Motivations and incentives for pro-environmental behaviour: *the case of silvopasture adoption in the tropical forest frontier*

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Preface

The following material from the research conducted for this thesis has been published:

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Unai Pascual has been my academic supervisor and Luis García-Barrios has been research programme coordinator. I led the development of research ideas, design of research methods, collection and analysis of data, and the elaboration, writing, and editing processes for all the chapters.

Declaration

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the Preface and specified in the text.

It is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text. I further state that no substantial part of my dissertation has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University of similar institution except as declared in the Preface and specified in the text.

This thesis does not exceed the regulation length of 80,000 words, including footnotes, references and appendices but excluding bibliographies.

Aiora Zabala

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Contents

Preface....3
Declaration....5
Acknowledgements....7
List of figures....15
List of tables....17
List of equations....18
Summary....19
Acronyms....20
Chapter 1. Introduction....23
1.1. Degradation in tropical forest frontiers: problems, monitoring, and causalities....25
1.2. Silvopasture as an alternative to address forest degradation....28
1.3. Encouraging pro-environmental behaviour through voluntary payments....30
1.4. Objectives and research approach....32

PART I: THEORETICAL BACKGROUND....41
Chapter 2. Conceptual framework: livelihood motivations and incentives in complex social-ecological systems....43
2.1. Conceptual framework....45
2.1.1. Describing a social-ecological system....45
2.1.2. Decisions....46
2.2. Poverty and payments for ecosystem services....50
2.2.1. Policy instruments to conciliate poverty and environment....50
2.2.2. Debates about paying for ecosystem services....52
2.3. Challenges in transposing theory about payments into practice....53
2.3.1. The influence of external payments on land use....54
2.3.2. Livelihood diversification and external payments....55
2.3.3. Heterogeneous motivations for pro-environmental behaviour....59
2.4. Decision-making theories and diffusion of innovative pro-environmental behaviour....61
2.4.1. 'Static' theories in psychology and economics....62
2.4.2. Behaviour and adoption as a sequential process....66

2.4.3. Diffusion theory and its applicability to pro-environmental behaviour................67
2.5. Overview of the chapter..68
Chapter 3. Factors influencing adoption of silvopasture and agroforestry: a systematic quantitative review of the literature..71
3.1. Overview of adoption literature..73
3.1.1. Topics: from agricultural innovations to silvopasture..76
3.1.2. Theories: economics, social psychology, and hybrid...76
3.1.3. Time and process: from static studies to panarchy...77
3.2. Data and inclusion criteria..78
3.3. Mapping independent variables...79
3.3.1. Economic, farm, and household characteristics...81
3.3.2. Institutions and social context..82
3.3.3. Knowledge and technology..82
3.3.4. Individual characteristics...83
3.3.5. The use of predictors in the adoption literature..84
3.4. Systematic quantitative analysis...86
3.4.1. Review studies...86
a. Silvopasture...88
b. Agroforestry...88
c. Sustainable agricultural innovations...90
d. Agricultural innovations..90
3.4.2. Regression studies: a vote-counting meta-analysis..91
a. Outcome variables...92
b. Significance of predictors..92
3.4.3. Empirical studies using qualitative and other quantitative methods.....................97
a. Silvopastoral projects..99
b. Motivations and typologies of perspectives beyond silvopasture...................100
3.5. Key messages...101
***Summary of Part I*..**104

PART II: CASE STUDY...107
Chapter 4. Pathway-dependent livelihoods and land-use mosaics in the Mexican tropical forest frontier, 1960-2010...109
4.1. Pre 1990s: tropical forest colonisation and food policies.................................111
4.1.1. Forest dynamics...111
4.1.2. Ejidos..112
4.1.3. Food production and livelihoods...113
4.1.4. Environmental impact of land-use change..114

4.1.5. Rampant deforestation and the frustrated attempt to return to food self-sufficiency 115
4.2. The 1990s and 2000s: liberalisation and the raise of cattle-farming........................ 116
4.2.1. National policy transformations........................ 116
4.2.2. Social-ecological trends........................ 118
4.3. The impact of macro-scale changes on the ground........................ 119
4.3.1. The protection of La Sepultura Biosphere Reserve and its effects........................ 120
4.3.2. The raise of cattle-farming........................ 123
4.4. Final words about recent transformations........................ 124
Chapter 5. Case study: silvopasture adoption in La Sepultura Biosphere Reserve, Chiapas (Mexico)........................ 127
5.1. Why the case of La Sepultura Biosphere Reserve........................ 129
5.2. The social-ecological system in the ejido of Los Ángeles........................ 131
5.2.1. Land regime and governance........................ 132
5.2.2. Livelihoods and cattle-farming........................ 133
5.2.3. Cattle-farming and land cover........................ 135
5.2.4. A complex setting of external payments........................ 137
5.3. Prospectives to transition towards a sustainable social-ecological system........................ 139
5.4. The pilot project for planting fodder trees........................ 142
5.4.1. Process........................ 144
5.4.2. Funding and monitoring........................ 145
5.5. Final remarks about the fodder tree planting project........................ 147
***Summary of Part II*........................** 149

PART III: DATA COLLECTION AND ANALYTICAL METHODS........................ 153
Chapter 6. Data collection and methods to understand the links between perspectives, livelihoods, and adoption........................ 155
6.1. Q methodology to understand heterogeneous perspectives........................ 158
6.1.1. Research design: statements and their structure........................ 160
6.1.2. Respondent selection and administration........................ 164
6.2. A novel method to collect livelihood data........................ 165
6.2.1. Design of the data collection method........................ 166
6.2.2. Additional questionnaire and secondary data on adoption........................ 169
6.2.3. Data entry and validation........................ 171
6.3. Computation of composite indicators........................ 171
6.3.1. Livelihood diversity........................ 171
a. Livelihood diversity in the literature........................ 172
b. Application of a diversity index to the case study........................ 173
6.3.2. Silvopasture adoption........................ 174

6.4. Cluster analysis....177

6.4.1. Cluster analysis to research livelihood strategies: a review....177

6.4.2. The method....179

6.4.3. Application of cluster analysis to distinguish livelihood strategies in the case study: analytical decisions....180

6.5. Econometric model of participation and adoption....182

6.6. Synthesis of the data collection and methods....184

Chapter 7. Enhancing the accuracy of Q methodology to uncover perspectives with the bootstrap....187

7.1. The standard analytical approach in Q method....189

7.1.1. Factor loadings of respondents....191

7.1.2. Statement scores....193

7.1.3. Distinguishing and consensus statements....195

7.2. Analytical considerations in standard Q....196

7.3. Bootstrapping Q....197

7.3.1. The alignment problem....200

7.3.2. Resampling the Q-sorts....202

7.3.3. Interpretation of the bootstrap results....202

7.4. An aggregate index of factor stability....205

7.5. Methodological discussion....208

***Summary of Part III*....**210

PART IV: RESULTS AND DISCUSSION....213

Chapter 8. Uncovering social-ecological perspectives towards silvopastoral innovation....215

8.1. Perspectives resulting from Q methodology analysis....216

8.2. Interpretation....222

8.2.1. The “self-sufficient pioneer”....223

8.2.2. The “environmentally-conscious follower”....223

8.2.3. The “payment-dependent conservative”....224

8.3. Discussion: incentives to trigger latent motivations for adopting silvopasture....225

8.4. Conclusion: heterogeneity of perspectives and incentive-based policies....229

Chapter 9. Understanding the relationship between livelihoods and silvopasture adoption....231

9.1. Livelihood strategies in the case study....234

9.1.1. Bivariate associations among livelihood, demographic, and wealth variables...234

9.1.2. Typifying livelihood strategies....238

a. Visual exploration....238

b. Cluster analysis......240
9.2. Reasons for livelihood preferences: perceived profitability and uncertainty......243
9.3. The influence of livelihoods on participation and adoption......245
9.3.1. Bivariate relations of livelihoods with participation and adoption......246
9.3.2. Selection model of adoption of silvopasture......249
9.4. Discussion: why do livelihoods affect participation and adoption?......254
9.5. Conclusion: heterogeneous livelihood strategies and silvopasture adoption......257
***Summary of Part IV*......**260

Chapter 10. Conclusions: improving the design of programmes to encourage sustainable land-use practices in the tropical forest frontier......263
10.1. Key findings of the thesis......265
10.1.1. Factors influencing the success of programmes to encourage adoption of sustainable land-use practices in the tropics......265
10.1.2. Motivations and hindrances for smallholders to adopt or discard silvopasture 267
10.1.3. Adaptation of incentives, particularly payments for ecosystem services, to fit motivations......268
10.2. Implications for policy design and implementation......270
10.2.1. Policy pre-assessment......271
10.2.2. Policy design adapted to heterogeneity: targeting pioneers and programme at stages......273
10.3. Research contributions of the thesis......276
10.4. Limitations, caveats, and future research......279
References......283
Appendix......313

List of figures

Figure 1.1: Deforestation patterns across the world (Source: Hansen et al., 2013)....26
Figure 1.2: The impact of livelihood decision-making on ecosystem dynamics........30
Figure 2.1: Conceptual framework of decision-making, livelihoods, and land use affecting ecosystem functions...48
Figure 2.2: The influence of heterogeneous goals on pro-environmental behaviour (based on the explanation by Steg et al., 2014).......................................60
Figure 2.3: Overview of the fields studying decision-making...................................62
Figure 2.4: Theories of decision-making of relevance for the adoption of sustainable innovation...63
Figure 2.5: Internal variables influencing behaviour...65
Figure 3.1: Scope of adoption studies, by topic, theoretical approach, and complexity of the process..75
Figure 3.2: Groups of predictors in adoption literature...80
Figure 3.3: Groups of predictors and average use in reviews and empirical studies..85
Figure 4.1: Location and zonification of La Sepultura Biosphere Reserve in Chiapas, Mexico...121
Figure 5.1: View of an ejido in La Sepultura Biosphere Reserve.............................136
Figure 6.1: Trends in publications using Q methodology in all fields (670 approx.) and in social-environmental studies (98)...159
Figure 6.2: Q methodology distribution and example response..............................161
Figure 6.3: Diagram of the peasant economy in La Sepultura Biosphere Reserve. .167
Figure 6.4: Distribution of tree heights for the two species planted.........................176
Figure 7.1: The standard analytical process in Q methodology...............................192
Figure 7.2: Algorithm for bootstrapping Q methodology data................................199
Figure 9.1: Correlations among the main livelihood, demographic, and wealth variables, and adoption...236
Figure 9.2: The stylised space of livelihood strategies..239

Figure 9.3: Description of livelihood clusters: boxplots of defining variables.........241
Figure 9.4: Activity profitability, measured as the ratio of benefits with land, effort, and investment..244
Figure A1: Diagram of the peasant economy as represented in the data collection board, and example of responded board...314
Figure A2: Livelihood questionnaire protocol..315
Figure A3: Livelihood questionnaire...316

List of tables

Table 1.1: Structure of the thesis....35
Table 3.1: Count and classification of articles included in the review on adoption…78
Table 3.2: Systematic quantitative analysis of reviews: predictors mentioned....87
Table 3.3: Meta-analysis of regression studies: predictors and significance....94
Table 3.4: Systematic quantitative analysis of qualitative and other quantitative methods studies: predictors mentioned....98
Table 5.1: Recommendations for a transition towards a sustainable social-ecological system in La Sepultura Biosphere Reserve....141
Table 5.2: Fodder tree planting project timeline (based on Trujillo-Vázquez, 2009) 143
Table 5.3: Budget from CONANP for the fodder tree planting project....145
Table 6.1: Q methodology statements....163
Table 6.2: Summary of primary and secondary data on livelihoods and adoption...170
Table 6.3: Variables included in the cluster analysis of livelihood strategies....181
Table 7.1: Theoretical classification of statements in Q according to interpretative power....204
Table 8.1: Q methodology results: factor characteristics....218
Table 8.2: Bootstrap estimates of statement factor scores....220
Table 8.3: Comparison of perspectives and key observed variables....221
Table 9.1: Descriptive statistics and differences between participants and non participants....247
Table 9.2: Comparison of clusters with participation and adoption....249
Table 9.3: Heckman selection model results (two-step): participation and adoption in the fodder tree planting project....252
Table 9.4: Robustness test: selection model with ordered probit....253
Table A1: Bootstrapped factor loadings and flagged Q-sorts....318
Table A2: Full Q methodology bootstrap results for statements....319

List of equations

Equation 6.1: Simpson diversity index.....172
Equation 6.2: Adoption index, in standardised metres of tree per plot.....176
Equation 6.3: Sample selection equation (probit model; participation).....183
Equation 6.4: Outcome equation (regression model; adoption).....183
Equation 7.1: Criteria for automatic pre-flagging of Q-sorts (Brown, 1980; Van Exel et al., 2011).....193
Equation 7.2: Reliability of a factor (Brown, 1980).....194
Equation 7.3: Standard error of factor scores (Brown, 1980).....194
Equation 7.4: Standard error of differences between factors (Brown, 1980).....195
Equation 7.5: Factor stability index for Q methodology.....205
Equation 7.6: Normalised factor stability index.....206
Equation 7.7: Maximum possible differences between two Q-sorts.....207

Summary

On the frontier of biodiversity-rich tropical forests, how land is used has an important role in buffering the primary ecosystem. Unsustainable small-scale cattle farming endangers soil quality and degrades the landscape. Silvopasture is a type of agroforestry that provides both ecological and livelihood benefits. A number of projects have been implemented across the tropics to encourage silvopasture adoption, with varying success. This dissertation questions the reasons for variable outcomes among participants within these projects: what motivates smallholders to adopt innovative land-use practices, and what form of incentives may help to overcome obstacles and catalyse adoption. This dissertation contributes to the ongoing debate on payments for ecosystem services, specifically about their suitability and effectiveness. To understand what influences decisions to adopt sustainable land-use practices, I review systematically and quantitatively the literature on adoption predictors, and I empirically analyse participation and short-term adoption in a pilot project for planting fodder trees in the border of a protected forest in Chiapas, Mexico, using primary and secondary data. I focus on subjective perspectives and livelihood strategies of actual and potential participants as explanatory variables, which have received unduly scarce attention in past studies. This lack of attention is partially caused by the difficulties of operationalising internal variables. I address this challenge by developing an analytical approach that increases the precision of the resulting perspectives in Q methodology. I cluster livelihood strategies and model adoption. This in-depth case-study suggests the type of incentives that are adequate to encourage adoption of sustainable land-use practices. Results indicate that payments may not be the best incentive for pioneer adopters, and that the adoption process is composed of separate individual steps, which are influenced distinctly by identifiable predictors, such as livelihood diversity. Uncovering this heterogeneity of motivations towards adoption provides useful knowledge for designing more effective external policy interventions.

Acronyms

CA.......................... Cluster analysis
CFA......................... Cattle-farming association of the *ejido* of Los Ángeles in Chiapas
CI............................ Confidence interval
CONABIO............. Mexican national commission for knowledge and use of biodiversity
CONAFOR............ Mexican national commission on forestry
CONANP............... Mexican national commission on protected areas
COPLADEM .... Mexican development planning committee, dependent on the finance secretariat
ES........................... Ecosystem services
FA........................... Factor analysis
IMR........................ Inverse Mills Ratio
NAFTA................... North American Free Trade Agreement
PCA........................ Principal components analysis
PEB........................ Pro-environmental behaviour
PES......................... Payments for ecosystem services
PESH...................... Mexican national programme for payments for hydrological services
PET........................ Mexican national programme for temporary employment, dependent on SEDESOL and often combined with conservation projects co-managed with SEMARNAT
PROARBOL.......... Programme for forest development and production, managed by CONAFOR

PROCAMPO...........Mexican national programme for direct support to farms, dependent on SAGARPA

PROCODES............Mexican national programme for conservation towards sustainable development, dependent on CONANP

PROCYMAF ....Programme for sustainable community forestry, managed by CONAFOR

PRODEFOR ....Programme for forest development, managed by CONAFOR

PRODERS ....Programme for regional sustainable development, managed by SEMARNAT

PROGAN................Mexican national programme to encourage cattle productivity, dependent on SAGARPA

REBISE...................La Sepultura Biosphere Reserve in Chiapas, Mexico.

SAGARPA..............Mexican department of agriculture, livestock, rural development, fisheries, and food

SE............................Standard error

SEDESOL...............Mexican national secretariat for social development

SEMARNAT...........Mexican secretariat of environment and natural resources

SES..........................Social-ecological system

SPS..........................Silvopastoral system

TPB.........................Theory of planned behaviour

TRA.........................Theory of reasoned action

Chapter 1. Introduction

Solutions towards sustainability exist and many of them are realistically compatible with current practices and capacities. Still, diffusion of environmentally-friendly behaviour among individuals involves decision processes of which our understanding is limited (Klöckner, 2013; Steg et al., 2014).

Intuitively and in the absence of major barriers, the reason why individuals find pro-environmental behaviour (PEB)[1] hard to take up is a lack of motivations (Pongiglione, 2014), broadly understood, and of suitable and convincing incentives to trigger them. But, what exactly is the absent motivational component? Why do incentives fail to bridge motives and deeds? While gargantuan effort is being made by researchers and institutions to attempt to find effective ways to encourage PEB, the transposition of theory into practice raises fundamental questions among policymakers, researchers, and programme developers alike (Fletcher and Breitling, 2012; Muradian et al., 2013).

Theoretically informed policies seem to fail too often to fit reality and to deliver (e.g. Clements, 2010; Friends of the Earth Europe, 2010; Sunderlin and Atmadja, 2009), yet the precise magnitude of failure remains unknown, arguably because rigorous impact evaluation is scarce (Ferraro, 2009). The consequences of failure are reflected in the continuation of environmental problems, in frustration of

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[1] Pro-environmental behaviour is defined as *"behavior that consciously seeks to minimize the negative impact of one's actions on the natural and built world"* (Kollmuss and Agyeman, 2002, p.240).

concerned agents, and, less tangibly but worryingly, in inefficient expenditure of limited policy budgets.

In this thesis I delve into the question of how to incentivise behaviour that mitigates the negative impact of smallholder farming pressure in the world's remaining tropical forests. These forests contain most biodiversity hotspots (Myers et al., 2000), and farming pressure is the single major immediate driver of tropical deforestation worldwide (Geist and Lambin, 2002; Lamb et al., 2005). The aim is to contribute to the literature and praxis of environmental policy instruments to encourage adoption of sustainable land-use practices, with a focus on debates about payments for ecosystem services (PES)[2] in low-income and biodiversity-rich contexts. To do so, I disentangle the motives that influence smallholders' adoption of silvopasture (an agroecological system which I define below), drawing from the literature and from an in-depth case analysis in the tropical forest frontier in Mexico. I empirically uncover motivations and hindrances for adoption,[3] and I suggest alternative forms of incentives to help overcome barriers and catalyse PEB.

Research towards sustainability can be compartmentalised into four stages, which structure the exposition in this chapter. The four stages are: identifying the *problem* (basic ecosystem science and monitoring), identifying *causalities* (threats and drivers of change), defining alternative *solutions* (based on technological innovation or traditional knowledge), and investigating hindrances and catalysts to *implement* these alternatives (Gardner, 2011). The goal of this thesis situates at the latter stage and is concerned with matching incentives with the motivation(s) of individuals for embracing sustainable practices.

In this introduction I provide background to this goal by connecting the fundamental concepts: forest and soil erosion and their causes (stages one and two, Section 1.1), the rationale behind silvopastoral systems (stage three, Section 1.2), and the challenges of encouraging PEB through PES in the frontier of degrading tropical forests (stage four, Section 1.3). On this foundation, Section 1.4 links the previous

[2] Also referred to as *markets*, *rewards*, or *compensation* for environmental or ecosystem services, each term having a slightly different definition (Wunder, 2006).

[3] Unless otherwise stated, adoption in this thesis refers to adoption of innovative land-use practices, and silvopasture more specifically.

issues to formulate the questions, sets out the approach adopted in this research, and advances this thesis' contribution to knowledge.

1.1. Degradation in tropical forest frontiers: problems, monitoring, and causalities

Reduced forest cover can induce degradation of soil and of the buffering capabilities of an ecosystem, consequently reducing beneficial ecological functions. Medium to high vegetation mitigates the effect of heavy rainfall on soil erosion because it attenuates the strength of rain drops and slows down surface-water (Toupet, 2010). It also helps sustaining soil mass and maintaining the physical properties of the topsoil, which are essential for adequate water infiltration. Both effects have an exponential relationship with plant cover (Durán Zuazo and Rodríguez Pleguezuelo, 2008).

The Himalayan dilemma describes a situation in which deforested steep slopes in mountainous areas exacerbate the impact of heavy seasonal rainfall and increase water run-off, causing soil erosion and compaction, and creating conditions for catastrophes such as landslides and floods, which would not be as intense had the forest cover not been removed (Ives and Messerly, 1989 in Richter, 2000). In addition, extensive cattle farming compacts soil under grazing (Valdivieso-Pérez et al., 2012), often changing its structural characteristics. Erosion and free grazing at forest margins increase the risk of degradation in primary forests adjacent to pastureland (Sanfiorenzo-Barnhard et al., 2009).

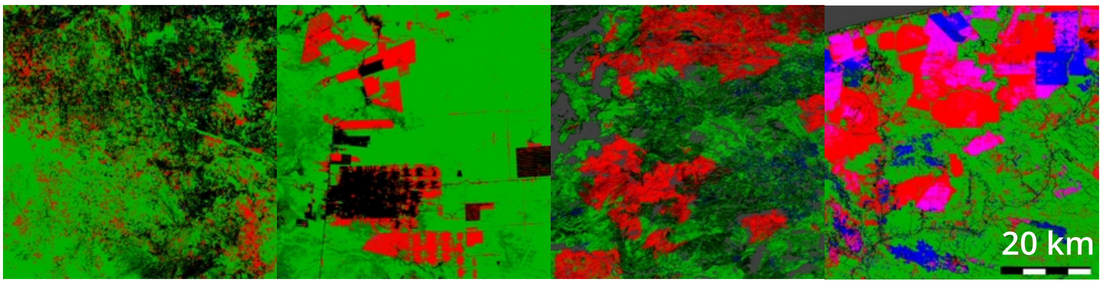
Land uses in the frontier of biodiversity-rich tropical forests have an important role in buffering the primary ecosystem, but also exhibit the symptoms of the tension between anthropisation processes and conservation needs. Population and agricultural pressure can lead to land-use change and degradation in forest margins. In turn, the loss of forest and of biodiversity can reduce the adaptability of social-ecological systems (SES), increase vulnerability to climate change and to other potential perturbations, and diminish opportunities to find alternative livelihoods. All in all, this affects ecosystem services, reduces resilience, and increases the likelihood of severe impacts from natural perturbations (Chomitz and Kumari, 1998; Napier, 1991; Richter, 2000), likely resulting in further landscape degradation.

To understand the causes of these problems and the potential solutions, one may look at the four main processes that affect forests. *Deforestation* is the conversion of forest to other uses such as farming land, formally defined as a reduction of 50% of the tree-cover (Hansen et al., 2013). *Degradation* refers to the partial elimination of forest biomass, or a reduction of 30% of the tree-cover percentage (Couturier et al., 2012). In contrast, *reforestation* and *afforestation* are the establishment of trees, the latter in an area where there the was no forest before. The drivers of each of these processes are numerous.

Causes of deforestation and degradation are many (Geist and Lambin, 2002), their importance varies geographically, and which factors have the greatest influence is argued to be context-dependent (Bray and Klepeis, 2005; Geist and Lambin, 2002). These causes include logging, agricultural expansion, high dependence on farming (Figueroa and Sanchez-Cordero, 2008), communication infrastructures, population density, and fire.

Deforestation can take many patterns as illustrated in Figure 1.1. Broadly, large-scale, visible deforestation can be distinguished from diffuse and gradual (Geist and Lambin, 2001). Large-scale deforestation occurs in patterns that are fairly detectable through remote sensing, normally driven by private companies, or large landowners (Figures *b-d*).

