings(kind or money)	Nuclear	12	12.38
	Extended	8	15.50
	Solitary/single	5	10.50
	Total	25	
income source	Nuclear	12	13.46
	Extended	8	13.25
	Solitary/single	5	11.50
	Total	25	
eco.land value	Nuclear	12	12.04
	Extended	8	12.81

	Solitary/single	5	15.60
	Total	25	
money-adoption	Nuclear	12	12.21
	Extended	8	9.44
	Solitary/single	5	20.60
	Total	25	
aesthetic	Nuclear	12	10.58
	Extended	8	13.62
	Solitary/single	5	17.80
	Total	25	
customs/traditions	Nuclear	12	14.33
	Extended	8	9.00
	Solitary/single	5	16.20
	Total	25	
recognition	Nuclear	12	12.46
	Extended	8	11.94
	Solitary/single	5	16.00
	Total	25	
personal incentives to land	Nuclear	12	13.25
	Extended	8	11.62
	Solitary/single	5	14.60
	Total	25	
networks	Nuclear	12	13.88
	Extended	8	12.31
	Solitary/single	5	12.00
	Total	25	

a. Technology Clusters = Intensive investment

Ranks[a]

	Family Type	N	Mean Rank
Humidity	Nuclear	39	30.10
	Extended	10	24.80
	Solitary/single	7	24.86
	Total	56	
fertility	Nuclear	39	28.64
	Extended	10	26.30
	Solitary/single	7	30.86
	Total	56	
topsoil	Nuclear	39	29.35
	Extended	10	24.70
	Solitary/single	7	29.21
	Total	56	
capture of sediments	Nuclear	39	29.24
	Extended	10	27.10
	Solitary/single	7	26.36
	Total	56	
area	Nuclear	39	28.97
	Extended	10	25.55
	Solitary/single	7	30.07
	Total	56	
labour-adoption(no.person)	Nuclear	39	25.71
	Extended	10	33.00
	Solitary/single	7	37.64
	Total	56	
Quality of labour/time	Nuclear	39	29.37
	Extended	10	23.30
	Solitary/single	7	31.07
	Total	56	
maintenance(labour)	Nuclear	39	26.32
	Extended	10	29.20
	Solitary/single	7	39.64
	Total	56	
skills/knowledge-adoption	Nuclear	39	31.33
	Extended	10	21.70
	Solitary/single	7	22.43
	Total	56	
impacts on other activities	Nuclear	39	27.73
	Extended	10	34.90
	Solitary/single	7	23.64
	Total	56	
accesibility of land	Nuclear	39	29.28
	Extended	10	22.60
	Solitary/single	7	32.57
	Total	56	
manageability of land	Nuclear	39	31.13
	Extended	10	19.95
	Solitary/single	7	26.07
	Total	56	
Tools needed for adoption	Nuclear	39	30.32
	Extended	10	27.55
	Solitary/single	7	19.71
	Total	56	
accessibility to land	Nuclear	39	28.62
	Extended	10	28.65
	Solitary/single	7	27.64
	Total	56	
material needed	Nuclear	39	27.85
	Extended	10	32.80
	Solitary/single	7	26.00
	Total	56	
impacts on production	Nuclear	39	31.29
	Extended	10	21.90
	Solitary/single	7	22.36
	Total	56	
savings(kind or money)	Nuclear	39	29.76
	Extended	10	29.05
	Solitary/single	7	20.71
	Total	56	
income source	Nuclear	39	28.18
	Extended	10	32.55
	Solitary/single	7	24.50
	Total	56	
eco.land value	Nuclear	39	30.77
	Extended	10	24.75

	Solitary/single	7	21.21
	Total	56	
money-adoption	Nuclear	39	25.55
	Extended	10	35.95
	Solitary/single	7	34.29
	Total	56	
aesthetic	Nuclear	39	30.27
	Extended	10	22.55
	Solitary/single	7	27.14
	Total	56	
customs/traditions	Nuclear	39	28.79
	Extended	10	27.80
	Solitary/single	7	27.86
	Total	56	
recognition	Nuclear	39	28.68
	Extended	10	26.70

	Solitary/single	7	30.07
	Total	56	
personal incentives to land	Nuclear	39	26.99
	Extended	10	27.80
	Solitary/single	7	37.93
	Total	56	
networks	Nuclear	39	28.59
	Extended	10	30.40
	Solitary/single	7	25.29
	Total	56	

Appendix VII.1 Preferences Between LUT

Technologies Adopted in Solar and Milpa		
Please write name of technologies	Solar Technologies	Milpa Technologies

Choose the best adopted technologies for each LUT

Best Adopted Technologies	
Solar	Milpa
1	1
2	2
3	3
4	4
5	5

Annex

Landscape of La Era, SPT

Gullies in La Era, SP

Plot in 1998

Plot in 2006

Maguey and milpa

Maize Milpa

Yellow Maize

Black Maize

White Maize

Maize colours

Maize storage

Cutting Canuela

Canuela and Manure

Forage


Digging ditch

Incorporating manure

Collecting Arena-pumice

Ditch

Seeding

Land preparation

Infilling gullies

Infilling gullies and constructing stone wall

All photographs taken by the Author