Figure 1.1: Deforestation patterns across the world (Source: Hansen et al., 2013)



a *b* *c* *d*

Legend: green, forest cover; red, deforested between 2000-13; blue, reforested; pink, deforested and reforested. The scale is equal in all images. From left to right: Oaxaca (Mexico), Bolivia, Quebec (Canada), and Malaysia. Each pattern of *deforestation can be attributed to a different activity: small (a) and large (b) scale clearing for farming, forest exploitation industry (c), and reconversion to tree plantation (d).*

Through diffuse, small-scale clearing (Figure *a*), people with low monetary income, who own, share, or occupy small plots of land, cut down trees in patches in order to make a living out of wood, crops, or cattle. It is argued that *"profit-maximizing behaviour is extremely low"* among individuals responsible for this pattern (Geist and Lambin, 2001, p.69). This diffuse pattern typically occurs in Central America and some parts of Africa (less so in the Amazon and Southeast Asia, where large-scale predominates), as observed in data from Hansen and colleagues (2013). Small-scale deforestation is further intensified by the reduction of sapling recruitment in forest margins due to animal browsing (Sanfiorenzo-Barnhard et al., 2009) or other soft but continuous perturbations. The effect of smallholder clearing is less detectable, but it has an important aggregated impact, is a critical driver of deforestation, and remains the current major land-use change trend in Latin America (Grau and Aide, 2008). Diffuse deforestation could theoretically arrive to the same result in the medium term as large extensions of suddenly deforested area, however it tends to be ignored in the identification of deforestation hotspots, which are the ones that capture public attention (e.g. Anderson, 2014; Vaughan, 2013).

In contrast, drivers of reforestation and afforestation have received much less attention in the literature. The strongest factors are passive or indirect, such as depopulation of rural areas due to out-migration and reduction of land used for agriculture due to intensification or to increased availability of off-farm employment. Driven by these factors, forests expand naturally leading to a forest transition (Barbier et al., 2010). The theory of forest transitions thus predicts increases in forest cover after high levels of development are achieved, *á la* environmental Kuznets curve (Dinda, 2004; Stern, 2004).

While the general applicability of the forest transition theory is widely discussed (Barbier et al., 2010; García-Barrios et al., 2009a; Sloan, 2008), less attention is paid in the forest policy literature to the impact of active forms of reforestation. Models of active reforestation assume that forest degradation can be avoided and repaired in the presence of—and thanks to—human population.[4] Active reforestation occurs through rehabilitation, community forest management, direct protection and regulations, or plantation programmes. These active efforts tend to be driven by a scarcity of forest products, specific state policies, changes brought by globalisation such as tourism and international private landholding, or intensification of agroforestry and other tree-based farming (Lambin and Meyfroidt, 2010). However there is a severe lack of systematic evaluation of reforestation programmes from which to draw lessons for further policies (Le et al., 2014), such as those within the frame of programmes for Reducing Emissions from Deforestation and Forest Degradation, particularly in terms of livelihood impacts (Caplow et al., 2011), which are considered critical for the permanence of agroforestry programmes (Le et al., 2012).

1.2. Silvopasture as an alternative to address forest degradation

In order to actively address forest loss and degradation, silvopastoral systems (SPS) are a type of agroforestry with great potential for sustainable SES based on cattle farming in forest margins. SPS involve the cultivation of fodder trees at low to medium density in pastureland. This system requires excluding livestock from accessing the plot for a period that ranges from nine months to a few years, until trees are strong enough to survive browsing.

SPS are an adequate compromise between conservation goals and livelihoods (Broom, 2013; Cubbage et al., 2012; Dagang and Nair, 2003; Murgueitio et al., 2011). Fodder trees have the double benefit of rehabilitating soil or avoiding further degradation, and of providing protein feed for cattle, especially during dry season when the lack of pasture is an important concern in the tropics. Therefore trees can help farmers adapt to changing environments, increase their resilience, and maintain

[4] For example, some authors find positive correlation between reforestation and the Human Development Index (Redo et al., 2012), and with institutional factors including land tenure security, monitoring, and management of social conflict (Nagendra, 2007).

cattle while conserving the landscape. SPS also have an important potential for carbon sequestration (Holderieath et al., 2012; Montagnini and Nair, 2004).

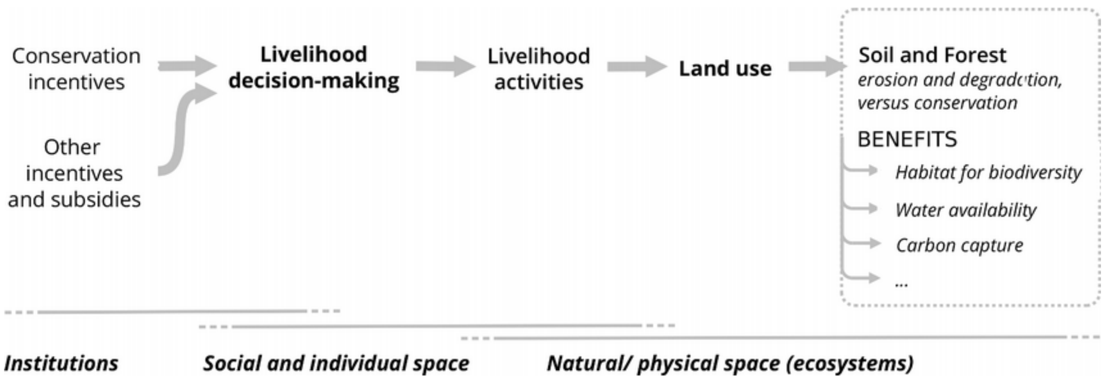
Silvopasture is the third most studied type of agroforestry in the agronomy literature (Montambault and Alavalapati, 2005), but much less so in the socio-economic literature about adoption processes (as seen in Chapter 3). There is little investigation on SPS uptake, although adoption is identified as a research priority (Dagang and Nair, 2003). In addition, the more extensive literature on agroforestry adoption is mostly focused on explicitly measurable farm, household, and personal characteristics, amenable to adoption probability analysis (Pattanayak et al., 2003), but rarely incorporates farmers' subjective perspectives or an integrated consideration of livelihood decisions. The relationship between cognitive variables and behaviour is abundantly stressed in social-psychology and decision-making theories, although its empirical application in the adoption of agroforestry and of sustainable agricultural practices is scarce (Lokhorst et al., 2011; McGinty et al., 2008). In sum, very few studies analyse the adoption of silvopasture beyond observable characteristics and these articles do so exclusively in a qualitative manner (e.g. Calle et al., 2009; Frey et al., 2012; Hayes, 2012).

Many decentralised projects for silvopasture adoption have recently been implemented in order to rehabilitate landscapes or avoid soil degradation in tropical forest margins while promoting sustainable livelihoods (e.g. RISEMP, carried out by regional research institutions in three Latin American countries, which is discussed in Section 3.4.3). Nonetheless, the diffusion of SPS is slower than envisaged from the economic and environmental performance assessments (Cubbage et al., 2012; Dagang and Nair, 2003; Gutiérrez et al., 2008).

1.3. Encouraging pro-environmental behaviour through voluntary payments

Decisions towards adopting sustainable land-use practices at the frontier of tropical forests are inherently related to decisions on livelihood strategies,[5] as illustrated in Figure 1.2. Rural households must confront trade-offs in the use of their closest natural environment as a source of livelihood, with their decisions directly impacting local natural resources and habitat conservation dynamics (Brock et al., 2009; Nainggolan et al., 2013). These microeconomic decisions are influenced by a number of factors, such as how members of the household perceive the costs and gains of alternative activities, constraints imposed by social norms and human capabilities, perception about alternative income sources, and concerns about medium and long-term impact on livelihoods (further on factors affecting decision-making in Chapters 2 and 3).

Figure 1.2: The impact of livelihood decision-making on ecosystem dynamics



This model of decision and land use connects the social, the institutional, and the ecological as intrinsic parts of the same system. Decisions to allocate effort and land across livelihood activities are reflected in land use. External policy instruments that provide subsidies and other incentives affect livelihood decisions and activities, which indirectly materialise in land-use mosaics with ecological implications for the soil and forests. This can reduce ecosystem resilience and diversity, and the system's

[5] A *livelihood strategy* is defined here as the combined allocation of assets to different activities which are intended to provide a means for living, and the subsequent portfolio of income sources.

capacity for providing wildlife habitat, services, and goods. Understanding what factors underlie livelihood decisions and influence preferences and behaviour is thus vital to design effective policies (Common and Stagl, 2005) that impact on ecosystems in the desired way, and to avoid incentives that can induce counterproductive side-effects.

Among policies to favour environmentally and socially sustainable systems, PES stand out in popularity among the range of policy instruments, from regulations to voluntary incentives (Swallow et al., 2009; Wunder, 2006). Because of their promising potential, PES have been implemented worldwide in varied contexts, at different scales, and promoted by diverse institutions (Fletcher and Breitling, 2012). Such projects flourished after the late 1990s, predominantly in developing countries, tropical areas, and for services provided by water, biodiversity, or carbon capture, often related to forests (Gómez-Baggethun et al., 2010). Much effort is paid to develop careful targeting of PES to maximise environmental additionality under constrained programme funds (Sierra and Russman, 2006; Wünscher and Engel, 2012).

However, heated discussions interrogate the suitability and the superiority of market-based instruments over other types of incentives, particularly when they are aimed at encouraging innovative activities (Kemp and Pontoglio, 2011) such as SPS. Most theoretical and empirical debates on PES, broadly understood (Muradian et al., 2010), refer to their long-term effectiveness and efficiency (Muradian et al., 2013; Sierra and Russman, 2006; Wunder, 2006), their potential interaction with social norms (Villamor and van Noordwijk, 2011), legitimacy (Corbera and Adger, 2004), effects such as crowding (in and out) intrinsic motivations for conservation (D'Adda, 2011; Narloch et al., 2012), to their intertwined efficiency and equity impacts (Corbera and Pascual, 2012; Pascual et al., 2010), and to the negative impacts of commodifying nature (Kosoy and Corbera, 2010). Thus their consequences and shortcomings ought to be sufficiently understood to know under which circumstances PES may be a preferable instrument to efficiently promote permanent environmental benefits.

Remarkably, major assumptions in PES refer to rationality and utility-maximising behaviour. It is assumed that agents act upon cost-benefit assessments of monetised, short-term utility values in which future flows have less weight. This portrait of human beings may be adequate to predict behaviour in contexts involving comparatively more financially productive innovation, self-interest driven decisions, and activities predominantly framed in monetary markets (Heyman and Ariely, 2004). However it may fall short when additional motivations or goals also have a heavy role in driving behaviour (Edwards-Jones, 2007; Steg et al., 2014), such as long-term benefits and livelihood security, social interest, maximising permanence, or limited self-interest.

In most cases of adoption of sustainable practices, the decision may not clearly lie in the realm of profit maximisation or in other realms of alternative motivations, but rather in a grey area where the weight of the former is balanced with further motives (Gsottbauer and van Den Bergh, 2011; Steg et al., 2014). Thus these decisions need to be framed in a more complex system in which simple short-term, static profit-maximising theories—upon which PES are thoroughly based—might fall short (Hayes, 2012).

1.4. Objectives and research approach

There is increasing impetus from international institutions to find ways to reconcile forests and livelihoods (Vira et al., 2015). The relevance of SPS can be expected to increase due to the continuing expansion of cattle-farming, particularly on forest frontiers in Latin America (Graesser et al., 2015), and the ability of SPS to attenuate subsequent environmental repercussions. Therefore it is surprising that little effort has been made to understand the process of SPS adoption at the individual level. Furthermore, the importance of behaviour beyond rationality and of livelihood strategies as a whole have been highlighted by many, but little attention is paid to them in empirical studies, even considering the broader literatures of adoption of agroforestry or of sustainable agricultural innovation (see Chapter 3). Still, I argue that these factors may potentially explain a considerable amount of the adoption process.

Despite that monetary incentives are intended to connect the goals of external policies and motivations for adoption, the efficacy of payments in practice remains largely untested (Wunder, 2006). For example, the effect of PES in the adoption of silvopasture was assessed by a number of authors across empirical studies in the largest international programme to encourage SPS to date (RISEMP funded by the World Bank and the Global Environment Facility, and reviewed in Section 3.4). Some studies were positive about the impact of payments, but a comparison of reports under the same umbrella project (Pagiola et al., 2007; Van Hecken and Bastiaensen, 2010) suggests that overall, findings on the use of payments alone were inconclusive. This illustrates a concerning shadow that underlies some of the literature arguing in favour of PES, which stems from the unclear effect that payments actually seem to have upon encouraging sustainable practices.

In this thesis I embrace the contention that payments could indeed have little effect on behaviour and I question why and under what circumstances this might be the case. I hypothesise that the obstacles for adoption may be diverse and dependent on a combination of attitudes[6] and social-economic variables, and that payments may have variable effects on individuals, depending on the motivations and interest of recipients, regardless of classical cost and benefit considerations (Heyman and Ariely, 2004; Steg et al., 2014). If this is the case, it may be suggested that adoption of pro-environmental practices may be better encouraged through an adapted combination of measures, which may include reduced costs and immediate benefits, but also information and other social or moral incentives (Calle et al., 2009), for example.

Therefore in order to help the elaboration of programmes that effectively encourage the uptake of sustainable land-use practices in rural areas, this thesis seeks to understand smallholder livelihood decision-making—what motivates them and what spurs this motivation. To guide this research, I question a) **what factors influence the success of programmes to encourage adoption of sustainable land-use practices in the tropics;** b) **what motivates and hinders smallholders' decision to adopt or discard innovative land-use practices;** and c) **how can incentives, particularly PES, be adapted to fit motivations and to help overcome obstacles and catalyse adoption**. The sustainable land-use practice in question is SPS, and the study looks at a particular case study in the Mexican tropical forest

[6] An *attitude* is defined as *"an individual's evaluation of the* [positive or negative character of a] *specific behavior"* (Lokhorst et al., 2011, p.340).

frontier, which fulfils the social-ecosystem dynamics described above (further justification is provided in Section 5.1).

Three main fields converge in this research: decision-making on livelihood strategies, payments and rewards for ecosystem services, and adoption of agroforestry innovation. This thesis attempts to connect the three topics by using analytical methods from social-environmental studies and ecological economics, and aims to contribute to the understanding of the uptake and diffusion of PEB by bringing together concepts from social-psychology and complex systems. In order to unravel important and underexplored motivations for adoption, I focus on perspectives and livelihood strategies on the basis further explained in Part I of the thesis.

Chapters are organised in four parts that correspond to theory, case study, methods, and results respectively (Table 1.1). Each part has a short introduction and a summary. In each chapter, the final section conveys its main messages.

Table 1.1: Structure of the thesis

	Chapter 1. Introduction	
PART I: THEORETICAL BACKGROUND	*Chapter 2.* Conceptual framework: livelihood motivations and incentives in complex social-ecological systems	*Chapter 3.* Factors influencing adoption of silvopasture and agroforestry: a systematic quantitative review of the literature
PART II: CASE STUDY	*Chapter 4.* Pathway-dependent livelihoods and land-use mosaics in the Mexican tropical forest frontier, 1960-2010	*Chapter 5.* Case study: silvopasture adoption in La Sepultura Biosphere Reserve, Chiapas (Mexico)
PART III: DATA COLLECTION AND ANALYTICAL METHODS	*Chapter 6.* Data collection and methods to understand the links between perspectives, livelihoods, and adoption	*Chapter 7.* Enhancing the accuracy of Q methodology to uncover perspectives with the bootstrap
PART IV: RESULTS AND DISCUSSION	*Chapter 8.* Uncovering social-ecological perspectives towards silvopastoral innovation	*Chapter 9.* Understanding the relationship between livelihoods and silvopasture adoption
	Chapter 10. Conclusions: improving the design of programmes to encourage sustainable land-use practices in the tropical forest frontier	

After this introduction, the two chapters in **Part I** I elaborate and discuss the theoretical background of the thesis. In **Chapter 2** the conceptual framework expands the model presented in Figure 1.2 and embeds decision-making within a broader social-ecological system. This framework integrates theory on complex SES, incentives and PES, and decision-making theories. Then it discusses important challenges of economic incentive-based policy in low-income contexts, and exposes why the theoretical underpinning of PES as a satisfactory and sufficient explanation of reality may be questioned. To seek a response, the thesis examines how this reality —decision-making—is explained in the theoretical literature across disciplines (Section 2.4) and in the empirical literature on adoption studies in **Chapter 3**. Chapter 3 thus focuses on a specific area of the conceptual framework (the factors influencing decisions to adopt sustainable land-use practices) and provides a systematic, quantitative and critical review of the literature. Due to the scarcity of SPS adoption studies, this review also includes literature on the adoption of agroforestry practices in general and of sustainable agricultural innovation, which makes it valuable to the broader adoption literature. This systematic analysis highlights differences in what the review, the quantitative, and the qualitative literatures discuss as the factors that most influence adoption, and reveals the lack of attention to three key variables: *perspectives* on topics related to SPS adoption, the range of *subsidies* available, and the level of livelihood *diversity* (the portfolio of activities that conform a livelihood; the meanings of these concepts are elaborated later on). These variables are central to the empirical analysis in Part IV, and instrumental for the assessment of the potential of alternative policy designs.

Part II provides background about the case study. **Chapter 4** is a historical reconstruction of the livelihood and land-use pathways that have shaped the region under study. It traces the current picture back to the recent history of the area during the last five decades, discussing the key micro and macro drivers of social and environmental change, in order to identify path dependencies and future trends, which are highlighted in the conceptual framework of Chapter 2 as key elements to understand current trends and decisions before intervening in a SES. The specifics of the social-ecological context under study are described in **Chapter 5**. A simple case of conservation practices (planting fodder trees) in a cattle-farming community is chosen to understand perspectives and behaviour. This case lies in the buffer area of La Sepultura Biosphere Reserve (REBISE, in its Spanish acronym, *Reserva de la Biosfera "La Sepultura"*) in Chiapas, Mexico, where extensive cattle-farming and intensive farming are an increasing threat to the conservation of soil, habitat, and ecosystem services in the mountainous forest frontier. In this location, I investigate the distinct motivations to participate in a pilot project that encouraged active reforestation in the form of planting and nurturing fodder trees.

Part III explains the methodology used in the empirical analysis. **Chapter 6** explains the innovative data collection method developed for this research, outlines the main methods for analysis, and explains the analytical choices. The goals of the empirical analysis are to identify the heterogeneity of perspectives *vis-à-vis* motivations and hindrances, and to analyse and model participation and short-term adoption, focusing on livelihoods and contextual subsidies (the set of subsidies that farmers are subject to receiving) as predictors. To do so, quantitative and qualitative methods are combined using primary and secondary data. Q methodology is used to understand perspectives, cluster analysis to unravel livelihood strategies, and econometric modelling to understand what influences adoption. I gather Q methodology data from 33 heads of household, and livelihood and socio-economic data and multiple-choice opinions about SPS adoption from 104 heads of household. While conducting the Q methodology study, I identify an important shortcoming of the standard analysis: it provides only rudimentary levels of confidence for its results. Therefore in **Chapter 7** I suggest a novel approach to provide comprehensive and precise levels of confidence in Q, using bootstrap. This approach is then used to analyse the Q data, which results are discussed in Part IV.

Part IV presents and discusses the empirical results on motivations for PEB. The results demonstrate the heterogeneity of perspectives and of livelihoods within a small and seemingly homogeneous community, and uncovers their relationship with adoption. This heterogeneity in perspectives towards SPS adds additional complexity to the SES. **Chapter 8** identifies varied perspectives among farmers regarding the adoption of SPS. It explores the internal motivations that drive participants' livelihood and conservation behaviour, by using the improved Q methodological approach, and suggests potential catalysts of the latent motivations that favour adoption. The analysis reveals three distinct types of individuals with regard to their social-ecological perspectives, so-called self-sufficient pioneers, environmentally-conscious followers, and payment-dependent conservatives. This typology is then related to key livelihood characteristics and to success in planting fodder trees. The role and distinctive motivations of pioneers in the adoption process are emphasised and discussed in detail, and this has direct implications for policy design in terms of targeting and adaptation of incentives. Results also suggest the need to better anticipate hurdles that individuals who are more likely to participate encounter once they start adopting. **Chapter 9** provides a thorough understanding of livelihood strategies and of how these affect SPS adoption. Types of livelihoods are identified and analysed in detail using a combination of bivariate and multivariate techniques, to find the likely limitations for adoption of individuals who practise each type of livelihood strategy. The participation in the project and the short term adoption of SPS are modelled. This statistical and econometric analysis shows that participation and adoption are separate decisions upon which predictors may influence in distinct ways. Such a sequential explanation is considered superior in the theoretical literature (as explained in Section 2.4) but rarely implemented in the empirical literature (as found through Chapter 3). Results show the link between diversification, predisposition to, and adoption of innovative practices, and are discussed in connection to diffusion theory.

In synthesis, this thesis has four main original contributions to knowledge, of theoretical, methodological, and empirical nature: a systematic, quantitative analysis of literature on factors influencing adoption of silvopasture and agroforestry (Chapter 3), a methodological innovation to improve results in Q (Chapter 7), an empirical analysis of perspectives that yields new insights into what motivates farmers to adopt sustainable and innovative practices (Chapter 8), and an empirical analysis of both participation and adoption that fully integrates livelihoods into the decision model, and that reveals how the two decisions are clearly distinct, and that (Chapter 9).

To end, **Chapter 10** revisits the findings and discusses the implications of the contributions of this thesis for research and for policy, by assessing the potential of alternative policy designs. It states the limitations of this research and outlines future research directions.

The outcomes of this research provide theoretical and empirical insights and specific policy recommendations for more effective targeting and efficient use of resources for environmental policies, and for improving the understanding about the potential of PES to encourage SPS adoption. The systematic literature review provides a pragmatic summary of the factors to be ensured or facilitated as a prerequisite for the implementation of adoption programmes. The research is novel in using diffusion of innovations to suggest that focusing on pioneers may be a cost-effective approach for policies encouraging PEB, and that PES may not necessarily be the best incentive to spur their motivation. Results also suggest that the obstacles to participation in a programme and to adoption of the activity encouraged may be different, to the extent that those that are more likely to participate may also be those more likely to have lower levels of adoption. This calls for particular attention in designing programme strategies to promote the adoption of sustainable land-use practices in the forest frontier. In sum, results lead to policy recommendations that integrate various forms of rewards and incentives, using payments or cash transfers only under certain circumstances, in order to achieve both environmental and social goals.

PART I: THEORETICAL BACKGROUND

To understand hindrances and motivations to adopt sustainable land-use practices, the next two chapters provide the foundation upon which the posterior empirical analysis is built. Chapter 2 outlines the conceptual framework that links external interventions with ecosystem dynamics, mediated by livelihood decisions. It then discusses the key concepts and their linkages in detail: instruments for external policies to reconcile livelihoods with conservation, debates and challenges of payments for ecosystem services, and selected theories explaining decision-making for pro-environmental behaviour. These linkages inspire the description of the case study in Part II. Chapter 3 reviews a specific but fundamental part of the conceptual framework, which is that of the factors influencing decisions. For that purpose, it reviews the literature on adoption of silvopastoral systems and of relevant works from the broader literature on adoption of agroforestry and of sustainable agricultural innovation. It identifies what factors are considered most influential, which ones have been more studied, and whether any potentially important factors have been overlooked. This review is instrumental for the empirical design explained in Part III.

Chapter 2. Conceptual framework: livelihood motivations and incentives in complex social-ecological systems

How do external interventions affect ecosystems? Understanding the mechanisms through which external incentives affect livelihood decisions may enable the design of effective schemes. This chapter develops an interdisciplinary conceptual framework for livelihood and land use decisions in low-income rural areas that are highly dependent on local ecosystems. It draws on concepts from the literatures on environmental psychology, pro-environmental behaviour (PEB), and social-ecological systems (SES). In essence, it is an extension of the model depicted in Figure 1.2 (p.26). In doing so, the chapter identifies major gaps in the understanding of the impact of payments on PEB, it provides a range of plausible theoretical explanations of decision-making and behaviour, and links both topics by discussing the variety of external instruments that can encourage this adoption.

Relevant frameworks to understand what drives and hinders PEB have been proposed by Kollmuss and Agyeman (2002) and Steg and Vleg (2009), from a psychological perspective. The framework presented here keeps similarities with previous literature and it advances it in three ways. It embeds the decision within a complex SES, in which behaviour affects land use, and therefore, also ecosystem dynamics. It is adapted to the context of low-income and land-used based livelihoods in biodiversity-rich contexts. Therefore the central tenet of this framework relates to decisions about livelihoods, which involve the allocation of resources across activities and their impact on land use.

Most theories explaining decisions and adoption in social psychology give little importance to the broader environmental context, and are concerned with the genesis of behaviour, rather than with the interaction of this behaviour with the natural world. In contrast, theories in economics tend to simplify adoption to linear decisions, homogeneous agents, and a single goal—maximising expected utility. However, decision-making for PEB should not be isolated from the context within which it occurs, especially if the final objective of a policy is to trigger a sustained effect on the environment. Also, the goals driving behaviour may be diverse, and the weight given to these goals might vary depending on the individual (Steg et al., 2014). The conceptual framework presented below brings together these perspectives.

Livelihood decisions are influenced by contextual factors such as the local social and environmental conditions, external policies,[7] macroeconomic changes, and recent historical trajectories. External policy interventions aim to affect this social-ecological decision process towards a direction that is socially and environmentally desirable: to maintain or increase the provision of a common good. These external interventions are integrated in this framework as one additional element affecting decision making, which aims to either spur favourable factors or minimise hindrances. Policy interventions embody in this framework in the form of incentives provided to influence decisions, and they can be either payments, training, material, or other types of rewards.

It is argued that interventions may be more effective if the factors influencing behaviour are understood (Steg and Vlek, 2009). Therefore, whether these interventions are successful in influencing the ultimate outcomes of this decision—land use and ecosystem dynamics—largely depends upon how well the key components of the framework presented here are understood.

The next section in this chapter describes and illustrates the framework in detail, it justifies the components on which this thesis focuses, exposes their connections, and explains where in the thesis they are dealt with. It also indicates

[7] *External programmes* are defined here as those designed and implemented by organisations exogenous to a local community.

which aspects are left aside and why. The next two sections expand on the component of policy interventions broadly. Section 2.2 focuses on theory and debates on payments for ecosystem services (PES). Section 2.3 discusses the challenges of using incentive-based external policies in low-income rural areas of high biodiversity, the influence of such incentives on land-use dynamics, and it elaborates on the challenges faced by these policies due to heterogeneous agents and to the complexities of livelihood diversification and contextual subsidies. Section 2.4 synthesises how decision-making processes and behaviour are explained across disciplines, mostly within economics and psychology. This synthesis helps to clarify what may occur in the black-box of the decision process.

2.1. Conceptual framework

In this section I briefly introduce the theoretical characteristics of the SES within which decisions for livelihoods are made (Section 2.1.1), and present the main components of the conceptual framework guiding this research, which revolve around the explanation of decision-making (Section 2.1.2). The framework points at crucial concepts and interactions that are necessary to respond to the main questions of this thesis and will be instrumental to the discussion of the potential role of incentives. I argue that these issues are essential to understand silvopasture adoption in the tropical forest frontier.

2.1.1. Describing a social-ecological system

The study of SES borrows concepts from systems thinking and complex systems, which portray reality as consisting of systems and subsystems, made of components and their interaction. Their complexity is argued to arise from features that characterise natural systems, such as multiple equilibria with tipping points, non-linearity, path dependence, and emergent behaviour. This understanding of a SES helps reshape the goal of an environmental policy intervention: promoting adaptive capacity for individuals to be able to pursue a number of potential and desirable goals, rather than to achieve a single scenario judged superior.

SES represent the social and the environmental as inextricably, reciprocally influencing components of the same system. The following concepts characterise the capacity of an SES to cope with uncertain and unpredictable perturbations (such as acute climatic events or price volatility in international markets): adaptability, robustness, resilience, and vulnerability (Young et al., 2006). Borrowed from ecology, the concept of resilience is defined as the capacity of a system to recover from disturbances (Gunderson et al., 2010), although often used across disciplines with a looser meaning.

Adaptability and resilience are desirable features of SES (Derissen et al., 2011) and form the basis of a broader framework based on resilience theory: *panarchy* (Gunderson and Holling, 2002). This framework describes how systems shift from one regime to another, in cyclical processes with four main stages and measured by entropy (Jost, 2006): conservation, release, reorganisation, and exploitation. Panarchy is arguably the most advanced framework to date to approach time-based explanations of complex processes (see further about the depiction of time theoretically in Section 2.4 and in empirical studies in Section 3.1).

Drawing on the previous concepts, *sustainagility* is the term coined for another desirable feature of SES: the capacity of a system to sustain itself by adapting to changing circumstances, while maintaining its core functions (Jackson et al., 2010; Verchot et al., 2007). This suggests that it is unrealistic to aim for a stable system with low variability or a resilient system that returns to the same state of equilibrium. Rather, the normative goal of a policy may be to encourage adaptability and achieve a system where the agents are able (*agile*) to adapt to changing conditions (Jackson et al., 2010) without compromising the core functions, thus becoming a complex adaptive system. Once the goal of a policy is decided, in order for the intervention to be most effective in changing behaviour, it is critical to understand what factors influence livelihood decisions.

2.1.2. Decisions

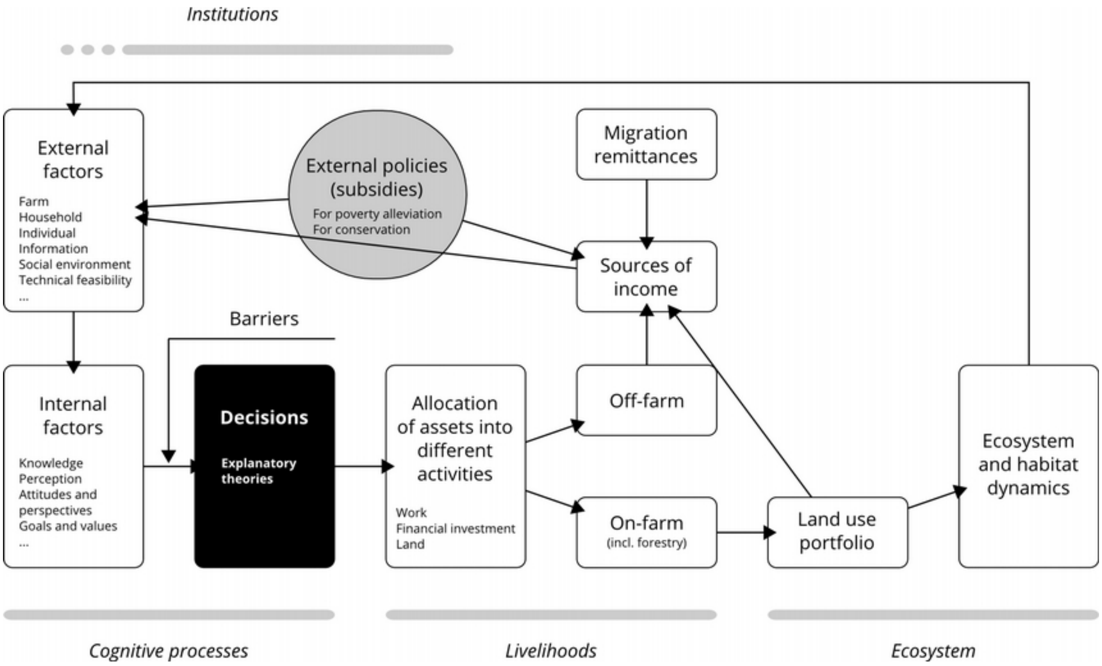
Decision processes are affected by both external and internal variables. External variables are those that occur outside of a person's mind, and can often be observed or measured objectively. Internal variables are primarily psychological constructs such as problem awareness, attitudes, moral norms, values, or identity processes (Osbaldiston and Schott, 2012) (this distinction is further developed in Chapter 3). According to Meijer (2014), the internal variables act as mediators of the external ones in determining adoption. Also, factors affecting decisions are filtered by a non-trivial number of barriers (Kollmuss and Agyeman, 2002), whose presence or absence may determine whether the decision and the consequent PEB finally occur.

Individuals decide how to invest their assets (land and financial capital) and labour available into alternative productive activities, and these decisions materialise in livelihood strategies. These strategies are characterised by levels of livelihood diversity, and ultimately by the proportion of income obtained from each source, such as migration remittances, local on and off-farm activities, or external programmes (more on livelihood diversity in Section 2.3.2). Factors such as resource scarcity, trade-offs of asset and labour allocation across activities, and expectations about returns affect these decisions and the resulting land-use portfolio, which in turn has direct effects on the ecosystem.

External policy enters (or parachutes into) the picture with two fundamental aims: to reduce barriers and to spur those factors that are in favour of adoption. External interventions, including PES, affect biodiversity habitats indirectly, mediated by livelihood decisions which result in land-use portfolios. These interventions are part of the institutional context. Choosing appropriate incentivising instruments is a crucial question in contemporary environmental policy studies (more on the variety of instruments in Section 2.2), although there is little study on the comparative impact of instruments (Osbaldiston and Schott, 2012).

Four main aspects are identified in the conceptual framework, which is illustrated in Figure 2.1: cognitive processes, livelihoods, institutions, and ecosystems. The cognitive processes include factors influencing decisions, which may be either internal or external, plus any barriers. The aspect of livelihoods consists on allocating assets and labour and carrying out activities. From the overall features of SES the essential characteristics of livelihoods are diversity, resilience, vulnerability, adaptability, and robustness (Ellis, 2000a; Scoones, 1998). The conceptual aspect of the ecosystem comprehends actual land uses derived from livelihood strategies and their ultimate influence upon ecosystem dynamics.

Figure 2.1: Conceptual framework of decision-making, livelihoods, and land use affecting ecosystem functions



This thesis concentrates on a few crucial components of the framework: external policies (including subsidies and market-based policy instruments) and, to understand decisions, on internal factors (individuals' attitudes or perspectives) and livelihood strategies. The topic of subsidies is discussed in Section 2.3. Individual attitudes (or perspectives) and livelihood strategies (holistically defined) have received little attention in previous research (as emerges in the review in Chapter 3) and have a large potential for developing more effective environmental policy, in terms of indicators of behaviour as to enable more precise targeting.

The methodology and results to understand perspectives are dealt with in detail in Chapters 7 and 8. According to this framework, livelihood diversity is reflective of a person's internal factors' influence on decisions (discussed in Section 2.3.2). The allocation of assets (financial investment, land) and effort across livelihood activities (such as agriculture and livestock) can be measured and aggregated into single indicators of livelihood diversity. Livelihood diversity is thus a key element to understand the process represented in this conceptual framework (its measure is discussed in Section 6.3, and this concept is central to Chapter 9).

A few elements are left out of the focus of this study. Social networks (an external factor) are highlighted as important predictors of the diffusion of innovation (Abrahamse and Steg, 2013; Lokhorst et al., 2011). However this thesis interrogates individual processes and makes use predominantly of psychological theories, whereas networks lie in the realm of collective processes, studied more appropriately using sociological techniques.

I also leave out the study of ecosystem dynamics. These dynamics are simplified in this thesis into the assumption that planting trees is favourable for the ecosystem. This is of course a monumental simplification which leaves aside relevant debates on whether plantations are forests, and on the actual impact of human-promoted species next to primary ecosystems. Studying this aspect would multiply the scope of the thesis, hence risking depth of analysis. This ecological understanding is also of secondary importance in this research, in which the main question interrogates what motivates people to act. Additionally, livelihood decisions coevolve with feedback from ecosystem dynamics. The empirical analysis in this thesis is focused on the linear process from factors influencing decision-making to the outcomes of these decisions, and analysing the influence of ecosystem feedbacks on decisions requires a longer term follow up. This evolutionary angle is partially provided by the narration of the social-environmental history.

Finally, migration remittances are considered to have a potentially important effect in household economies. However, this is highly context-dependent and, as will be seen in Part II, in the case study selected during the period studied, the importance of this source of revenue had diminished notably (see Chapter 4). Consequently, its study would give little additional information, and would require increasing remarkably the institutional scale to be studied.

In the remainder of this chapter I synthesise the links between rural livelihoods and payments, the challenges of external monetary incentives, and theories explaining decision-making and behaviour.

2.2. Poverty and payments for ecosystem services

Why are external interventions needed? Why are PES controversial? This section briefly introduces the rationale behind intervening for environmental governance in low-income and resource-rich areas, including a discussion of the instruments available, to continue with an outline of key interrogations on PES. This contextualises the main arguments surrounding the institutional side of the conceptual framework in Figure 2.1.

2.2.1. Policy instruments to conciliate poverty and environment

Rural livelihoods are often linked to poverty and as such, it is frequently assumed that their development brings the degradation of local environments. It is famously argued that the solution to environmental problems lies in achieving a threshold level of development, a tipping point beyond which capacities are sufficient to manage secondary priorities such as (for some) the environment. This Kuznets hypothesis might materialise in rural communities which are heavily influenced by urban economic, social, and cultural processes, where either pathways of human-nature relationships have a very short trajectory, or traditional lifestyles are losing strength against pressures from external policy and macroeconomic changes. Others argue that under some circumstances, people may actively and cooperatively protect their local ecosystem, which they consider a priority because it is the base of their livelihoods (Martinez-Alier, 2002); the so called *environmentalism of the poor*.

Where environment and development goals present a trade-off, in some cases either bottom-up cooperation and *environmentalism of the poor* emerges, or wealth increase leads to environmental impact reduction (Kuznets or decoupling). If neither of these occur, the third way to advance environmental governance is to intervene with policy instruments that promote innovative practices for sustainable rural livelihoods.

A number of instruments are available for this purpose. Osbaldiston and Schott (2012) provide a comprehensive inventory from a psychology perspective, based on a literature meta-analysis: making the practice more convenient, prompts (e.g. reminders), information (justifications and instructions), feedback about performance, rewards, social-psychological models, and others (including locus of control or message framing). *Rewards* include monetary incentives and penalties, gifts, or coupons. *Social-psychological processes* include social modelling (such as role models), making use of cognitive dissonance (persuasion or adaptation to previous behaviour), commitment (written or oral pledges), and goal setting. In the field of conserving biodiversity and ecosystem services, payments have risen in popularity worldwide (Clot et al., 2015), due to reasons that go beyond the scope of this thesis, such as their *win-win* appeal for poverty alleviation and their voluntariness.

The meta-analysis by Osbaldiston and Schott (2012) finds that combinations of two instruments (also called treatments or manipulations; from those listed above) are most effective, and that rewards are so if combined with goal setting. This combination of goal setting with payments relates to what the economic literature calls conditionality (Honey-Rosés et al., 2009), but Osbaldiston and Schott's interpretation of goals also comprehends compromises set by participants themselves. Nonetheless, the authors found that *"no one treatment* [instrument] *is highly effective across all the possible PEB"* (the PEB studied include energy and water conservation, recycling, etc.) and that *"practitioners need to match the treatment to the behavior"* (Osbaldiston and Schott, 2012, p.240). They thus suggest that each PEB should be matched by the type of instrument that most effectively encourages the specific PEB, and that combinations of instruments are more effective than single ones. This leads to interrogate whether PES may be most effective in the case of conservation of ecosystem services.[8]

From an economic perspective, incentives to encourage sustainable livelihoods may be developed in a gradient (Kolstad, 2011) that ranges from direct Pigouvian-like subsidies, or with the aim of developing markets upon negotiation, as envisioned by Coase. The theoretical underpinnings of PES derive from the latter approach, in which clear and enforceable assignment of property rights—either tacit or explicit—leads to the internalisation of externalities and, under certain conditions, to the optimal allocation of resources (Engel et al., 2008; Muradian et al., 2010).

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[8] Other relevant distinctions between instruments are made by Steg and Vlek (2009). One is that of *antecedent* (e.g. informational) and *consequence* strategies (e.g. feedback or rewards). Another is that of *informational* and *structural* strategies. PES would classify within consequence and structural instruments.

In order to inform schemes of economic incentives, since the late 1990s and with the rise of the paradigm of ecosystem services (ES), the study of PES and ES predominates in ecological economics over other topics (Gómez-Baggethun et al., 2010; Plumecocq, 2014), and valuation to obtain quantified values for natural capital occupies an important part of the research agenda. Among others, the application of PES is deemed promising for carbon capture in the frame of policies for the Reduction of Emissions from Deforestation and Degradation (Bond et al., 2009; Skutsch et al., 2011).

2.2.2. Debates about paying for ecosystem services

Debates on PES and market-based instruments involve perspectives that range widely (Sandbrook et al., 2013) and which are shaped by diverse languages of valuation emerging from distinct paradigms (Martinez-Alier, 2002; Rodríguez-Labajos and Martínez-Alier, 2013). An important fraction of the literature on ES takes the format of short articles or commentaries and responses to journals (e.g. Corbera and Pascual, 2012; McCauley, 2006; Toman, 1998). This arguably reflects the subjective and contested nature of the topic, and suggests that values and science are strongly intermingled in this debate. On one end, the radical environmentalist position condemns ES valuation as yet another aberration of the commodification of nature. On the other end, the radical neoclassical economist believes that the assignation of monetary value and property rights to formerly non-marketed goods and services is a panacea to address environmental problems, assumed to be textbook examples of externalities. Obviously, these are two caricatures of both sides of a spectrum: opinions lie across this range and include a range of individuals across fields who agree that PES could contribute towards the mitigation of environmental issues, but disagree on the magnitude of the potential contribution of markets (Farley and Costanza, 2010; Sandbrook et al., 2013).

The key topics in this debate are ethical concerns over valuing and commodifying nature (Kosoy and Corbera, 2010), equity and fairness (Pascual et al., 2014), effectiveness and efficiency (Ferraro and Simpson, 2002), and—as questioned in this thesis—the fitness of the theory behind PES as a satisfactory and sufficient representation of reality (Muradian et al., 2010). To advance in this discussion, it is important to gain understanding of the influence that payments and commodification have in human behaviour within social-ecological contexts (e. g. Bowles, 2008). The outcome of this controversy may be neither a full rejection nor a full embracing of PES as a policy tool, but rather their consideration as an instrument among others, to be informedly chosen under certain circumstances and conditions.

In practice, the compensation in many so-called PES schemes does not reach to cover the opportunity cost of non-sustainable alternatives, hence violating the postulates necessary to create a self-sustaining market (Gómez-Baggethun and Muradian, 2015). The praxis of PES reveals a blurry differentiation between markets and subsidies—where the government intervenes to address market failures. One might argue that an initial subsidy scheme is necessary to create a self-sustaining market.

While the debate evolves in the scientific arena, many practitioners increasingly consider payments as a cost-effective approach for conservation; these instruments have been and are going to be implemented worldwide (Clot et al., 2015), with outcomes that may be difficult to predict. Thus it is imperative to interrogate their impact on decisions for PEB. Such impact has been partially studied in the economic literature through experiments focused on specific mediators of impact (e.g. Clot et al., 2015), and also in the psychology literature in terms of comparing the effect of different types of instruments on PEB (Osbaldiston and Schott, 2012). However, no research is found that provides general insights about the impact of payments on PEB in the context of ecosystem services.

2.3. Challenges in transposing theory about payments into practice

To understand the effect of incentives on behaviour, this section examines the challenges derived from implementing external payment schemes (used in this thesis to refer to monetary instruments such as subsidies and market-based mechanisms) in real contexts. These challenges stem from the broader set of contextual subsidies (Section 2.3.1), from their interaction with livelihood diversification (Section 2.3.2), and from the heterogeneity of agents who are distinctly motivated (Section 2.3.3). The discussion in each section leads to the formulation of hypotheses.

2.3.1. The influence of external payments on land use

There are various plausible (and sometimes contrasting) views on the effect of external payments on land-use decisions, ecosystem conservation, and forest cover. This impact logically depends on the type of activity subsidised and on the support received for sustainable management. Uncoordinated programmes with different goals can generate counteracting stimulus leading to opposite directions (García-Barrios et al., 2009a). For instance, subsidies may be harmful if they promote unsustainable production.

The net forest-cover change in a particular location may be affected by the balance between subsidies that favour afforestation and those that discourage it. Incentives that promote off-farm income induce to a reduction in land use, therefore allowing secondary succession to take place (Isaac-Márquez et al., 2005). In contrast, incentives that promote on-farm activities may induce farmers to clear further land—sometimes incentivising deforestation—beyond their actual self-interest, capacity, or stewardship (Isaac-Márquez et al., 2005). Some argue that individuals who receive subsidies in general have more forest cover in their land. Access to abundant subsidies can reduce the need to farm, but also for out-migration (Sánchez-Hernández, 2010). The consequent duality of reduced land pressure but increased population can drive land cover in opposite directions.

The pre-existing context of external payments for different purposes may also shape livelihood decisions. This overall context can also affect the effectiveness of payments intended for conservation, for example, if development programmes with comparatively larger budgets dilute the relevance of conservation payments. PES can also be seen by recipients as yet another subsidy from external sources. However this interaction between programmes has been scarcely investigated (Kemp and Pontoglio, 2011).

External payments could plausibly bring three main negative consequences in attitudes at the interface between conservation and livelihoods, which are all related to shifts in market perception (Heyman and Ariely, 2004): the shift from a sense of stewardship to a sense of *right to degrade*, a diminished expectation of reliance on the land, and the emergence of free-rider or rent-seeking strategies. First, incentivising gain goals[9] has been suggested to diminish the weight of normative goals of individuals *vis-à-vis* PEB (Steg et al., 2014). In a transposition of this argument to land use, I suggest that if individuals get used to being paid, for example, for having cattle, for the land declared as agricultural, for hydrological services, or for planting trees, this plurality of external income sources can be seen as a driver to crowd-out the intrinsic stewardship over land (Fisher, 2012). This shift in expectations may involve diverting the sense of responsibility of stewards, towards a hypothetical extreme of individuals expecting to get paid in order to not degrade forests. Second, and somewhat related to eroding stewardship, it can be logically expected that abundant access to external payments can disincentivise conservation practices, by undermining two beliefs: that the local environment is an essential asset, and that future livelihood will directly rely on the health the soil. Third, access to abundant subsidies can encourage rent-seeking strategies (Kosoy and Corbera, 2010; Muradian et al., 2010) and arguably, external payment programmes often promote self-interested rather than cooperative behaviour (García-Barrios, 2012). When conditionality and monitoring are not rigorously enforced, an individual may participate in a payment programme in order to use it either to develop his or her own self-sustaining business and human capacity, or to obtain the extra income—indifferent to the purpose of the programme—hence acting in a rent-seeking or opportunistic manner. These consequences highlight further the need to question the fitness of instruments for the recipients of these policies.

2.3.2. Livelihood diversification and external payments

When considering whether to adopt pro-environmental practices, smallholders encounter trade-offs with various other livelihood activities in which to allocate their resources and effort. In a single community strategies may be found which are highly specialised in a single activity, or highly diversified. Livelihood diversification[10] is a

[9] *Gain* goals are defined as those that *"prompt people particularly to be sensitive to changes in their personal resources, such as money and status"*, in contrast to *hedonic* goals that refer to improving *"feelings in a particular situation"*, and *normative* goals which *"focus on the appropriateness of actions"* (Steg et al., 2014, p.104).

[10] Livelihood diversification is defined as *"the process by which rural families construct a diverse portfolio of activities and social support capabilities in order to survive and to improve their*

reliable strategy in low-income rural areas where families can be highly vulnerable due to the social dynamics of poverty and unequal empowerment in which they are embedded, rooted in long trajectories of multi-directional changes. In subsistence agriculture, diversity is a common feature, used traditionally to increase resilience and adaptability to environmental changes and to cope with perturbations. In recent decades, diversification also became a source of economic resilience for smallholders to cope with market price fluctuations. Diversity is deemed a positive strategy in sustainable rural livelihoods (Ellis, 1998), as it decreases vulnerability to both environmental and macroeconomic perturbations. It can also diminish degradation in tropical forest margins through reduced forest dependence (Illukpitiya and Yanagida, 2008).

The link between livelihood diversity and other characteristics such as wealth is unclear, and empirical evidence is contradictory (Fabusoro et al., 2010; Illukpitiya and Yanagida, 2008; Vedeld et al., 2007). Fabusoro et al. (2010) find that education and income are negatively related to diversity, whereas household size increases it. It is also argued that diverse strategies are more typical in strata with the lowest and highest wealth levels (Reardon, 2001, in Galván-Miyoshi et al., 2009). Poor households may opt for it due to the lack of capacity and resources to specialise, their precarious conditions, the need to increase resilience to economic crises, or as a result of coping behaviour (Perz, 2005; Vedeld et al., 2007). Wealthier families have opportunities to branch out, yet they also have more opportunities to specialise (Vedeld et al., 2007): they may choose specialisation if their focus is on increasing income, and diversification if they prefer livelihood security to immediate income, or to achieve higher positions in society (Galván-Miyoshi et al., 2009).

Drivers of livelihood diversification are numerous (Ellis, 2000a, 1998). Specialisation occurs when the marginal return of an activity increases as more assets and labour are invested, whereas households diversify when opportunities abound to perform tasks with decreasing marginal returns (Ellis, 2000a). The same author explains the major determinants of diversification: seasonality of labour returns, risk strategies (before an undesired event), alternatives offered by labour markets, uncertain access to credit to purchase inputs for agriculture, investments to increase

standards of living" (Ellis, 1998 p.1).

the future capacity to generate income (*asset strategies*), and coping behaviour (after an undesired event). An argument that is unseen in the literature, but plausible, is that the level of diversity correlates with attitude towards innovation: the higher the inclination to trying new practices, the more diverse the strategy. Whether policies should promote livelihood diversification is contested, though Ellis (2000a, 1998) argue in favour of it, or at least against policies that prevent it.

I suggest a new driver of diversification that could arise as an unexpected side-effect of external payment policies, which can be explained under the light of rent-seeking strategies. In the last decades, the introduction of a wide range of external programmes (e.g. in Mexico) adds a third dimension to the previous drivers for diversification: readiness for new external payments. The idea of payments encouraging rent seeking has been already suggested for PES (Kosoy and Corbera, 2010). The intuition is that if the chances of obtaining more external payments increase with a larger portfolio of activities, paradoxically but logically, a recent experience of abundance of payments can induce diversification.

According to this hypothesis, having access to manifold external payments encourages opportunistic multitasking strategies, because the latter become instrumental to attract payments. By having a varied portfolio of livelihood activities, farmers increase their chances to fulfil the requirements to participate in current and future programmes—which conditionality and monitoring are often relaxed. Diversity is thus an attractive strategy for its adaptability not just to changing biophysical and macroeconomic conditions, but also to changing settings of external payments.

Livelihood diversity could thus predict participation in a conservation programme. Diversified rent-seekers may partake just for the reward: signing up and undertaking the minimum required, while overlooking longer term commitments wherever they are not enforced. They may not try an activity for the associated expected benefits, but in order to demonstrate sufficient performance for the payment provider to give the reward.

This new motive would arguably alter the positive characteristic of livelihood diversity as a source of resilience. Due to multiple, uncoordinated payment programmes, diversification as an ecologically and economically coping strategy is distorted. Multitasking becomes a simulation driven by opportunism; a means that enables individuals to readily access income from any external policies that might arrive.

Such a hypothesis of the exposure to subsidies encouraging diversification has not been suggested in the rural livelihoods literature to the author's best knowledge. However, some basis can be found in the finance and entrepreneurial literature. Portfolio theory (Markowitz, 1991) argues that a portfolio may be optimised, under certain risk preferences, through diversification. In the case of livelihoods, the perceived risk is altered by the subsidy context; the individual perceives that there is less risk in increasing the number of productive activities than in staying specialised, because the perceived probability of new subsidies is higher. Opportunism is also linked to diversification driven by subsidies in contexts of crisis (Knight, 2013), according to which, participation in Europe-funded photovoltaic programmes is driven by the prospect of a stable income. The author argues that individuals negotiate their options based on a social-economic history shaped by uncertainty and instability, that has led them to think in short-term solutions and invest in policy-driven sources of income. If this is the reason to participate, then as soon as the funding programme terminates, then the PEB may be abandoned, and new livelihood opportunities may be sought.

One can thus distinguish between *genuine* or *stable* diversification (to increase adaptability to changing environments and markets) and *opportunistic* diversification (to increase the likelihood to benefit from programmes). Commitment to a conservation programme may range from intrinsic or self-motivation to passive or opportunistic interest for the potential payment (Brunel and García-Barrios, 2011). Some people may accept subsidies following an opportunistic attitude (as a non-recoverable fund, driven by short-term perspectives and looking for immediate benefits) and others as interested innovators (as aid to compensate for opportunity costs, with longer term perspectives, actual interest in the activity implemented, or intrinsic motivation).[11] Arguably, most people's motivations may range in a continuum between these two extremes.

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[11] The genuine motive can be interpreted as part of a broad definition of intrinsic motivations. The latter are conditional upon autonomy and freedom of choice, and diminish when there are external rewards that exercise excessive exogenous control (Fiske, 2001).

If rent-seeking driven behaviour is assumed, then the PEB will not sustain in the long term if the immediate benefits disappear. This reasoning implies that diversity does not necessarily entail more self-capacity, self-sufficiency, or sustainability. Rather, these characteristics depend on the main driver, which can also be a temporary adaptation to seek rent.

2.3.3. Heterogeneous motivations for pro-environmental behaviour

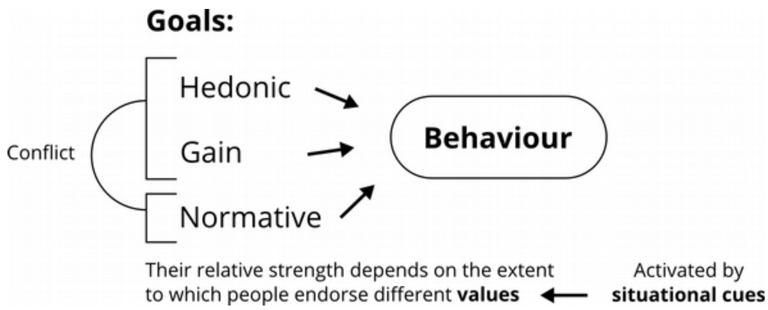
In addition to heterogeneity in observable livelihood strategies, individuals have diverse ways of construing the same topic, and even small, a priori homogeneous, microcosm such as a low-income rural community comprehends a variety of individual behaviours driven by different goals and values (Bathfield et al., 2013; Newton et al., 2012).

A number of theoretical approaches are applied to analyse decision-making in rural livelihoods (Bebbington, 2001; de Janvry et al., 1991). Following a neoclassical approach, it is often assumed that these decisions hinge upon cost-benefit analysis, leading to policy instruments such as developing markets (Kolstad, 2011). However, this model fails to include multiple factors influencing decision-making for PEB (Gsottbauer and van Den Bergh, 2011).

In a more complex conceptualisation of processes, the profit-maximising rationale is entangled with other behavioural motivations (Calle et al., 2009), such as variable time-horizons, risk aversion, social pressure, or other-regarding preferences. When including these other factors, the importance of direct costs and benefits can diminish to the extent that the resulting behaviour could be remarkably different to that theorised by a purely rational analysis (Steg and Vlek, 2009).

Not only multiple motivations, but also variability in the weight given to each motivation may generate heterogeneity (Steg et al., 2014). Due to heterogeneous preferences, goals and motivations, individuals can assess incentives differently and participate in external programmes attracted by diverse reasons. As a consequence, recipients can respond unexpectedly to the same types of incentives (D'Adda, 2011; Shogren and Taylor, 2008; Turaga et al., 2010). Steg and colleagues (2014) for example, suggest that three main goals determine PEB: hedonic, gain, and normative goals (Figure 2.2, see definition on page 55). Hedonic and gain goals tend to be in conflict with normative ones, and according to the authors, this is a main reason why environmental actions are not adopted. The influence of each goal depends on an individual's values, which are affected by cues from the context. This simple framework explains heterogeneous behaviour beyond purely contextual conditions. Additionally, the authors suggested that incentivising only hedonic and gain goals may just lead to a short-term behavioural change, and suggest that the three types of goals should be balanced to obtain a sustained change in behaviour (Steg et al., 2014).

Figure 2.2: The influence of heterogeneous goals on pro-environmental behaviour (based on the explanation by Steg et al., 2014)



This heterogeneity can be distinct enough to induce variable outcomes of external interventions for development and environment (Kline and Wichelns, 1998) and it can mitigate or distort the impact of conservation payments. For example, it is argued that monetary incentives may not outcompete other instruments in incentivising behavioural change of pioneers (Egmond et al., 2006). Thus, such heterogeneity should be acknowledged (Darnhofer et al., 2005) especially when designing policy instruments aimed at stimulating what motivates the potential early adopters of PEB (Baumgart-Getz et al., 2012; Egmond et al., 2006).

In contrast, few studies use information about heterogeneity of preferences for decision-making in order to explain the adoption of pro-environmental actions (Läpple and Kelley, 2013). Diffusion theory is used to qualitatively identify the distinct effect that alternative policy instruments—including regulatory, economic, informational, and infrastructural instruments—have on early and later adopters (Egmond et al., 2006) (these roles are explained in detail in Section 2.4.3). The policy implications of assuming heterogeneity can be fundamental, for example, deriving in the design of interventions that catalyse trust between early and later adopters, by enhancing social networks and interaction in order to encourage knowledge flows (Baumgart-Getz et al., 2012; Morris et al., 2000). The next section provides an overview of theories on decision and behaviour that suggest possible sources of this heterogeneity.

2.4. Decision-making theories and diffusion of innovative pro-environmental behaviour

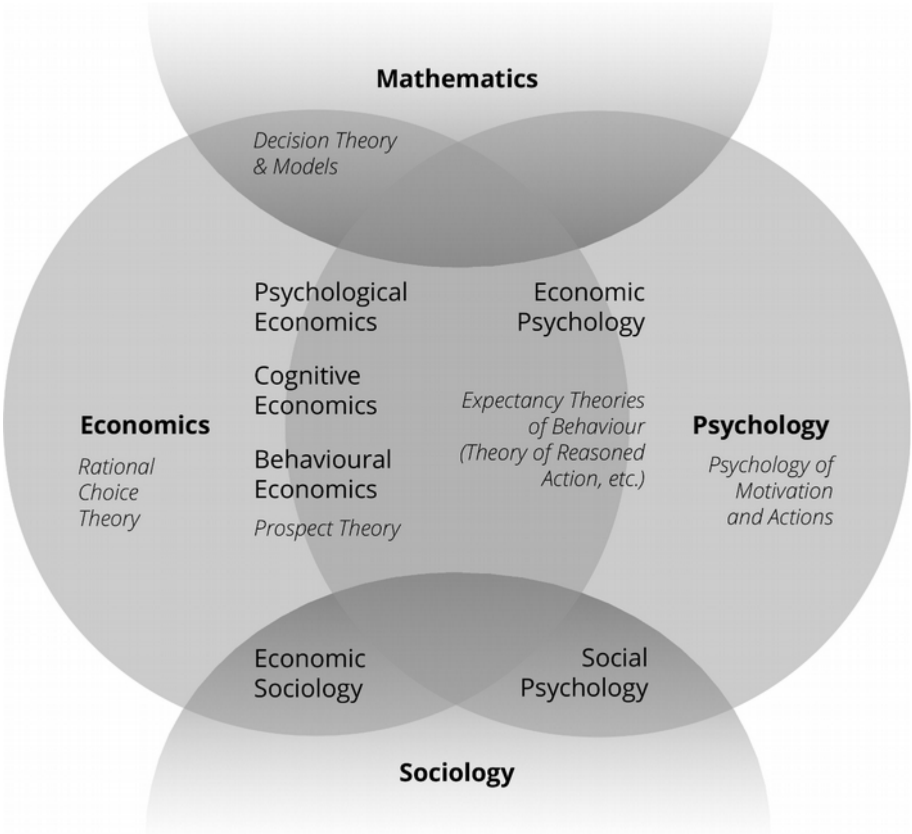
What are the underlying behavioural processes that PES are intended to influence? How can alternative models of PEB help increase the fitness of these instruments? This section synthesises the most important theories that explain and model decision-making, either as a static combination of individual variables into a single step, or as a process composed of differentiated phases. From these theories, those relevant to PEB are reviewed, in greater detail, in Turaga et al. (2010) and Gsottbauer and van Den Bergh (2011).

Most decision-making theories refer to individual choice processes and are discussed at the interface between economics and psychology, predominantly social psychology and behavioural economics (see an overview of the fields in Figure 2.3).[12] The former explains decisions and behaviour within a social space, influenced by other people. The latter seeks to explain deviations from rational behaviour. Psychological and cognitive economics expand beyond bounded rationality and bring explanations from other disciplines to the understanding of behaviour. The application of these theories to investigate adoption of conservation practices and environmentally-sound technologies in farming contexts is still incipient but with a

[12] Social psychology *"studies how individual people's thoughts, feelings, and behavior are influenced by other people"* (Allport 1954 in Fiske, 2001, p.14413). See Fiske (2001) for a succinct overview of the most prominent theories out of over 500 in the discipline. The distinction between economic psychology and psychological economics is discussed in Earl (2005). The same author describes cognitive economics as bringing "*together theories of learning, complex systems thinking and agent-based simulations*" (Earl, 2005 p.913), and sets a series of axiomatic foundations of psychological economics.

high potential.[13] Beyond these disciplines, decision-making is also discussed in sociology with the aim of understanding collective processes through aggregated individual decisions, and tools from mathematics are employed in modelling decisions.

Figure 2.3: Overview of the fields studying decision-making



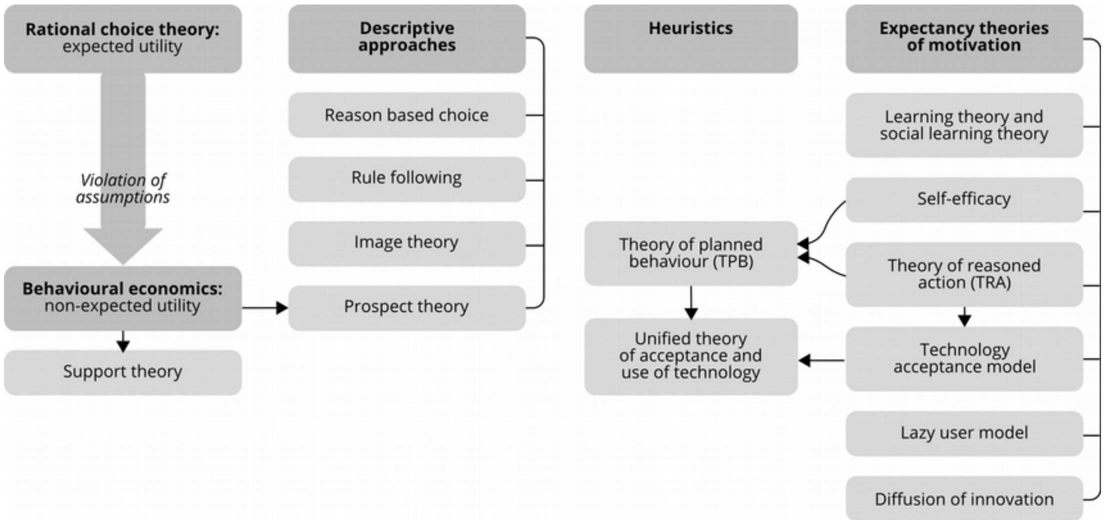
2.4.1. *'Static'* theories in psychology and economics

Most theories explain decisions as a single-step process, in which predictors are aggregated to produce an output (decision or behaviour). I refer to these as *static* theories (as opposed to process-based, which are explained in the next Section). In the rationality paradigm, it is assumed that the option with highest utility is chosen after an analysis of costs and benefits of alternatives. Objections to (or generalisations of) this dominant understanding and to expected utility theory are

[13] See Gsottbauer and van Den Bergh (2011) for an overview of the implications of bounded rationality for environmental policy.

embodied in a number of theoretical proposals that account for limited human cognitive abilities as explanations to observed non-rational behaviours (the most relevant theories are mapped in Figure 2.4).[14]

Figure 2.4: Theories of decision-making of relevance for the adoption of sustainable innovation



PEB may be importantly affected by deviations from rationality such as heuristics, self-identity concerns, hyperbolic discounting, seeking status, or habitual behaviour (Gsottbauer and van Den Bergh, 2011). Gintis (2000) discusses the implications that the postulates of the neoclassical behavioural model have for environmental policy, and suggests further factors to be considered. In addition to factors directly drawn from rational, self-interested individuals, the following are often found to predict behaviour among smallholders: emotions, social learning, social influence, and environmental perception, attitudes, and values. It is also argued that the economic costs associated to undertaking action determine which factor influences PEB most: a rational cost-benefit analysis may be determinant when the

14 Mellers (2001) and Pligt (2001) summarise violations of rationality, which include loss aversion (and endowment effect), framing effects (how the status quo is perceived), contextual effects, uneven effects of time on utilities (variations in discounting), inaccurate forecasts of future preferences (due to the fact that the overall value of an experience is predominantly the value at the end and at peak value times), and heuristics. A thorough overview of the theories proposed within non-expected utility theory is given by Starmer (2000).

investment in the action is high, but not so influential when costs are low (Diekmann & Preisendoerfer, 1992, in Kollmuss and Agyeman, 2002; Turaga et al., 2010).

Remarkably, (*cumulative*) *prospect theory* (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992) describes risk aversion, by which the linearity of the rational value function of losses and gains is distorted, following cognitive deviations from rationality, such as valuing options relative to wealth changes.

In psychology, a wide range of theories aim to structure the myriad behavioural drivers. Prominently, expectancy theories of motivation explain the reasons behind choices among alternatives (von Cranach and Tschan, 2001). Within these, two models of subjective expected utility are the most used in empirical studies: the *theory of reasoned action* (TRA) (Ajzen and Fishbein, 1974) and its later update, the *theory of planned behaviour* (TPB) (Ajzen, 1991).

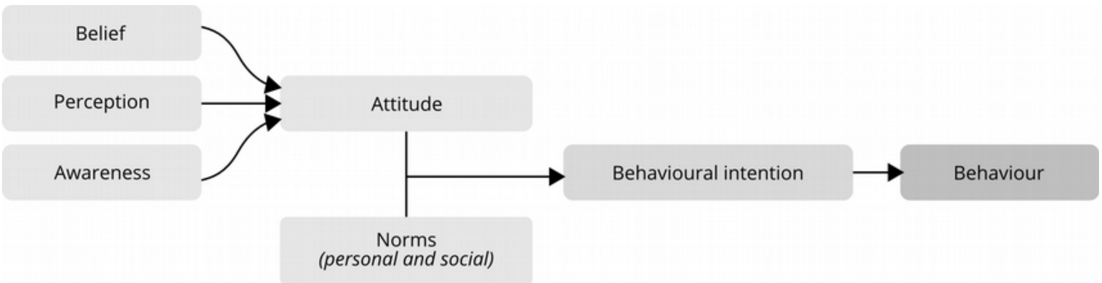
TRA explains behaviour as a function of attitudes, normative beliefs, and behavioural intention. Normative beliefs are also called subjective norms and, broadly understood, they include habits, moral obligations, and self-identity. Behavioural intention is measured as the strength of the belief and the evaluation of the desirability of the consequence (Burton, 2004).

To the variables used in TRA, TPB adds perceived behavioural control: how capable the individual feels of executing and controlling the outcome, which is mediated by both the difficulty and the attitude towards the practice. Perceived behavioural control can be measured by asking respondents about the limitations to participate in a programme (Lokhorst et al., 2011). The quantification of behavioural control is a measure of *self-efficacy*, which conveys the confidence in one's own capacity and the persistence in the face of challenging tasks (Bandura 1977, in Ajzen, 1991). TPB has been used to successfully explain farmer conservation practices under different incentives, finding that self-identity and personal norms are significant predictors only for non-subsidised practices (Lokhorst et al., 2011). Recent experimental data points at enhancing self-identity as a cost-effective approach to encourage PEB (van der Werff et al., 2013).

Focusing specifically on technology adoption models, the *technology acceptance model* adapts TRA and suggests that intention is also influenced by the perceived usefulness and ease-of-use of the innovation (Chuttur, 2009; Davis, 1989). The *unified theory of acceptance and use of technology* combines the previous theories to suggest that performance and effort expectancy, social influence, and facilitating conditions predict behavioural intention and posterior behaviour. These four predictors are mediated by individual characteristics: gender, age, experience, and voluntariness of use (Venkatesh et al., 2003). The *lazy user model* states that, among alternatives that satisfy a need, and individual will choose the one that requires least effort (Collan and Tetard, 2007). Other theories seek to explain more specifically why an individual adopts certain technologies, and some of the factors they consider may be useful to complement TPB. However, providing a wider background for each of them is out of the scope of this chapter.[15]

From these theories, I synthesise the main elements to be considered when applying them to PEB (Figure 2.5). This illustration fits in the black-box of decisions in Figure 2.1.

Figure 2.5: Internal variables influencing behaviour



The internal processes leading to decision-making and behaviour are based on beliefs, perception, awareness, which shape attitudes (or perspectives). This attitude is combined with existing norms, either personal or social norms, and with personal capacities and constraints, to result in a certain behavioural intention and posterior behaviour (as in TRA and models thereof). As explained later, these internal variables can be considered intermediaries between external—observable—variables

[15] The *norm-activation theory* suggests the conditions that are necessary but not sufficient to activate behaviour, namely awareness that the action has positive consequences, and sense of personal responsibility (Schwartz 1977, in Turaga et al., 2010). These factors could be reinterpreted in the frame of TPB as social norms (within normative beliefs and behavioural control), hence this theory is excluded from the core argument. The *value-belief norm theory* is based on the norm-activation theory, and is focused on the influence of values and moral norms (Stern 2000 in Lokhorst et al., 2011). Land pressure is the key factor in the *theory of induced innovation* (Scherr, 1995).

and behaviour. This simple model is consistent with TPB and with that of Bamberg and Möser (2007) who perform a meta-analysis of the factors influencing PEB.

2.4.2. Behaviour and adoption as a sequential process

The previous models explain a single decision. However, a complete adoption process usually comprises more than one decision and it may be more realistic to explain it as a sequential process of planning, testing, and implementation. Theories that purport such a sequential approach are much scarcer and have had little empirical application. For example, Satake et al. (2007) investigate the role of social learning in the field of forest management. They modelled how landowners decide whether or not to cut down trees to make profit, showing that stochastic decision and short-term memory conduced to synchronised deforestation, in which landowners deforest after seeing their neighbours doing so. They conclude that one-generation learning is not enough to manage forests sustainably, and that social transmission of accumulated knowledge is necessary to justify the sacrifice of short-term gains for long-term benefits.

Three theoretical models deserve special attention: innovation-decision process, decision-trees, and diffusion. The *innovation-decision process* depicts a detailed process focused on the individual. Instead of assuming a single step as in previous models, innovation is described as a process with the following stages: knowledge, persuasion, decision, adoption, and confirmation (Morris et al., 2000). The key implication is that the set of most influential predictors is different at each stage. The process of adoption can also be described as a decision tree in two main phases of discrete binary alternatives (Darnhofer et al., 2005). In the first, pre-attentive phase, all the alternatives that have any undesirable feature are eliminated, eliciting only those which hold certain characteristics. In the second phase, the few remaining alternatives are assessed using a number of criteria. Diffusion theory has been much more widely discussed and applied, thus it is explained separately.

2.4.3. Diffusion theory and its applicability to pro-environmental behaviour

The theory of diffusion of innovations (Rogers, 1962) has been abundantly used to explain adoption of agricultural innovation and eco-innovation in an ecological scale. This theory predicts that a few pioneers (also called innovators or visionaries) will initially adopt, followed by early adopters. Under certain conditions, a threshold in the number of adopters is reached so that early and late majority follow, and finally the fewer laggards adopt only once the practice is widespread. This suggests five different groups of adopters. The number of groups varies depending on the application, but the key message is the emergence of a small number of pioneers, who are followed by the majority.

Some effort has been made to understand the characteristics of those who initiate adoption of sustainable practices. For example, pioneers are identified (in the context of adoption of thermal systems) to be financially better off, have more technological knowledge, be intrinsically motivated (as opposed to motivated by social pressure), have a novelty attitude, and less concern over payoffs (Woersdorfer and Kaus, 2011).

Diffusion is fuelled by imitation through communication and social influence, and affected by the characteristics of the innovation, of the innovator (including socio-economic, personal characteristics, and position in social networks), and of the environment where the diffusion takes place (Wejnert, 2002). The rate of adoption depends on the perceived characteristics of the technology: namely, complexity, observability, trialability, compatibility, and relative advantage (Rogers, 2003, in Atwell and Schulte, 2009). The effect of social influence at the initial stage of spreading new practices has been demonstrated (in the field of online networks) to have a non-linear behaviour: there is a threshold in the number of users below which the practice vanishes, and above which the practice grows logarithmically (Onnela and Reed-Tsochas, 2010).

It is assumed that diffusion theory, defined as a logistic function of the number of adopters over time, stands true as long as some basic assumptions are also true, remarkably, that the innovation is comparatively profitable and that social networks function. The relative advantage of the practice has a critical role in this diffusion: the innovation needs to be better than current practices. If it is not more profitable, emphasising communication can lead to frustration of those involved (Pannell et al., 2006). In such a situation, I argue that the effectiveness of initial monetary incentives may be limited; the policymaker may opt to propose adaptations to improve current practices, rather than for the adoption of fully novel practices.

Whether diffusion theory applies in the context of conservation practices and PEB has been questioned, due to the assumption of comparative profitability (Miller et al., 2008; Morris and Potter, 1995; Padel, 2001). It is argued that the model is not appropriate because sustainable practices do not always fulfil this condition, at least strictly in monetary terms. Where the conservation practice or eco-innovation is not more profitable than business-as-usual under standard cost-benefit analysis, allegedly the process of diffusion based on social networks and neighbour imitation does not occur. More moderate criticisms suggest that these differences induce a slower rate of adoption (Padel, 2001).

I argue however, that diffusion is a logical and valid framework to explain the process of adoption of sustainable practices. The argument against the validity of diffusion for PEB implicitly assumes that the motive for action is merely seeking monetary profitability. In effect, as argued earlier in this chapter, PEB may include other motives. These behaviours have a more complex motivational setting; hence the assumption of comparative profitability ought to include broader valuation considerations (Greiner and Gregg, 2011). In order to fully estimate the comparative profitability, it is thus necessary to include values beyond the monetary one, which an individual also takes into account in their decision-making. This variety of considerations influencing adoption of pro-environmental innovation in the context of agroforestry is mapped next.

2.5. Overview of the chapter

This chapter develops the conceptual framework that gives cohesion to the rest of the thesis. This framework, illustrated in Figure 2.1, poses livelihood decisions as the key node that explains how external incentive-based policy interventions affect ecosystem dynamics in low-income rural contexts of high biodiversity. To reconcile livelihoods and ecosystems, external policies can use a number of voluntary instruments, among which PES stand out. However, PES are subject to heated debates around a number of questions. Notably, the suitability of PES as a sufficient explanation of reality is interrogated here. In order to address this question, I explore the challenges that payment programmes encounter when applied to reality, namely the influence of other contextual subsidies, interactions with livelihood diversification, and the heterogeneity of agents. Finally, I resort to alternative theories explaining decisions across disciplines and beyond expected utility theory: I summarise how internal factors may affect PEB and distinguish between one-step theories and sequential theories, to finally embrace diffusion theory as a satisfactory basis to explain adoption processes of PEB. The next chapter delves into the specific factors that influence the adoption of sustainable agricultural practices.

Chapter 3. Factors influencing adoption of silvopasture and agroforestry: a systematic quantitative review of the literature

A long standing research challenge has been to identify what factors affect adoption of agricultural innovations. These factors are the key input for the decision-making process described in the conceptual framework. Understanding them may be instrumental to find what hinders and what favours adoption in a given context, a knowledge that is critical to plan external policy interventions.

In this chapter I review and integrate current knowledge about predictors of the adoption of silvopasture and widely of sustainable agricultural innovations. The integration has the following goals: to inventory and explain the predictors used in the literature to understand silvopasture adoption (and more generally of agroforestry), to estimate which ones are more frequently used and have been suggested as most influential, and to assess whether there are any gaps in the coverage of likely and potentially important predictors. This systematic review leads to the identification of elements overlooked in previous research and identified in the conceptual framework as important: heterogeneity of agents, internal variables, and the level of diversity of livelihood strategies. As a secondary goal, I contrast the quantitative, qualitative, and review literatures in terms of the predominant factors discussed and analysed in each of the three bodies.

Descriptive enumerations of the findings of various studies on adoption of SPS have been published (Calle et al., 2013; Clavero and Suárez, 2006; Dagang and Nair, 2003), but these are limited in scope and coverage, and an overall integrative framework has not been provided. A systematic, comprehensive synthesis of these predictors—as presented here—may be useful for further research on uptake and for developing and adapting adoption programmes. Understanding what the literature suggests that affects adoption is instrumental to select an appropriate set of variables in empirical analysis (as explained in Part III). It also helps interpret empirical results (presented in Part IV) and discuss how the affecting factors can be influenced through policy (as presented in Chapter 10).

This evaluation of the literature is based on 70 publications that include reviews, meta-analyses, and quantitative and qualitative empirical studies. The chapter is structured as follows. Section 3.1 describes the extent of the literature by using three classificatory vectors: topics (from silvopasture to agricultural innovations), disciplinary origin (economics and psychology), and approach to temporal complexity (which different approaches are clarified in Section 2.4). Section 3.2 explains the criteria used to select the studies reviewed and provides statistics of what is included. For each study, I identify the predictors of adoption discussed, and I map and categorise them. These predictors are described in Section 3.3. Section 3.4 presents and discusses the results of the analysis of the literature clustered in three bodies of research: review articles, quantitative regression models, and qualitative and other quantitative studies (hereafter *mixed*). For each body, I quantify the frequency of categories of predictors across studies. Additionally, for the empirical studies using regression models I also perform a vote-counting meta-analysis which shows the frequency in which the coefficients of variables within each category of predictors are found significant.

This comprehensive and structured inventory advances in a number of ways the two most important reviews on adoption of silvopastoral systems (SPS) (Dagang and Nair, 2003) and of agroforestry (Pattanayak et al., 2003) thus far. Dagang and Nair's (2003) review is focused in Central America and it does not provide a structured summary of the variables affecting adoption of SPS. More than a decade after the important review of agroforestry adoption by Pattanayak and co-authors (2003), further evidence has been provided that contributes to a better understanding of agroforestry adoption processes. In particular, some recent empirical studies include behavioural theories and internal variables as well as process-based explanations that uncover the importance of predictors previously ignored, and also distinguish the role of predictors at different stages.

In order to explain agroforestry adoption, the literature focuses mostly on external farm, household, and personal characteristics (Pattanayak et al., 2003). *External* characteristics are those explicitly and objectively measurable, amenable to adoption probability analysis—equivalent to revealed variables. *Internal* variables are cognitive and to a great extent, subjective; they respond to an individual's mental processes, which can usually be measured only via statements from the respondent. The relationship between internal variables and behaviour is abundantly addressed in psychology models (see Section 2.4), although its empirical application in agroforestry adoption and conservation practices in farming is scarce (Blazy et al., 2011; Fischer and Vasseur, 2002; Lokhorst et al., 2011), plausibly due to the harder methodological challenges posed by internal variables (Blazy et al., 2011; Meijer et al., 2014). Accordingly, the following question guides this critical review: Do external factors influence adoption more than internal ones?

While the review is centred on SPS adoption, its findings are relevant and applicable to broader concepts of PEB, for two reasons. The literature on SPS adoption is scarce, therefore the review also includes key literature at the more general categories of agroforestry and sustainable agricultural innovation (see criteria to include studies, and the dependent variables identified). In addition, many of the explanatory mechanisms are sufficiently general and valid to explain adoption of PEB more broadly (see the discussion about independent variables).

3.1. Overview of adoption literature

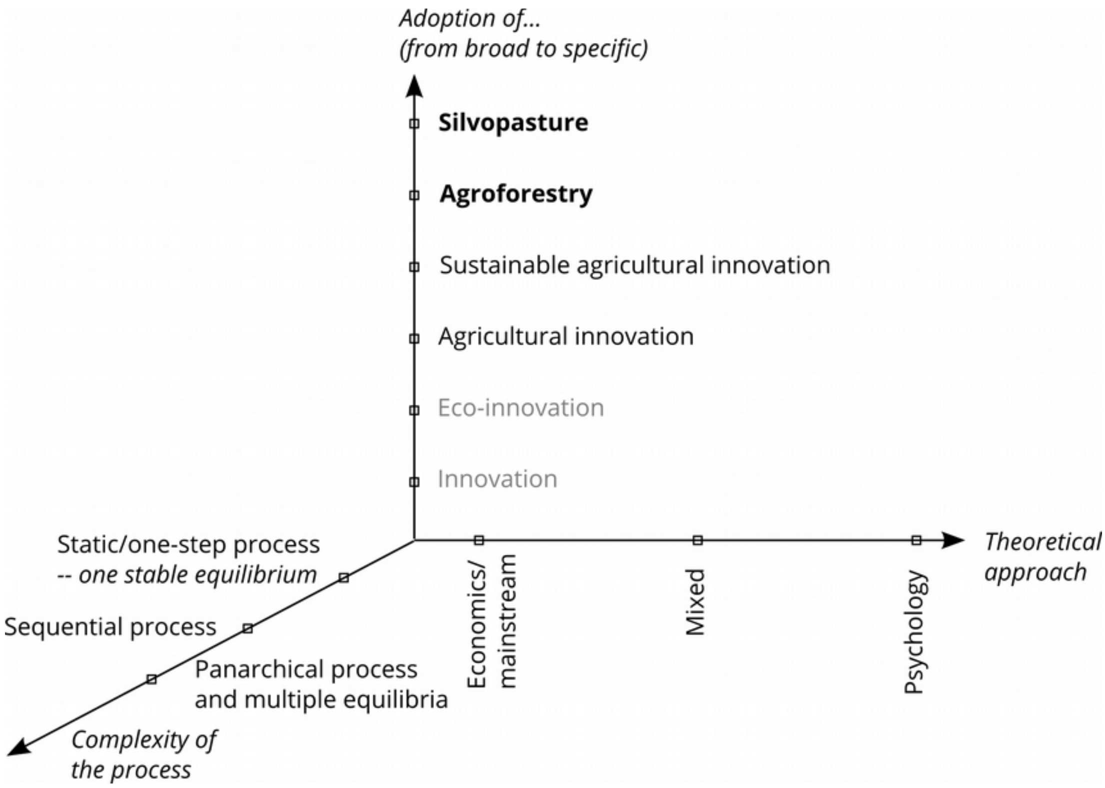
Literature on adoption of agricultural innovations blossomed during the 1980s (e.g. Feder and Umali, 1993; Feder et al., 1985) and that on agroforestry thrived in the 1990s, mostly focused in the tropics and in Asia and Latin America (Montambault and Alavalapati, 2005). The gap between abundant advances in science on agroforestry innovation and the lack of widespread adoption motivated much of this work (Mercer, 2004). A few key publications synthesise the reasons for the (non)adoption of innovation in agriculture and agroforestry (Fujisaka, 1994; Mercer, 2004; Pannell, 1999; Pannell et al., 2006; Pattanayak et al., 2003).

About SPS adoption, there is little investigation (Jera and Ajayi, 2008; Pagiola et al., 2008, 2007), albeit adoption is identified as a research priority (Dagang and Nair, 2003). Few qualitative articles analyse this process beyond external characteristics (Calle et al., 2009; Frey et al., 2012; Hayes, 2012).[16] Also, a number of studies on payments for ecosystem services (PES) use SPS as an example (Garbach et al., 2012; Hayes, 2012; Holguín et al., 2007; Montagnini and Finney, 2011; Pagiola et al., 2008, 2007; Schleyer and Plieninger, 2011; Van Hecken and Bastiaensen, 2010). There is no general consensus about the most relevant predictors due arguably to the variability of agroforestry practices and geographical locations, and also due to the measurement of the outcome, as discussed below.

I guide the navigation through this literature using three classification criteria that correspond to the axes in Figure 3.1. The review covers a wide range of adoption topics relevant to SPS (*y* axis), of theoretical (and methodological) approaches (*x*), and of approaches to depict temporal complexity (*z*).

[16] The process of adoption of silvopasture has been detailed in a role-game simulation (Etienne, 2003), though focusing on the physically observable actions, rather than on decision processes.

Figure 3.1: Scope of adoption studies, by topic, theoretical approach, and complexity of the process



Topics range from studies specifically on SPS to agricultural conservation and eco-innovation more generally, the latter gathering practices such as soil conservation, water management, or pollution and energy technologies. I group the literature into economic studies, predominantly psychological, and hybrid (mixed). This classification roughly indicates whether predictors are external (more frequent in economics), internal constructs of attitudes and perceptions (typical in social psychology and cognitive economics), or an integration of both, in which socio-economic predictors are mixed with internal ones. The temporal approach indicates whether predictors are considered to have a variable impact throughout time. The static view assumes that predictors affect the outcome in a single step and this impact does not change throughout the process of adoption and continuance (as explained in Section 2.4).

3.1.1. Topics: from agricultural innovations to silvopasture

Several studies model the adoption of agroforestry, few analyse silvopasture, and very few model the level of adoption beyond binomial measurements of adoption and non-adoption. Studies on adoption of agroforestry present a high variability in the definition of predictors, and sometimes also in the measurement of dependent variables. Variables that represent the same concept are often measured in different ways, for example, available labour operationalised as number of males in the household, available on-farm labour, or ratio of adults per child.

This body of evidence suffers from a lack of rigorous comparability and it would be unreliable to draw more quantitative and generalizable conclusions. Thus although abundant, the published peer-reviewed literature on agroforestry is unsuitable for more sophisticated meta-analysis due to the reasons already identified by Pattanayak et al. (2003) and which still remain applicable. In turn, the number of studies that regress adoption of silvopasture barely reaches a handful (e.g. Frey et al., 2012; Garbach et al., 2012; Jera and Ajayi, 2008).

3.1.2. Theories: economics, social psychology, and hybrid

Empirical econometric studies are more abundant than the rest, and predominantly focused on directly measurable variables of a socio-economic nature (Adesina and Chianu, 2002; Adesina et al., 2000; Amsalu and Degraaff, 2007; Bannister and Nair, 2003; Jera and Ajayi, 2008; Scherr, 1995), farm characteristics such as land (Mangabat et al., 2009; Marenya and Barrett, 2007; Mukadasi et al., 2007), or human capital (Casey, 2004).

A second body of literature draws primarily from theories in psychology, such as TPB or TRA (e.g. Läpple and van Rensburg, 2011; Lokhorst et al., 2011; McGinty et al., 2008; Wauters et al., 2010). These empirical studies construct predictors that approximate the abstract concepts defined for the behavioural equation (see Section 2.4.1).

More recent economic studies integrate behavioural constructs in their analysis (e.g. Edwards-Jones, 2007; El Tayeb Muneer, 2008; McGinty et al., 2008). These hybrid studies address the shortcomings of using only external variables and aim to increase explanatory power by including variables discussed in bounded rationality, such as the influence of risk, uncertainty, intertemporality on choice, and judgement problems (Gsottbauer and van Den Bergh, 2011). Scherr's (1995) is a pioneering work. It engages with the ideas that household livelihood strategies influence adoption of agroforestry, that these strategies may be driven by motivations other than profit maximising, and that heterogeneity induces highly variable responses.

While in studies on agricultural innovation the economic body is mainstream, in adoption of environmental conservation and eco-innovation there are several hybrid examples that include a behavioural approach. This is plausibly for environmental studies are a more recent area as well as of higher complexity.

3.1.3. Time and process: from static studies to panarchy

Most studies assume a static process, arguably due to its simplicity and empirical applicability using cross-sectional data. Advances beyond static explanations were summarised as early as 1985 from previous work on adoption of agricultural innovations (Feder et al., 1985), which included changing preferences after learning, but have not seen much application.

I refer to sequential explanations of adoption as *process-based* models (as opposed to *static* models). These models account for temporal heterogeneity, or *"changes in driving forces (...) through time"* (Veldkamp and Lambin, 2001, p.3), and conceive that the outcome variable can change from participation to adoption, and then to continuance. Likewise, the effect of predictors may be dynamic, influencing the outcome differently at each step. This approach includes theories explained in Section 2.4: innovation-decision and adoption-decision tree. Studies taking this approach often also acknowledge the heterogeneity of adopters and/or of spatial diffusion. Such multiple-step studies are less frequent because they require data that includes two or more measurements of a number of decisions or events (such as participation in a programme and success of implementation).

The cost and complexities of panel data also discourage empirical studies that represent social-ecological processes as panarchy cycles, where the dependent variable does not just evolve, but it is path-dependent, turns into discontinuance and returns as a new practice with some traits from the previous one. Such framework has been used only qualitatively in this sample of studies (Atwell and Schulte, 2009).

3.2. Data and inclusion criteria

The 70 peer-reviewed papers of this inventory are summarised in Table 3.1. Studies on adoption of SPS include all the papers found to date that aim at explaining predictors in developing countries. On adoption of agroforestry and (sustainable) agricultural innovations, I include all review papers. Previous reviews under-represent studies that integrate psychological or hybrid approaches, which use internal variables or process-based explanations. In order to represent the breadth of approaches, the thematic threshold is set at a broader category of literature on agricultural innovation, but leaves aside adoption of eco-innovation in general (e.g. Kemp and Pontoglio, 2011), unless they had a unique theoretical or sequential approach that was not found in closer topics (Arslan, 2011; Bosselmann, 2012; Woersdorfer and Kaus, 2011).

Table 3.1: Count and classification of articles included in the review on adoption

Theoretical approach	**SPS**	**Agrof.**	**SAI**	**AI**	**Other**	**TOTAL**	***a***
Review	3	4	4	4	—	15	—
Economic	6	9	2	1	1	19	*6*
Hybrid	4	7	11	—	1	23	*13*
Psychology	—	3	9	—	1	13	*8*
TOTAL	13	23	26	5	3	70	*27*

Key: 'SPS', silvopastoral systems; 'Agrof.', agroforestry systems; 'SAI', sustainable agricultural innovation; 'AI', agricultural innovation; 'Other': eco-innovation or land-use change. 'a': From the total, those articles included in the category of 'qualitative or other quantitative methods'.

Studies were searched in Scopus and Web of Science, using the keywords *adopt**, *agrofor** and *silvopast**, and relevant studies were selectedbased on the title and abstract.[17] A snowball sampling continued; further relevant articles were

[17] I also searched silvopasture adoption literature in Spanish (*silvopastoreo*) and in French (*sylvo-pastoralisme*). The former yields further relevant references of studies in Latin America, considered in this review. The latter indicates that agronomy SPS research published in French is

searched within the reference lists, until a saturation point was reached (Randolph, 2009). Grey literature is excluded. This is because a preliminary search of grey literature did not yield relevant case studies additional to those reported in peer-reviewed literature. Grey literature on SPS with references to adoption incentives tends to be either of a technical nature, or diffusion material for practitioners and adopters. Its assessment suggests that they do not encompass further insights beyond those found in peer-reviewed literature.

Studies are labelled as *regression* if they sufficiently report model variables, including coefficients and significance test values. Due to the nature of the dependent variables, the models are typically logistical, and rarely process-based models such as tobit or selection models.

Criteria for including empirical studies using other quantitative and qualitative methods are as follows. Studies on agroforestry adoption are included if they analyse motivations and attitudes for conservation behaviour, and/or use social-psychology theories. The same applies to studies on sustainable agricultural innovations (e.g. Ahnström et al., 2008). Among the agroforestry studies, three more are included because they refer to the role of livelihoods, which is a topic rarely discussed and of major concern for the questions of this thesis. The selection on agroforestry is thus aimed at diversity and to comprehend approaches that were not included in previous reviews, hence the emphasis on these topics may appear greater than it is in the average literature.

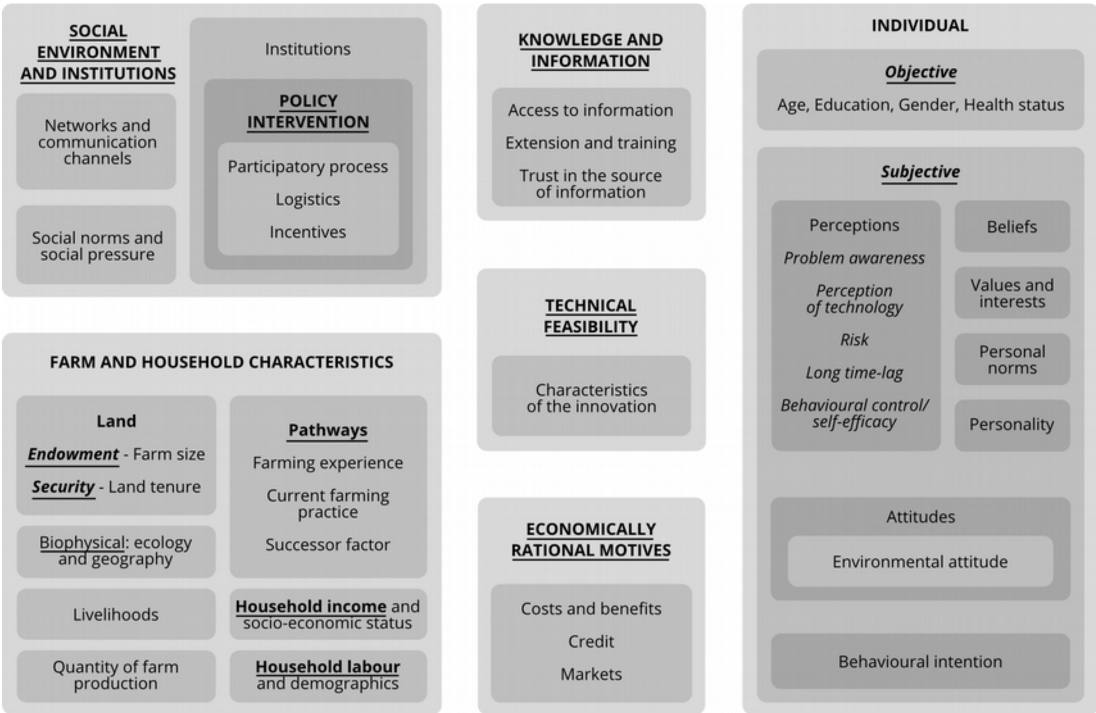
3.3. Mapping independent variables

I classified the predictors present across studies—over two hundred different variables—into thirteen broad groups. These are underlined in Figure 3.2: farm and household characteristics (biophysical factors, income, labour, land endowment, tenure security, and pathways), individual characteristics (objective and subjective), knowledge and information, economically rational motives, social environment,

abundant, but only one reference on adoption modelling was found (Rapey, 2000) which is strictly focused on household income and forestry productivity.

institutions and policy intervention, and technical feasibility.[18] The basis for these categories is a hybrid between previous frameworks, and the emergent structure from the studies, based on whether there are sufficient studies which mention these variables (hence the farm and household characteristics are separated into six groups, because most studies use these variables).[19]

Figure 3.2: Groups of predictors in adoption literature



This diagram focuses on one aspect of the conceptual framework depicted in Figure 2.1 (p.48): the external and internal factors that influence decision-making. The categories in Figure 3.2 are detailed in the next sections. This enumeration is not exhaustive and categories are not completely exclusive, however the description is sufficient to apprehend where to categorise further predictors.

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[18] In a few of these studies, some of the variables are very contextual dependent and unlikely to be extrapolated to other studies, therefore these variables are excluded from this review.

[19] The variables considered in each article were organised according to topic similarity, hence forming a mind-map of the variables considered in adoption studies, on which the Figure is based.

3.3.1. Economic, farm, and household characteristics

Variables related to **economic rationality** are divided into cost and benefits of the practice (profitability), access to credit, and macroeconomic context. The first includes cost, amortisation time, opportunity costs, and comparative advantage with respect to the activity which will be superseded. The last includes price and demand of products.

Farm characteristics, strictly speaking, are land, biophysical characteristics, and quantity of production (productivity). Variables related to land are **endowment**, and tenure **security** (status and rights). The **biophysical** variables usually considered are those mainly related to geography and ecology, and spatial variables. Geography and ecology include hectares under cultivation, land pressure and shortage, proportion of already-cleared land, topography, soil quality, and erosion intensity. Spatial variables include the area or scale of farm, access by road, distance of plot to home, and physical access to markets.

At the interface between farm and household characteristics, I include livelihood strategies and pathways related to the farm-cycle. **Livelihood strategies** include, from broad to specific, the level of household pluriactivity (total diversity), on-farm income dependence (or similar measures such as ratio of off-farm versus on-farm income), crop diversity, main occupation, main type of farming, major crops, importance of livestock as a source of income, or livestock herd size. **Farm pathways** include past experience, previous adoption history, current practices, current stage in the farm life-cycle, the future prospective of the farm in the business, and the *successor factor* (Wilson, 1997). The successor factor represents future expectations about the farm and whether heirs will continue farming, which perception may be mediated by the length of residency of the farmer; if the family has lived in the location for generations, the smallholder is likely to feel more attached to the land, hence have stronger long-term expectations. The farm's future in the business may thus be related to variables of other categories, namely the age of the head of the household, the existence and number of descendants, and the probability of them staying at the farm.

Household characteristics strictly speaking are divided into demographic variables and those related to the household economy. Demographic variables include the size of the family, mean age of the household, number of youth (usually those below 15, also referred to as students or dependent children), number of elderly (beyond 65), number of adults (15-64), ratio of adults to dependants (youth and elderly), and other measures of family size and available labour. **Household income variables** include wealth level or mean income, loans, savings, wealth in livestock or other assets, or remittances.

3.3.2. Institutions and social context

The review reveals only a few but important factors related to **institutions**, in the form of specific policies to promote adoption of the innovation (institutional transparency and design of incentives).[20] No reference to the external institutional context was found, such as to other subsidies that may be interfering or synergistic.

The **social context** and how the person interacts in social networks are considered very important to predict adoption in many studies, and it somewhat overlaps with the category of flow of knowledge. Social influence (norms and pressure) can be divided into what others do, what others think of the self, and the willingness to keep social cohesion. On *what others do*, variables include *'follow the leader'* attitude, presence of the technology among peers, rate of neighbour participation, or attitude of trusted friends and of influencers. *What others think of the self* include aim to keep public image, whether the person is accepted in the community, showing one's environmental commitment to others, being highly perceived by others, and satisfying landscape users. Social participation and compliance attitudes refer to community reinforcement through interpersonal communication, participation in collective action events, membership of farmers association, contacts outside the community, cosmopolitanism, or the existence and following of norms.

3.3.3. Knowledge and technology

Knowledge variables capture the amount, quality and flows of information that the individual has access to, which affect the acquisition and improvement of the necessary skills to command the technique. Information usually increases perceived

[20] This category also includes the presence of conflict, in the understanding that conflict degrades institutions.

feasibility and reduces perceived complexity of the technology, ultimately affecting self-efficacy (see definition in Section 2.4.1). Knowledge variables are divided into access to information and trust in the source of information. Access to information includes access to technical assistance; attendance at meetings, workshops, training courses, or events; contact with extension agents and research institutions; or frequency of consultation with advisers. Trust in the source of information includes the first impression about the conservation scheme and about the person presenting it, the competence of those administering the programme, and source(s) of information about the technology.

The **technical feasibility** of the technology depends on its complexity, whether it is readily available, and whether its use is known by or familiar to the recipient. Compatibility is also critical: the innovation being compatible with farmer's previous experience and knowledge, with farm priorities and practices, with current farming practices, and seed availability and suitability. These objective characteristics are filtered by flows of knowledge and by internal variables (explained below), to shape the perception of technology. Perception of the *benefits of the technology* include whether it is worth trialling, whether the innovation promotes a farmers' objectives, its comparative advantage versus current practices, whether it is functional and effective (it works), and perception of immediate profitability. The perception of a technology *over time* is critical for continuance: how it is perceived after adoption, and whether the practice is adaptable to specific or to changing farming conditions.

3.3.4. Individual characteristics

Objective **individual characteristics** are those conventionally considered in economic analyses of adoption: age, gender, marital status, education, and (exceptionally) health to understand capacity and labour availability. These are widely discussed in previous reviews (see Section 3.1).

Individual subjective variables comprise perceptions, attitudes, and motivations (the latter shaped by beliefs, values and interests, personal norms, and personality). *Perception* includes awareness of the seriousness of the problem, exposure to the problem, familiarity with conservation programmes, perception of the technology (as described above), perception about time-lags and time-discounting, risks of adoption (risk of changing prices, natural catastrophes, and uncertain benefits), previous experience with similar measures, or self-efficacy. *Beliefs*, *values*, and *personal norms* comprise ideas such as stewardship motivation, doing what is considered right, not feeling guilty about one's own choices, specific individual motivations such as health-related, cultural values, fulfilling various livelihood welfare objectives simultaneously, individual aspirations, plans for the future, and *psychic income* from the activity (Arslan, 2011) such as personal satisfaction, happiness, well-being, and emotional benefits arising from performing the activity. *Personality* and *attitudes* may be towards risk, environment, information gathering, management style, confidence in interpreting information, ability to try, and propensity to interact with policy instruments.

Psychological, cognitive, and motivational variables require using abstract constructs in psychological tests, or else the use of stated values. Both features are a source of uncontrolled variability that generates uncertainty in empirical research, thus many studies exclude them. However, their power to predict behaviour is potentially very high, thus it is imperative that these are not overlooked.

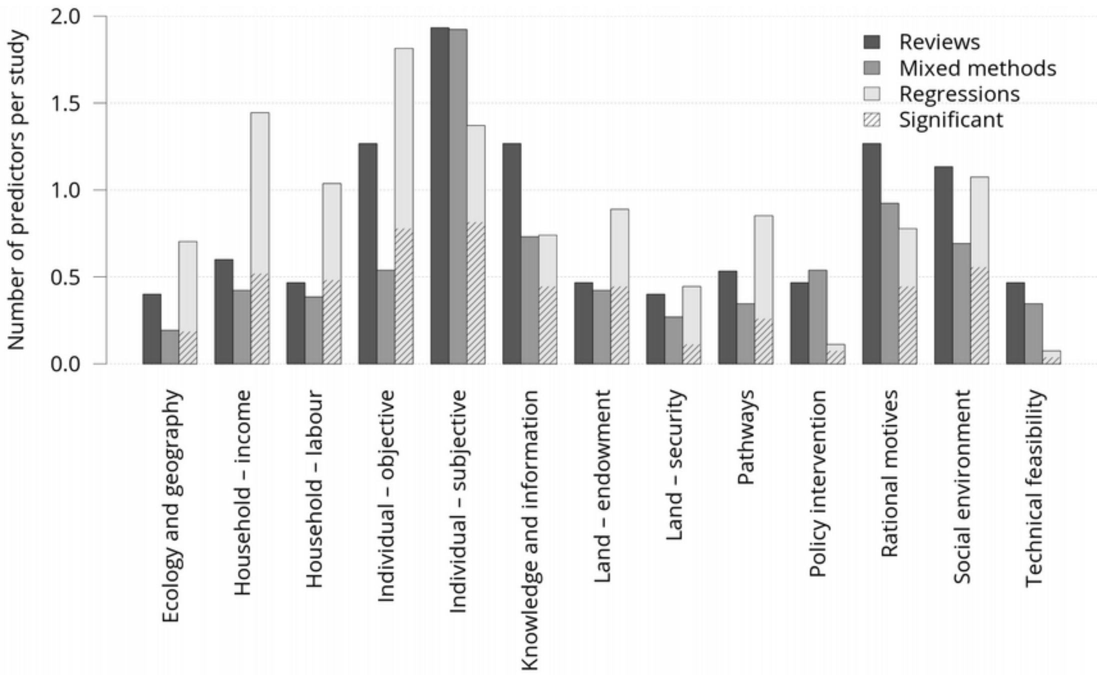
3.3.5. The use of predictors in the adoption literature

Many of these variables overlap, the boundaries are fuzzy, and empirical studies narrow the psychological variables down to very specific proxies. For example, the variables used in TPB and TRA need not be regarded as additional separate entities of equal explanatory value as to the conventional socio-economic ones, but rather as variables that are at a separate, more subjective layer. Considerations beyond profitability need not be in contradiction with rational theories of utility maximisation, and both approaches can be jointly understood if the concept of utility is broadly conceptualised (Turaga et al., 2010). For example, self-identity or self-image can be a form of utility. Likewise, increases in social welfare due to increases in environmental quality or in social cohesion also can satisfy the individual.

A number of variables may affect adoption indirectly by affecting other variables. Regardless of how much a quantitative model is simplified, acknowledging interactions and mediations between covariates is useful to devise what policy instruments can reduce a major barrier. For example, if the perception over the complexity of technology is likely to influence adoption, then a policy that facilitates access to and trust in technical assistance may be appropriate.

How variables that influence adoption are used in the literature is summarised in Figure 3.3. This overview indicates how many variables of each group are mentioned in each of the three bodies of literature on average. Higher frequency does not imply most relevance for adoption, but it is an indirect indicator: how much a variable has been discussed hints how much it may affect the outcome. A downside of frequency as an indicator is that the consideration of predictors is influenced by previous literature, therefore somewhat endogenous.

Figure 3.3: Groups of predictors and average use in reviews and empirical studies



In bars indicating the frequency of predictors in regressions (light grey), the area with diagonal stripes shows the fraction in which the coefficients of these predictors were found significant (e.g. half of the regressions that included land endowment found its coefficient significant).

Differences between the regression literature and the rest are probably due to the complexities of operationalising certain types of variables. Regressions more often include biophysical, income, labour, and objective individual variables (which are significant in a little less than half of the times), whereas qualitative and other quantitative studies (mixed methods) highlight individual subjective variables. Empirical studies do not reflect the frequency in which reviews highlight the importance of knowledge and information and, surprisingly, also rational motives. Likewise, qualitative studies include less about social environment, and regression studies largely omit technical feasibility and policy intervention. However, all these variables that are less often included in regressions are found to be significant in over half the times in which they are incorporated.

The next section unfolds the main messages drawn from each of these bodies of literature, regarding what influences adoption. The 13 categories above are expanded into 35 groups (top rows in Tables 3.2, 3.3, and 3.4). The following exposition about each body of literature is subdivided into subsections according to the most relevant messages found inductively.

3.4. Systematic quantitative analysis

3.4.1. Review studies

Three papers give a general overview of adoption of SPS (Calle et al., 2013; Clavero and Suárez, 2006; Dagang and Nair, 2003), none of which are strictly reviews. I complement these with four reviews on agroforestry, and eight on (sustainable) agricultural innovations (shown in Table 3.2). The most comprehensive in terms of predictors discussed are Clavero & Suárez (2006), Pannell et al. (2006), Edwards-Jones (2007), and Pattanayak et al. (2003).[21]

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[21] In some reviews, motives that are not included in the table were also mentioned, but were considered unimportant by the papers. The table only includes factors that papers discuss as relevant.

Table 3.2: Systematic quantitative analysis of reviews: predictors mentioned

Topic and authors	Year	Education	Age	Gender	Income and socio-economic status	Livelihoods	Farm size	Quantity of farm production	Land tenure	Farming experience	Current farming practice	Successor factor	Characteristics of the innovation	Labour	Credit	Costs and benefits	Long time-lag	Markets	Biophysical factors	Risk	Information	Extension and training	Networks and communication channels	Subjective norms and social pressure	Institutions	Policy interventions	Participatory process	Knowledge	Perceptions	Attitudes	Beliefs	Problem awareness	Environmental attitude	Personality	Values and interests	Perceived behavioural control/ self-efficacy
Silvopasture																																				
Dagang & Nair	2003												■				■			■																
Clavero & Suárez	2006										■		■	■	■		■		■		■	■	■					■			■					
Calle et al.	2013																				■	■	■			■	■									
Agroforestry																																				
Pattanayak et al.	2003	■	■	■	■		■	■	■	■				■	■	■		■	■			■	■													
Mercer	2004				■								■			■							■													
Montambault	2005			■					■					■		■		■				■		■	■										■	
Meijer	2014	■			■											■			■		■	■	■		■			■	■	■						
Sustainable agricultural innovation																																				
Fujisaka	1994								■				∗	■		■				■		■		■	■	■						■				
Padel	2001	■	■	■	■		■			■						■							■	■						■		■	■			
Lee	2005	■	■						■	■				■		■			■	■	∗									■		■				
Pannell et al	2006	■	■		■	■	■					■	∗			∗	■			■	∗	∗	■	■		■			∗	■	■			■		■
Agricultural innovation																																				
Feder et al.	1985	■					■		■					■	■	■				■																
Feder & Umali	1993	■					■		■				■		■	■		■	∗	■	■	■				■										
Edwards-Jones	2007	■	■	■		■	■				■	■	■	■	■							■	■		■	■				■				■		
Baumgart-Getz et al.	2012	■	■		∗		■			■						■			■	■	∗	∗	∗			■						■	■			
TOTAL		9	6	4	6	2	7	1	6	4	2	2	7	7	5	11	3	3	6	7	7	10	9	4	4	6	1	2	2	5	2	4	2	2	1	1

Categories shown in the synthesis of empirical studies, but not in this table of reviews are: types of agents, health, behavioural intention. ■ *considered important;* ∗ *considered critical.*

Cost and benefits of the practice are almost universally discussed as the key criteria that induce adoption. The next most recurrent variables are associated with information and knowledge, namely extension and training, education, and networks and communication channels. After this, frequent variables refer to the availability of assets (income, farm size, land tenure) and labour, to direct hurdles for adoption (characteristics of the innovation, biophysical factors, risk), and to the specific policy intervention to promote adoption.

Variables related to internal processes (clustered towards the right of the table) are rarely mentioned in SPS and agroforestry, with the exception of Clavero &

Suárez (2006) and Meijer (2014). Internal variables are found when expanding the scope from silvopasture to broader literature on sustainable agricultural innovation, and to most recent reviews on agricultural innovation (Baumgart-Getz et al., 2012; Edwards-Jones, 2007).

a. Silvopasture

Dagang & Nair (2003) assume rational farmers, and highlight the time elapse needed for establishment as the main barrier for adoption. However their goal is not to provide an overview of predicting variables, but to highlight the need for further research to understand the reasons for adoption, including farmer needs, objectives, and perceived gains.

Calle et al. (2013) discuss the key elements of a successful extension of SPS in Colombia, reportedly a country with relatively large adoption: participatory approaches, capacity building, incentives, successful demonstrative projects, and innovation networks. Incentives include monetary,[22] technical, and social recognition in the form of innovation awards. Pilot projects demonstrated that farmers respond to payment incentives (although these are not sufficient) and that technical and knowledge barriers are as important as financial barriers.

b. Agroforestry

Studies on agroforestry and its adoption are mapped by Montambault & Alavalapati (2005), who draw attention to the emphasis of the literature on studying benefits over other social and economic topics. The two key publications reviewing agroforestry adoption (Mercer, 2004; Pattanayak et al., 2003) are based on earlier work on agricultural innovation, prominently Feder et al. (1985) and Feder and Umali (1993). Pattanayak et al. (2003) group factors in five broad categories:

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[22] A wide range of instruments are mentioned: provision of material, allocating land property rights, exonerate from land taxes, provision of technical assistance, provision of funding for projects of interest for the farmer in exchange of his environmental activities, ease of credit, provision of payments to overcome the initial investment and linked to credits, payments for ecosystem services, non-monetary compensation (social acknowledgement, investment in local welfare), environmental certification, and certificate of origin (Calle et al., 2012; Murgueitio, 2009), In Calle et al. (2012), these instruments are described in detail, together with their socio-economic context, the scale of application, constraints, and risks.

preferences, resource endowments, market incentives, biophysical factors, and risk and uncertainty, and this classification is reused in Mercer (2004). According to them, the relative profitability and the adaptability of the technology are critical for adoption. Both articles assume profit maximising behaviour and therefore adopt a predominantly socio-economic approach, although acknowledge the importance that other disciplines give to social rewards, communication, and norm compatibility.

Mercer (2004) frames adoption within diffusion theory and suggests that tenure security has a more important role in agroforestry than in other agricultural innovations due to the time lag required for tree establishment. He concludes that *"early adopters will tend to be those relatively better-off households who have more risk capital available [...] (land, labor, capital, experience, education) to allow investments in uncertain and unproven technologies"* (Mercer, 2004, p.325). Padel (2001) also identified innovators (in the context of organic farming) as having more education and social contacts beyond the community, less farming experience, and giving less importance to profit maximisation.

Several of the weaknesses identified by both Feder (1993) and Pattanayak and co-authors (2003) still remain in recent ex-post studies of adoption: namely, lack of full and complete reporting of results of empirical studies, the limited linkage between findings and theory, and the infrequent use of statistical models beyond binary choices that account for probability and extent of adoption. Mercer (2004) also highlights the little emphasis of studies on the role of risk and uncertainty, and argues that the main gap in adoption studies is the lack of focus on the temporality of adoption: who adopts first, at what rate, and at what intensity.

Meijer (2014) suggests a conceptual framework for the adoption of agroforestry and agricultural innovations which integrates the extrinsic (or external) and intrinsic (or internal) factors in an orderly manner. Instead of considering all predictors horizontally towards the decision, her model suggests that the intrinsic (knowledge, perceptions, and attitudes) is an intermediate layer between the extrinsic and the decision. She argues that previous empirical studies have predominantly focused on extrinsic factors, but that the intrinsic ones are key.

c. Sustainable agricultural innovations

An early study based on expert assessment of a number of projects enumerated the key elements for the adoption of sustainable agricultural innovations (Fujisaka, 1994). These elements relate mostly to the characteristics of the innovation: the practice must work under the farmer's conditions, it should work better than current practices and not generate negative side effects, and the initial costs need not be too high. In addition, the policymaker should identify carefully the problem and target farmers that fulfil three conditions: those who are facing the problem, are aware of it, and for whom it is critical.[23]

Lee (2005) indicates that the most influential variables are biophysical and informational, which shape problem awareness, attitudes, and expectations, thus bringing the internal component fully into the picture. Information includes the flow of knowledge, communication and collaboration channels, and learning attitudes.

Pannell et al. (2006) emphasise the relative advantage of the practice, and whether the landholder perceives that the innovation will enhance the achievement of their personal (economic, social, and environmental) goals. Adoption is viewed as a social process in which learning happens at various stages, and where risk is addressed by seeking information or reinforcement from the social or familiar environment. They also suggest that the aim of extension programmes should be to raise awareness and change perceptions instead of changing the goals and motivations of landholders, and to accelerate the process rather than to increase absolute adoption. The same first-author in an earlier paper posed four main conditions for adoption, namely *"awareness of the innovation, perception that it is feasible to trial, (...) is worth trialling, and (...) promotes the farmer's objectives*" (Pannell, 1999, p.393).

d. Agricultural innovations

Feder and colleagues (1985) in their seminal review of adoption of agricultural innovations focus on farm size, risk and uncertainty, human capital, labour, credit

[23] According to this author, further elements to add to the policy are ensuring correct communication of the innovation along the chain of agents; securing land tenure against either conflict, grabbing, or commons tragedies; and facilitating farmer participation.

constraint, tenure, and supply constraints. In a 1993 update, they reviewed studies at more advanced stages of adoption (Feder and Umali, 1993). Both reviews assume expected utility and profit maximisation, and focus predominantly on large-scale producers of commodities. A remarkable finding is that agents might adopt despite present losses if they expect that, as a result of learning, they can improve their future performance. This implies that risk aversion may not always deter adoption of innovation. They also argue that major deviations from rational choices are due to imperfect information that produces an unrealistic perception of risk, concluding that learning processes are key to enable fully rational decisions. They indicate that risk is not an issue for later adopters, who benefit from the information provided by early adopters. Therefore early adopters produce a positive externality.

Edwards-Jones (2007) integrates economic and social-psychological approaches in his review of decision-making models. He provides an insightful conclusion about the interaction and the usefulness of both approaches: *"profit maximisation can give some very broad predictions about land use (...), but as the importance of financial factors in the decision making process starts to decline, so the usefulness of the profit maximisation assumption also starts to decrease"* (Edwards-Jones, 2007, p.784). He also identifies as a research challenge the need to quantify the magnitude of the influence of the economic and the psychological across decision domains.

In a quantitative meta analysis of US farming, Baumgartz-Gerz and colleagues (2012) synthesise the variables studied in adoption of best-management practices. They suggest a policy in phases, first targeting farmers who are most likely to adopt, and then enhancing social networks and communication channels, although their conclusion is more an expert opinion rather than a direct deduction from their results.

3.4.2. Regression studies: a vote-counting meta-analysis

For the 28 regression studies of adoption included in the vote-counting meta-analysis, I inspected model results and introduced coefficients and their significance in a database. The studies contain almost two hundred differently measured predictors (some of which are used in more than one study), which I group in two levels of categories as in the review and qualitative studies (the 13 categories shown in Figure 3.3 and the 32 shown in Table 3.3). In terms of models used, 19 studies used logistic or probit models, and there are one or two articles using either of the following: multinomial logit or probit, ordered probit, tobit, and selection model.

The approaches and measurements of predictors across studies are highly heterogeneous; they are not appropriate for a meta-analysis calculating size-effects, but they are sufficient for a vote counting meta-analysis (e.g. Pattanayak et al., 2003). The latter provides meaningful insights on what are the important variables in a clear and reliable way. The main insights drawn from this body of literature refer to how outcome variables are measured, and to the significance of coefficients for the independent variables.

a. Outcome variables

It is recommended that the outcome is measured in terms of rate or level of adoption, either in the form of continuous numerical or of ordered categorical variables (Feder et al., 1985; Pattanayak et al., 2003). However, in most empirical studies adoption is measured as a dichotomy of adoption and non-adoption. Whether the adopted activity is continued over time is also crucial to assess effectiveness, but this requires follow-up data which are less frequent.

A clear distinction is to be made between participation in a programme, adoption, degree of adoption, and long-term continuation. Many studies focus on the first, while policy may be predominantly concerned with long-term success. Often, studies do not describe with precision at which stage of adoption the outcome variable is defined or measured: whether it is measured as stated use at a single time point, or whether it has been practised for a period. Plausibly, in each study the outcome variable may be different or at a different stage in the process, and I argue that this ambiguity in measuring and defining the dependent variable obscures consensus about the impact of predictors.

b. Significance of predictors

For each regression study, Table 3.3 shows the count of predictors within each of the 32 categories, and the count of coefficients that are significant at a p-value <.1. In some cases, all the predictors grouped within a category were measured in the same direction (e.g. *Education*), whereas other categories include variables representing the same concept, but measured in opposite directions (e.g. *Labour*). For some categories measured in the same direction, a positive effect was almost universal (e.g. *Education*, which includes variables such as years of schooling, level of education, primary studies, secondary studies etc.), but for others, the direction of the effect is unclear and context-dependent (e.g. *Age*), or more difficult to measure consistently. Therefore the frequency in which the significant coefficient was positive or negative is not shown.

Table 3.3: Meta-analysis of regression studies: predictors and significance

Topics and authors	Year	Education	Age	Networks and communication	Gender	Income and socio-economic status	Livelihoods	Farm size	Quantity of farm production	Land tenure	Farming experience	Farming practice	Successor factor	Characteristics of the innovation	Labour	Credit	Costs and benefits
Silvopasture																	
Pagiola et al.	2008				1	1*	1	1*			1				1	1*	
Jera & Ajayi	2008	1	1	1*	1			1*	1						1		
Garbach et al.	2012	1		1											1*		
Frey et al.	2012													1			2**
Agroforestry																	
Sanginga et al.	2006	1	1*	3**	1	1		1							1		
Mukadasi et al.	2007	1*	1*	1	1*		1								1*	1	
Mercer and Pattanayak	2003	1	1*	1		1*	1	1*		1*	2*		2*		1*		
McGinty et al.	2008		1*			1*					2				2		
Marenya & Barrett	2007	2**	1		1*	1*	1*	1*			1	1*			1*		
Mangabat et al.	2009	1	1*	1		1		2*		1					2*		
Faße & Grote	2013		1*	1*	1	1*		1*		1*	1*					1	
Casey	2004	1*	1				2	3*	1*				1		1		
Adesina et al.	2000	1	1	1*	1*		2			2			1		1		
Adesina & Chianu	2002	1		1	1*		1*	1		2	1*		1*		1		
Sustainable agricultural innovation																	
Wauters et al.	2010													1*			
Mzoughi	2011	1*	1		1		1										3*
Miller et al.	2008		1		1	1		1*							1		
Lokhorst et al.	2011	1	1					1									
Läpple & van Rensburg	2011	1	1*	1*			1	2**							1*		1*
Läpple & Kelley	2013																1*
Hynes & Garvey	2009		1*			2*	3	1			1	3			1		
Calatrava & Franco	2011							1		1*	1				1		1*
Blazy et al.	2011							2	1			1*			1		1
Amsalu & Degraaff	2007		1*		1	1*		1*		1					1*		2**
Agricultural innovation																	
Giovanopoulou et al.	2011	1*	1*	1*				1*									
Ecoinnovation																	
Woersdorfer & Kaus	2011		1	1*	1	1*				1							
Land-use change																	
Bosselmann	2012	1	1*	1*		4	3**	1		2			1		6*****		1*
Arslan	2011	1	1			1*	1	1	1			2			2*	1	2*
TOTAL		17	20	15	12	17	18	24	4	12	10	7	6	2	28	4	14
Frequency of significance		0.3	0.6	0.6	0.3	0.5	0.2	0.5	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.3	0.7

Table 3.3 (continuation)

Topics and authors	Year	Long time lag	Markets	Biophysical factors	Risk	Information	Extension and training	Subjective norms	Institutions	Policy interventions	Attitudes	Beliefs	Problem awareness	Environmental attitude	Values and interests	Perceived behavioural control	Behavioural intention
Silvopasture																	
Pagiola et al.	2008		1	1			1										
Jera & Ajayi	2008																
Garbach et al.	2012						1			2*							
Frey et al.	2012	1			1												
Agroforestry																	
Sanginga et al.	2006								4**								
Mukadasi et al.	2007						1*										
Mercer and Pattanayak	2003			2*		1	1*										1*
McGinty et al.	2008													1*		2*	1*
Marenya & Barrett	2007																
Mangabat et al.	2009			4			1*										
Faße & Grote	2013	1	1														
Casey	2004			2			1*							1			
Adesina et al.	2000						1*						3**				
Adesina & Chianu	2002		1*				1*						4***				
Sustainable agricultural innovation																	
Wauters et al.	2010							1			1*					1	1*
Mzoughi	2011				1*			4*							1*		
Miller et al.	2008						5***							1			
Lokhorst et al.	2011							2*			1					2*	
Läpple & van Rensburg	2011				1	2*	1							1*			
Läpple & Kelley	2013							1*				1*				1*	
Hynes & Garvey	2009			1*													
Calatrava & Franco	2011	1*		1*		1*							1				
Blazy et al.	2011			1					1								
Amsalu & Degraaff	2007			4**									1				
Agricultural innovation																	
Giovanopoulou et al.	2011				1*	1*			1*	1*	1*		1	1*			
Ecoinnovation																	
Woersdorfer & Kaus	2011					1								1*			
Land-use change																	
Bosselmann	2012			1													
Arslan	2011			2													
TOTAL		3	3	19	4	6	14	8	6	3	3	1	10	6	1	6	3
Frequency of significance		0.3	0.3	0.3	0.5	0.5	0.6	0.4	0.5	0.7	0.7	1.0	0.5	0.7	1.0	0.5	1.0

Numerical values indicate the number of covariates under the category. Each star represents one covariate found significant. For example, in Frey et al. (2012), the characteristic of the innovation was used once, and not found significant, whereas two variables within costs and benefits were used, and both were significant.

Some papers present a high number of predictors within a single category of variables. This may be useful when this category is at the core of the argument of the study, and particularly illuminating if the regression is run with and without the collection of very-similar variables. This is the case for *extension* in Miller et al. (2008), *conflicts*—included as institutional factors—in Sanginga et al. (2006), and *social pressure* in Mzoughi et al. (2011). But if it is not the main focus of the study, it can obscure the effect of other factors (e.g. labour in Bosselmann, 2012).

Two thirds of the studies or more use farm size, available labour, age, income, livelihoods, and biophysical factors. The frequency of their significance is highly variable: farm size, available labour, and age are significant half of the times, and the sign of the last two varies.[24] Livelihoods and biophysical factors are influential in a quarter of the studies. The former include a diversity of measurements, usually the total income from a given activity such as commerce or off-farm. Remarkably, only 2 of the 21 variables on livelihoods refer to livelihood diversity (Bosselmann, 2012; Mukadasi et al., 2007). Biophysical factors predict differential adoption in larger regions, but present little variability in smaller communities.

Consistent with discussions in review and qualitative studies, costs and benefits are included in half of the regressions, and found to be significant 10 out of 14 times. In the middle ground, some important predictors are extension and training, and networks and communication (both training and networks are significant in over two thirds of the studies that included them).

Other qualitatively different predictors, according to the above table, are those which are included rarely but which are found to be significant. These are mostly internal variables and, when they are included, they are usually central to the argument of the study. The main examples are attitudes and environmental attitudes (both significant in two thirds of the cases), behavioural intention, beliefs, and values and interests (all found significant in all cases, but used in very few studies).

[24] The frequency of available labour is highly influenced by Bosselmann's study (2012), who included six different measurements related to labour availability: number of adults, children/adult ratio, hired labour, ha of coffee per adult, adults working on and off-farm. The author tested for multicollinearity and excluded one variable (*altitude*) for this reason.

3.4.3. Empirical studies using qualitative and other quantitative methods

This selection of studies includes quantitative methods such as the comparison of adopters and non-adopters using descriptive or inferential statistics (almost half of the studies), or the classification of adopters using cluster analysis or Q methodology. There is also a diversity of theoretical approaches, predominantly hybrid. In agroforestry and sustainable agricultural innovations, some papers also present a strictly social-psychology approach (Beedell and Rehman, 2000; Zubair and Garforth, 2006). The inclusion of internal variables is a recent trend (with the exception of Scherr, 1995). Over half of the analyses adopt a static explanation, although more in this group explain adoption as a process than in reviews and regressions (e.g. Darnhofer et al., 2005; Morris et al., 2000).

Table 3.4: Systematic quantitative analysis of qualitative and other quantitative methods studies: predictors mentioned

Topics and authors	Year	Heterogeneity of agents	Education	Age	Gender	Health status	Income and socio-economic status	Livelihoods	Farm size	Quantity of farm production	Land tenure	Farming experience	Successor factor	Characteristics of the innovation	Labour	Credit	Costs and benefits	Long time-lag	Markets	Biophysical factors	Risk	Information	Extension and training	Networks and communication channels	Subjective norms and social pressure	Institutions	Policy interventions	Participatory process	Knowledge	Perceptions	Attitudes	Beliefs	Problem awareness	Environmental attitude	Personality	Values and interests	Perceived behavioural control/ self-efficacy	Behavioural intention	Other (in one study only)
Silvopasture																																							
Pagiola et al	2007	■									■					■	■	■					■				*												
Holguín et al.	2007						■																■				*												
Van Hecken et al.	2010						*		*						*	■	*	■	■				■	■			■												
Shrestha et al.	2004							■									*	■		■	■		■				■							■					
Mekoya et al.	2007								*					*	■		*			*		■	■	■					■	■						■			*A*
Calle et al.	2009		□										■		■	■	■					*	■				■	■		*			■						
Hayes	2012											■					■						■	■			■	■									*		
Agroforestry																																							
Bannister & Nair	2003		■	■					■		■			■						■																			
Sood	2006						■	■		■					■											■													*B*
Jerneck & Olsson	2014	■				■			■			■		*	*			*			*																		*C*
Scherr	1995				■			*	■					*	■		■		*		■												■						*D*
Fischer & Vasseur	2002										■			■				■	■		■	■	■			■		■											
Snelder et al.	2007								■		■	■					■	■	■	■	■									*									
Valdivia et al.	2012	■										*		■	*		*	■				■								■			■						
Sood & Mitchell	2004																		■							■				*	*		■						
Zubair	2006		■	■				■	■		■			■			■		*	■					*								■				■		
Sustainable agricultural innovation																																							
Morris & Potter	1995	■																																					
Wilson	1997		■	■				□	□		□		■							■		■		*			*												
van der Horst	2011												■		■							■		*										■					
Greiner & Gregg	2011						■				■				■		■		■		■		■			■	■			■	*			■					
Brodt et al.	2006	■	■	■					■			■																											
Atwell & Schulte	2009													*			*						■	■	*		*												
Vignola et al.	2010	■	■	■			■		■												■											■	■			■			
Beedell & Rehman	2000																						■	■	■		■			■	■	■		■	■			■	*E*
Morris et al.	2000													■			*					■		*	■		■							■			■		
Darnhofer et al.	2005	■						■							■		■				■					■					■		■	■					
Ahnström et al.	2008			■					■				■				■						■		■		■			■	■			■		■			
Barnes et al.	2011	■																															*						
TOTAL		8	6	6	1	1	5	6	11	1	7	5	4	9	10	3	15	7	7	6	8	7	12	8	5	5	12	3	1	8	5	2	8	7	1	3	3	1	

*Key: □ discussed in the study; ■ discussed and considered important; * considered critical. 'Other': A, Knowledge; B, Quantity of farm production; C, Health status; D, Gender; E, Personality and Behavioural intention. Category not shown: current farming practice.*

Overall, costs and benefits are most frequently mentioned (e.g. Snelder et al., 2007), and also considered one of the most decisive variables in five studies. The examination of extension and training also predominates. As frequent as training are policy intervention, available labour, and farm size. This finding contrasts with the reviews where these three variables were at a third level of importance, after information and knowledge. In particular, four studies in this group emphasise policy intervention as a major predictor. Networks and communication channels are mentioned less frequently than the above variables. Three studies consider networks to be one of the most influential variables together with perceptions and the characteristics of the innovation.

Beyond the messages drawn from reviews and regressions, this body of literature adds specific insights about SPS and about typologies of adopters.

a. Silvopastoral projects

Three pilot projects tested the impact of technical assistance, PES, and both, on the adoption of silvopasture, using randomised experiments in Costa Rica (Garbach et al., 2012; Holguín et al., 2007), Nicaragua (Pagiola et al., 2007; Van Hecken and Bastiaensen, 2010), and Colombia (Zapata et al., 2007, a case also discussed in Calle et al. 2009). These projects were part of RISEMP, a World Bank programme funded by GEF between 2003 and 2008 (Pagiola et al., 2007). In the experiments, payments were provided according to an *environmental services index* (described in Montagnini and Finney, 2011).

The analysis of the projects in Nicaragua and Colombia is based on panel data on land-use change. In Nicaragua, Pagiola et al. (2007) find that the main barriers to adoption (low profitability, opportunity costs from time-lags, credit, land security, and access to credit) are more salient to poorer households. They suggest that PES may be useful but not sufficient, and find that payments have a positive effect for one qualitatively identified group: those for whom establishment costs are too high and for whom the practice is profitable afterwards.

Their analysis excludes the control group due to a biased selection that resulted in the groups not being comparable, according to the authors, and to complications in the implementation of this group because of perceived unfairness, according to Van

Hecken and Bastiaensen (2010). The latter authors argue that, when including the control group (which reportedly had higher adoption) payments lost significance and the main predictors were capital constraints and opportunity costs. More generally, the case study showed that the training and social momentum reduced risk-perception and encouraged experimentation.

Garbach et al. (2012) and Holguín et al. (2007) look at the project in Costa Rica. The former find a positive influence of technical assistance, particularly for the adoption of practices with private benefit, whereas payments had a positive effect mostly in practices providing predominantly a common good. Payments and technical assistance together had the highest positive effect, although their interaction was negative. The results of Holguín et al. (2007) support those of Garbach and colleagues (2012): the group with training and payments together had highest compliance—although this treatment was self-selected and defined ex-post (participants chose whether to participate in training events or not). They also compare the level of participation in training events with socio-economic variables, finding that those who had more fixed capital had less participation. The highest performance of the group with both payments and technical assistance is confirmed in the Colombian experiment (Zapata et al., 2007).

Mekoya et al. (2007) published the only study that includes disadopters: those who, having tried, did not continue with the practice. Disadopters perceived that land shortage and the lack of information were not a major limitation, but rather the low multipurpose value of trees and, above all, agronomic problems. This perception was in stark contrast with that of adopters and of non-adopters, suggesting that once the experimentation starts, the profitability and adaptability of the practice are critical. In this case, disadopters had a remarkably higher preference for local species, which hints that a major drawback in this project was the inappropriate selection of species.

b. Motivations and typologies of perspectives beyond silvopasture

Valdivia et al. (2012) factorise the perceived barriers of agroforestry adoption into *transaction costs* and *profitability concerns*. Their cluster analysis yields three types of landowners: *environmentalists*, *agriculturalists*, and *disengaged.* These types differ in their perceptions of the two barriers: none of the barriers are important for the environmentalist, whereas both are for the agriculturalist. However they do not differ largely in terms of adoption.

Zubair and Garforth (2006) use the TPB (analysing attitudes, subjective norms, and perceived behavioural control) to find that early adopters are more compliant with others' opinions. The authors explain this reliance on others' views as an uncertainty-reduction strategy, and thus suggests that targeting opinion leaders can be instrumental for others to adopt.

Moving towards sustainable agricultural innovations, Morris and Potter (1995) distinguish adopters based primarily on motivations. Motivations of *passive* adopters are unrelated to environmental factors, and they undergo a minimal change in their attitude to conservation. In contrast, *active* adopters have environmental or altruistic motivations. They further distinguish between *resistant* non-adopters and *conditional* non-adopters, and suggest specific ways to adapt policy to each type.

A number of authors define typologies of (non)adopters using different (semi)quantitative methods. Brodt et al. (2006) categorise a number of management styles using Q methodology: *environmental stewards*, *production maximisers*, and *networking entrepreneurs*. Darnhofer et al. (2005) describe adoption of organic farming as a decision-tree in two phases (as explained in section 2.4.2). This is used to identify types of farmers: *committed conventional*, *pragmatic conventional*, *environment-conscious but not organic*, *pragmatic organic*, and *committed organic*. Barnes et al. (2011) grouped adopters into *resistors*, *apathists*, and *multifunctionalists*, and argue that willingness to change depends on problem awareness.

3.5. Key messages

This chapter presents a systematic quantitative review of 70 peer-reviewed studies on adoption of SPS and of sustainable agricultural innovations more broadly. The main messages drawn from this review relate to the goals posed at the beginning of the chapter and provide detailed background to understand what motivates and hinders individuals to adopt SPS. These messages refer to the dependent variables, the factors influencing adoption and their frequency of use in the literature, the comparison between reviews and quantitative and qualitative studies, the comparative effect of external and internal variables, and the gaps identified in terms of what covariates are considered influential in adoption processes.

The heterogeneity in the dependent variables is an unexpected finding with major implications for drawing general conclusions about what influences adoption. Adoption is measured heterogeneously in two ways: in terms of the practices to adopt, and in terms of the stage of the adoption process at which it is measured. The former heterogeneity is widely known and its implications acknowledged. However the latter source of heterogeneity is largely ignored in previous reviews. Assuming that the independent variables can have a dynamic, changing effect depending on the step of the adoption process (Morris et al., 2000), the use of measures that capture adoption at distinct stages implies that each study is analysing a different part of the process. This is plausibly a source of the lack of consensus in the conclusions about the effects of covariates across models.

Six main groups of factors influencing adoption are found (Figure 3.2): farm and household characteristics (including livelihoods), social environment and institutions (including external policy interventions), knowledge and information, technical feasibility, economically rational motives (including cost and benefits), and individual factors (including objective or external, and subjective or internal). In terms of the frequency with which the literature says these factors are important, the top ones refer to economically rational motives and farm and household characteristics (Figure 3.3). Individual objective characteristics are incorporated in most studies in the form of control variables. Individual subjective characteristics are deemed important in many studies, mostly reviews and qualitative research, but they are less included in quantitative regressions, due arguably to difficulties in operationalising them. Also, very few regression studies incorporate technical feasibility and specific policy interventions to their specification.

Consistently, most studies across the three bodies assume implicitly (and sometimes explicitly) clearly rational and profit maximising behaviour, and costs and benefits are the predominant variable considered to influence adoption. The frequent significance of cost and benefits is consistent with the idea of multiple motivations for decision, because a number of other factors are also found significant very frequently, particularly subjective variables. Subjective variables are largely included in the qualitative literature, but not so much in regression studies. However, where included in regression models, variables of attitudes, behavioural intention, beliefs and values were almost always significantly related to adoption (see significance in Figure 3.3). This suggests that internal variables may influence adoption more than the external ones.

Three elements are considered to provide superior explanations of adoption: behavioural theories, internal variables, and process-based approaches. However, they are more rarely included in the literature, although their use seems to be increasing. These elements were highlighted in the previous chapter as important to provide sufficient understanding for intervening policies.

Payments were found to be most influential where establishment costs were high and the practice was beneficial afterwards. They were also found influential when combined with training. The qualitative literature suggested that barriers may be most relevant in predicting behaviour, thus analysing potential and likely limitations might be more effective to adapt policy design, than promoting motivations that are already favourable.

Variables related to livelihoods are included in a large proportion of the studies. However, these comprehend a wide range of concepts, and livelihood diversity was considered only in two studies. This is surprising, considering the importance given to livelihood strategies in the poverty literature, though understandable because the adoption literature largely overlooks the broader livelihood impacts that new practices may have. In order to contextualise these potentially influential factors, a recent project to encourage SPS adoption is explained in Part II.

Summary of Part I

The first part of this thesis sets out the conceptual framework on complex SES, livelihood decisions, and payments, and critically synthesises the literature bodies on pro-environmental behaviour and agroforestry adoption, to which it contributes. This provides the foundation for the rest of the thesis.

The conceptual framework situates what is needed in order to address the major question posed in the introduction: how to incentivise the uptake of pro-environmental behaviour in rural low-income areas of high biodiversity. In order to build a realistic framework, I embed adoption within more general livelihood decision processes influenced by the complex SES in which they occur. This framework is illustrated in Figure 2.1 and is fundamental to understand how the components of the rest of the thesis tie together.

I discuss the challenges of PES, a promising instrument to encourage pro-environmental behaviour in biodiversity-rich areas. I argue that a major question is whether the theoretical underpinning of PES is a satisfactory and sufficient explanation of reality. To seek a response, I examine how this reality—decision-making—is explained in theoretical and empirical literature. The framework leads us to identify three critical challenges of external interventions for conservation: heterogeneity of agents, contextual subsidies, and livelihood diversity.

Many theories in psychology and economics are static, one-step considerations of a number of objective and subjective variables (Section 2.4). Process-based decision-making presents a more accurate explanation of adoption, which aggregation leads to the prevalent and proven diffusion theory.

Abundant literature aims to explain what predicts adoption of silvopasture, and of sustainable agricultural innovation more broadly. To summarise this literature and empirical gaps, I make a systematic quantitative analysis of reviews and (quantitative and qualitative) case studies in Chapter 3.

A number of general messages can be drawn from this review. Regression studies often fail to include subjective (internal) variables and livelihood diversity. It is also rare to find studies that model adoption as a process and beyond binary variables of adoption and non-adoption (or of participation and its counterpart). This predominance of dichotomous dependent variables instead of scaled or continuous measurements of uptake—a shortcoming already identified by Feder et al. (1985)—does not seem to be changing, and this represents a major gap. The few empirical explanations of adoption of agroforestry innovation that integrate heterogeneity of agents, reveal very valuable insights for the design of incentive programmes, thus it is a research approach with great potential. Very few studies focus on the level of diversification of farmers as an explanatory variable of their behaviour (Sood, 2006). However as it emerged from Chapter 2, I argue that these variables are important. In addition, no study was found paying attention to the impact of contextual subsidies.

The summary of decision-making theories of relevance for pro-environmental behaviour guides the discussion of attitudes and perspectives in Chapter 8, and the model choice and explanation in Chapter 9. The analysis of the literature on adoption of silvopasture and agroforestry aids choices in designing the empirical study in Part III, and reveals the lack of attention to three variables around which the rest of this thesis revolves, namely heterogeneous perspectives, subsidies, and livelihood diversity. Next, in Part II the case study is explained.

PART II: CASE STUDY

This part narrates and explains the context in which the theoretical background of Part I is made concrete for the empirical analysis. The context selected is the buffer zone of a biosphere reserve in Chiapas, southernmost Mexico. This reserve protects a tropical forest and, recently, efforts to encourage farmers in the buffer area to adopt silvopasture have been made. To understand the context and the decisions of these farmers, Chapter 4 provides an account of the recent environmental and socio-economic history affecting livelihoods and ecosystem dynamics in the area, pointing at recent land use transitions and the strong preference for cattle-farming, thus highlighting the need for making this practice more sustainable. Chapter 5 describes in detail the current picture of the community under study, as well as the process through which silvopasture was encouraged in a recent pilot project carried out by a regional research institution. The understanding of this case and its recent history, together with the framework explained in Part I, is instrumental for the empirical design developed in Part III.

Chapter 4. Pathway-dependent livelihoods and land-use mosaics in the Mexican tropical forest frontier, 1960-2010

The inventory of factors for adoption of sustainable land-use practices in the previous chapter cannot be understood in isolation from the context within which these practices occur. Among these factors and in the framework of complex systems, path dependence emerges as a concept that shapes current livelihood practices and preferences (Section 2.1 and Figure 3.2, p.80). This thesis explores path dependence by critically narrating how recent socio-ecological and macroeconomic trends led to current unsustainable land-use practices and environmental problems.

The chapter links economic, social, and environmental trajectories, converging towards the emergence of cattle-farming as a preferred activity, and of silvopasture as a feasible alternative towards sustainable rural livelihoods.[25] This is done in order to assess how pathways affect current motivations, preferences and hindrances to adopt innovative land-use practices, as posed by the main question in this thesis. The narration aims to diverge from declensionist accounts of gradual natural decline,

[25] The chapter assembles several accounts of recent land-use transitions and economic and political changes, gathered from graduate theses in Spanish, working papers, and peer-reviewed papers across disciplines. Few first-person personal narratives collected during fieldwork complement this assemblage, for which I used qualitative analysis, coding the source texts by topics that structure the narration.

which are common in recent environmental history reports of Latin America (Carey, 2009). It encompasses a synthetic overview of how the current landscape is fabricated through transitions of land-use change, forest clearance, and soil erosion.

The narration begins in tropical Mexico, where vast areas exhibit the diffuse type of deforestation (Geist and Lambin, 2001; Hansen et al., 2013) described through Figure 1.1 (p.26). The recent history of the relationship between humans, their livelihoods, and the ecosystem shaped the landscape and led to mining soil nutrients (Sonnenfeld, 1992). In the tropical forest frontier in Chiapas, extensive cattle-farming and logging activities were carried out at least since the mid 19th century (García-Barrios, 2012), yet widespread colonisation did not begin until the 1960s (Jackson et al., 2012). Farming activities such as maize crops and cattle-farming quickly caused deforestation and expansion of pasture. Cattle and agricultural practices were not initially adapted to the humid tropics, and were driven by the internationalisation of markets, by industrial maize production, and by increasing population and poverty pressures. This decades-long relationship can be interpreted as a learning process in which farmers try different options and sway their strategies with the flow of macroeconomic and political waves, albeit not without some resistance.

The narration focuses on the subjects of dependence on subsidies, livelihood activities, and soil degradation, mostly during the last five decades (Sections 4.1 and 4.2). As suggested in the conceptual framework in Chapter 2, forest loss and soil degradation are driven by livelihood decisions and thoroughly affected by subsidies in this such contexts. In turn, ecosystem dynamics feedback into decisions. This exposition of historical drivers then zooms on the impact of macroeconomic forces on the ground, by explaining how these transformed people's livelihoods and landscapes in a representative location in the state of Chiapas (Section 4.3; further justification of this representativeness is given in Chapter 5). Finally, the major recent social-ecological transitions are synthesised (Section 4.4).

4.1. Pre 1990s: tropical forest colonisation and food policies

4.1.1. Forest dynamics

The forests that the Maya cleared in Mexico, Guatemala, and Belize grew again after their civilisation collapsed around A.D. 900, and became part of a forest continuum along Central America (Bray and Klepeis, 2005) until the Spaniards arrived. It is estimated that, following the collapse of the Mayan empire, temperate and tropical primary forests covered half of Mexico (García-Barrios et al., 2009a).

At the beginning of the 20th century, forest management in Mexico followed a colonial pattern. According to Klooster (2003), the forester De Quevedo was highly influential in early century forestry policies and encouraged the 1926 Forestry Law, which established the figure of national parks among other innovations. His ecological principles were rather advanced; De Quevedo acknowledged that ecosystem services provided by forests were more important than their logging productivity, and he promoted a forestry culture based on that premise. However, the policy instruments utilised were not aimed at enhancing the stewardship of land dwellers, the approaches were considered repressive, punitive, and top-down, and, as a consequence, the implementation of his policies was unsuccessful (Klooster, 2003).

By 1956, it was estimated that only 22% of the post-Maya primary forests remained in Mexico (Villasenor, 1956 in Klooster, 2003) due to logging. In tropical areas of southern Mexico, deforestation began to be a serious problem in the 1960s, when colonisation policies led to the population of formerly forested areas (Bray and Klepeis, 2005). This expansion was partially induced by a national Mexican policy to populate the southern border and protect it from Central American *guerrillas*. Thus with some delay with respect to the rest of the country, population in Chiapas expanded remarkably across hitherto barely populated tropical forest. The ejido system was a key instrument for this expansion.

4.1.2. Ejidos

The Mexican Constitution in 1917 created the figure of the *ejido* (Art. 27), a land regime that is unique to Mexico. This was not implemented in practice until 1934, following an agrarian reform for land redistribution (Isaac-Márquez et al., 2005). Ejidos were a revolutionary concept of land tenure which abolished the previous model of *encomiendas.* An earlier period of large landholdings (*latifundios*, *haciendas)* and land owned by survey companies had left native communities with 10% of their original land, therefore preventing land concentration was perceived as a necessity (Klooster, 2003).

Originally, ejidos were a collective property of land expropriated from landholdings that exceeded the definition of small properties and which were granted to a group of formerly landless *campesinos*. The conditions for this grant were that campesinos farmed the land, that land was held collectively, and that it could not be sold or rented (Appendini and Liverman, 1994; Klooster, 2003). Groups of farmers would apply together, obtain collective access to forests and pastures, and each head of household was entitled to a parcel, which was transferred by inheritance to a single individual (Corbera et al., 2009).[26]

In the 1940s ejidos managed half of the Mexican cropland (Knight, 1991 in Klooster, 2003) and a fifth of forests (Hinojosa-Ortiz, 1958 in Klooster, 2003). Despite an initial period in which land previously exploited by private companies was redistributed (Galván-Miyoshi et al., 2009), from the mid 1950s onwards the land allocated was mostly marginally productive and exposed to environmental hazards. This resulted in production in the ejidos being more vulnerable than in private lands (Appendini and Liverman, 1994).

[26] *Ejido* in English is translated as *cooperative, communal* or *shared land*. However, the original communal system changed significantly in the early 1990s after constitutional reforms (explained in Section 4.2). Nowadays ejido embodies in a diverse range of land regimes. The system of ejidal rights and assembly still remains a major land institution throughout the country, next to communal and private lands. The consequences of this model distinguish Mexico from other Latin American countries even today; land is still more equally distributed than in other countries.

4.1.3. Food production and livelihoods

During the 1940s, many subsistence farmers in Mexico joined national food markets (Appendini and Liverman, 1994). The food production system at the time focused on substituting imports and protectionism. In 1953 a price support was introduced to aid basic crops, an aid that was frozen later between 1963 and 1973 (Appendini and Liverman, 1994). However the productivity in industrial agriculture increased, which in turn incentivised agricultural expansion in a sort of Jevons paradox of agricultural intensification. This phenomenon was empirically demonstrated later in other tropical countries in the Americas (Ceddia et al., 2013). Consequently, Mexico achieved food self-sufficiency (Appendini and Liverman, 1994). By the end of the decade, cash-crops became more profitable than basic crops and sorghum took over from maize in modernised agriculture, while maize remained dominant in marginalised areas where mechanisation had not taken root (Appendini and Liverman, 1994).

Between 1945 and 1970 the Mexican population in urban areas grew at a fast rate. The country witnessed one of the most intense urbanisation processes in the world (UN, 2006, in Galván-Miyoshi et al., 2009) and the most accelerated in Latin America (Hansen, 1978, in Galván-Miyoshi et al., 2009). Population grew at an average of 1.7% annually between 1940 and 1980 (Galván-Miyoshi et al., 2009), and with a fertility rate of around 7 in rural areas between 1960 and 1980 (Nunez, 1998, in Galván-Miyoshi et al., 2009). The industrialisation that led to this intense urbanisation was also driven by import-substitution and cheap food production (García-Barrios et al., 2009a), at a time when more than half of the population was in the farming sector (Galván-Miyoshi et al., 2009). In the late 1950s the proportion of the population living in urban areas surpassed that of rural areas (Galván-Miyoshi et al., 2009).

During the 1970s the national government promoted food-crop agriculture due to a chain of reasons (Appendini and Liverman, 1994). In the 1970s, the balance of food exports peaked and then plummeted (Fernández Ortiz and Tarrío García, 1983), paralleling the global oil crises. Because agriculture had shifted to more profitable cash-crops such as fodder grains, the production of staple food slowed down and early in the decade Mexico started to import maize (Appendini and Liverman, 1994), contributing to an already increasing external debt. Uncertainty about the provision of food to urban settlements increased the Mexican government's fear for social unrest. In order to address this, the government promoted staple food and mostly maize agriculture via increasing access to credit, distributing inputs, selling crops at subsidised prices, and fully regulating the *tortilla* industry (Appendini and Liverman, 1994). National prices were also regulated in the 1970s for coffee and sugar (Ribeiro Palacios et al., 2013).

4.1.4. Environmental impact of land-use change

In the mid 1970s, Mexico had around 561,000km^2 of primary temperate and tropical forests (Galván-Miyoshi et al., 2009), which was approximately 50% of the original cover (García-Barrios et al., 2009a). In the same decade, cattle-farming expanded in tropical forests across Latin America (Toledo, 1990 in Valdivieso-Pérez et al., 2012). Farmers would deforest areas for the cultivation of maize during one or two cycles and later convert them into pastureland (Aguilar-Martinez, 2007).

Two parallel dynamics took place meanwhile: the 'productivity-gap' between industrial farming and traditional farming increased, and soil erosion became more acute (Appendini and Liverman, 1994). Comparatively higher costs of production and limited access to government funding for traditional practices forced farmers onto lower incomes. Modern farming enabled easier access to subsidies because these were given upon conditions such as acquiring chemical inputs. These inputs reduced the need for labour, for cooperation to carry out soil conservation activities (Galván-Miyoshi et al., 2009), and for fallow and other conservation practices (García-Barrios et al., 2009a), because chemical inputs would make up for decreasing soil quality, at least temporarily. Input use increased the monetisation of agriculture and when adverse climatic conditions reduced the yield, farmers faced not only food scarcity, but also financial debt.

The higher productivity enabled by chemical inputs brought increasing problems of soil erosion (García-Oliva and Mass, 1998 in Valdivieso-Pérez et al., 2012), which traditional practices at low density had avoided thus far. Topsoil loss was estimated (for the case of coffee farming in Chiapas) at a rate between 100 and 1,000 faster than that of traditional practices, mostly caused by water run-off erosion due to reduced vegetation cover (Hagerdorn, 1995 in Richter, 2000). This was an early environmental cost of agriculture based on external inputs, which remains in subsequent decades.

Following modernisation, between the 1970s and 1994 a boost in maize production occurred in southernmost Mexico, intensively fed by agrochemical inputs (García-Barrios et al., 2009a). This translated into a regional *commodity boom* and Chiapas (and the central valleys of La Frailesca in particular) became the major maize producer, the *granary* of Mexico.

4.1.5. Rampant deforestation and the frustrated attempt to return to food self-sufficiency

Deforestation at the end of the century was acute in Mexico and Chiapas alike. During the 1980s, the average rate of deforestation in Chiapas was 2% per year (INE, 1999, in Rico García-Amado, 2008). Overall, tropical forests in Mexico exhibited a similar rate, with regional maximums of 12% (World Bank, 1995, in Bray and Klepeis, 2005). In 1986 a new national Forestry Law was approved to promote community forestry, but it was rapidly superseded owing to a radical change in the national focus; from import substitutions and national production, towards open international markets (Klooster, 2003), for reasons that will become clear.

In the late 1970s and early 1980s the Mexican government was able to provide abundant subsidies to farming due to oil exports. These subsidies benefited a quarter of the population, that which remained in farming by 1980 (Galván-Miyoshi et al., 2009). Between 1980 and 1982, the country developed an ambitious food programme to recover the self-sufficiency lost in the previous decade. The policy comprised an increase in public expenditure for agricultural extension and technological risk reduction for peasants. Maize production peaked in 1981 with 14 million tons (Appendini and Liverman, 1994).

However, the attempt for food self-sufficiency was frustrated by the external debt and climate crises of 1982. These events diverted the national priority from food security and self-sufficiency towards the management of external debt (Appendini and Liverman, 1994) and progressively during the decade, subsidies for agriculture decreased at an average rate of 8% per year, paralleled by a reduction in agricultural production (Appendini and Liverman, 1994). In 1986, Mexico joined the General Agreement on Tariffs and Trade (Klooster, 2003). During the 1980s, from the total maize consumed in Mexico, one quarter was imported (Appendini and Liverman, 1994). By the end of the decade, the price of imported food plummeted to half of that of national food, a gap that intensified with the elimination, in 1989, of import tariffs for all agricultural imports but maize and beans (Appendini and Liverman, 1994).[27]

Concurrent to the reduction of subsidies, chemical input industries were largely privatised as part of a governmental strategy to reduce state intervention and to attract private investment to rural areas (Appendini and Liverman, 1994; Galván-Miyoshi et al., 2009) in order to promote competitive cash-crops (Ribeiro Palacios et al., 2013). These changes increased the vulnerability of farmers to debt in low-production years. Aiming for competitiveness and in order to promote private property and land concentration for productivity purposes, the Mexican Constitution would be modified for land reform soon after (De Janvry et al., 1997, in García-Barrios et al., 2009a).

4.2. The 1990s and 2000s: liberalisation and the raise of cattle-farming

4.2.1. National policy transformations

Three major transformations took place in Mexico during the 1990s: the end of the iconic land regime, a macroeconomic shift affecting the profitability of maize, and the beginning of an era of diversity of payment programmes. These became strong drivers at the local level.

In order to ensure productivity in turmoil times, the Mexican regimes of land and subsidies underwent a twist in the early 1990s. In 1992 the modification of Article 27 of the Constitution terminated the long-standing land redistribution. This modification allowed to privatise ejido lands, to rent and sell them, and to abandon productive activities without losing ownership (Isaac-Márquez et al., 2005). This was

[27] Also in 1989, international coffee-prices collapsed (Schroth et al., 2009). This collapse, together with the elimination of the institution that regulated national prices and of government subsidies, caused a drastic reduction in the profitability of coffee-farming (Ribeiro Palacios et al., 2013).

done because secure private property was deemed a priority to ensure productivity (Galván-Miyoshi et al., 2009), and the former rural institutions were perceived incompatible with free markets (Walt and Rees, 1994, in Klooster, 2003). Changes to land reform also sought to increase the autonomy of ejidos and to overcome a previous period in which the state was regarded as having too much control of ejidos' internal affairs. Yet the success of these changes with respect to autonomy and democracy are disputed (Klooster, 2003). This law modification ended an era in which more than half of the Mexican land—including 80% of forested land containing three quarters of the biodiversity and two thirds of the water (SRA, 2008, in Galván-Miyoshi et al., 2009)—had been redistributed to more than 4 million households (INEGI, 2007, in Galván-Miyoshi et al., 2009).

In 1994, Mexico signed the North American Free Trade Agreement (NAFTA) and maize production became definitely unprofitable in comparison to the highly subsidised maize from the US (García-Barrios et al., 2009c). This resulted in a crisis that forced people to return to the emergency strategy of diversity, which provided more livelihood resilience. Temporal migration to the US also became a popular alternative, and the consequent increase in remittances helped avoiding rural depopulation (García-Barrios, 2012; García-Barrios et al., 2009a). Industry stagnation in the mid 1990s further contributed to US migration and to a deceleration of urban migration (Galván-Miyoshi et al., 2009).

The government also began to promote cattle as an alternative to maize. All these factors encouraged the expansion of extensive cattle-farming in small and medium herds (Valdivieso-Pérez et al., 2012), which became a preferred livelihood activity. Thus far, cattle-farming had been mostly limited by financial capital and land ownership, and both constraints softened with increasing remittances and with the subsidies that would soon arrive.

In terms of subsidies, government policies directed to reduce non-competitive farming and discourage self-sufficient agriculture (García-Barrios et al., 2009a). In 1993, the introduction of subsidies to agriculture from the national programme for direct support to farms (PROCAMPO),[28] managed by the Mexican department of

[28] The acronyms are based on the programme name in Spanish. See full list of acronyms on page 20.

agriculture, livestock, rural development, fisheries, and food (SAGARPA) brought another expansion of cropland in Mexico (Galván-Miyoshi et al., 2009).

An equivalent programme for forest development was created in the late 1990s and early 2000s, but it had a negligible budget compared to PROCAMPO. Other payment programmes for sustainable development in rural and forested areas started in the late 1990s and early 2000s (e.g. PROCYMAF, PRODEFOR). Among these, PRODERS for sustainable development began in 1996, and was later managed by the Mexican national commission on protected areas (CONANP), which renamed it in 2008 as the national programme for conservation towards sustainable development (PROCODES) (Rico García-Amado et al., 2013). Besides, payments for hydrological services (PESH) at the national level started in 2003 and a year later also for carbon, biodiversity, and agroforestry services (PSA-CABSA; Corbera et al., 2009).

4.2.2. Social-ecological trends

In Mexico, *ejidos* represent a major component in terms of land and population. In 2008, almost 6 million ejidatarios from over 30,000 ejidos managed 54% of the Mexican land (INEGI, 2008 in Rico García-Amado, 2008). In Chiapas in 2002, 59% of the land was in ejidos or communities, and 30% was in private hands (National Agrarian Registry in Villafuerte Solís, 2005). In contrast to the highly populated urban centres in Mexico, rural settlements are very small and dispersed: 92% of the settlements have less than 500 inhabitants, 43% of rural population live in average villages of 60 people, and 76% of the villages are isolated (CONAPO, 2004 in Galván-Miyoshi et al., 2009).

Between 1976 and 2000 the extension of pastureland increased 32% while cropland increased 18% in the country (Galván-Miyoshi et al., 2009). In the same period, primary forest cover decreased 31% and secondary forest increased 45%, resulting in a net balance of forest cover reduction of 13% (Galván-Miyoshi et al., 2009). The rate of land transitions in Mexico was less pronounced in the 1990s than in the previous two decades, due to an increase in opportunities to diversify livelihoods, a reduction of the importance and profitability of local agriculture (Ribeiro Palacios et al., 2013), and the increase of landless households due to the end of land redistribution (Galván-Miyoshi et al., 2009).

However, deforestation was still severe. Between 1990 and 2005, the extension of primary forest lost in Mexico was the third largest globally, only after Brazil and Indonesia (FAO, 2006). In 2000 primary temperate and tropical forests covered around 390,000 km^2—30% less than in 1976—and from the total primary cover, less than 40% remained, including just 10% of the original tropical rainforest (Galván-Miyoshi et al., 2009).

4.3. The impact of macro-scale changes on the ground

An example of population expansion and social-ecological changes in the southern frontier of Mexico is the ejido of Los Ángeles. This ejido was founded in 1960 by 44 heads of household arriving from the nearby ejido of Agrónomos Mexicanos (Torrez-Pérez, 2008), both within the municipality of Villaflores, who settled on land that was previously owned by large cattle-farmers, but mostly covered in primary forest. The new ejidatarios were officially given 2,950 ha in 1966 and later expanded to 4,739 ha, with lands ranging between 600 and 2,000 m above sea level (Sanfiorenzo-Barnhard et al., 2009). The ejido is located in the upper area of the Tablón river basin, which crosses west to east the northern part of Sierra Madre, a latitudinal mountain range in the Pacific coast of Chiapas.

The community broadly reflected the agricultural history of Mexico in the ensuing decades. Following the settlement, surrounding forest was progressively cleared, first for maize crop and later for cattle-farming (Valdivieso-Pérez et al., 2012). Land-cover at the time comprised agriculture, pasturelands, pine, oak, and deciduous forests (Aguilar-Martinez, 2007) and it was partially subject to logging in upper parts of the Tablón river basin and to cattle-farming in lower areas (García-Barrios, 2012). Maize was initially of subsistence cultivation using slash-and-burn (Sanfiorenzo-Barnhard et al., 2009), but commodity specialisation came rapidly, causing most deforestation. Existing big fauna was shut away to the core of what currently is the protected area. Reportedly, monkeys and other large animals inhabited the immediate surroundings of the settlement, but these were progressively hunted and after a few decades, the largest animals were displaced or went extinct.

The maize boom of the 1970s encouraged important transformations of forest areas in Sierra Madre by landless farmers who aimed to join the rush. At the Tablón river basin, people started farming marginal lands in narrow alluvial valleys and steep slopes (>30%) of thin erodible sandy soils (Sanfiorenzo-Barnhard et al., 2009), and using intensive methods reliant on high levels of inputs (García-Barrios et al., 2009a). The establishment of land rights also encouraged deforestation in the basin (Brunel and García-Barrios, 2011). This trend for farming marginal areas would continue in the following decades, but for different reasons.

In Villaflores in 1980, maize was still predominant while cattle-farming was a marginal emerging activity, because there was not enough capital or credit to invest in cattle (Aguilar-Martinez, 2007). Chemical inputs for maize and beans were intensively used on steep slopes (García-Barrios et al., 2009c) and fallow was often reduced (Sanfiorenzo-Barnhard et al., 2009) causing soil erosion.

Between 1994 and 2003, the area of maize cultivation in Chiapas increased by 32,000 ha and the output grew nearly by one third. These increments paradoxically came together with a relocation of maize production to low productive areas from highly productive ones that were used for cattle (Villafuerte Solís, 2005). Cattle started to be subsidised by the national programme to encourage cattle productivity (PROGAN, managed by SAGARPA) since 2003, of which Chiapas is the second largest beneficiary (Rodríguez Gómez, 2008).

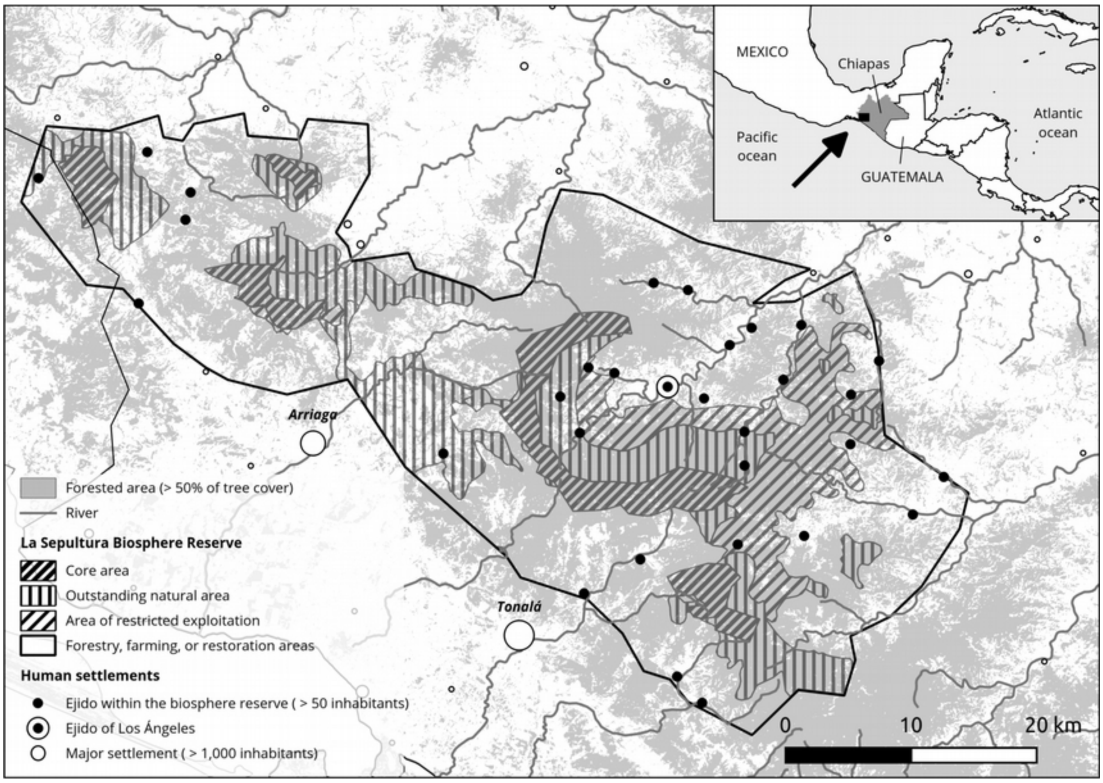
According to local inhabitants of the ejido of Los Ángeles (Aguilar-Martinez, 2007), in the last two decades of the century, water flows in Tablón river and feeding streams diminished, and so did wild animals and plants. Although quantitative information on vegetation reversal in the area is inconclusive and there is a lack of long-term monitoring on fauna, both tendencies were presumably mitigated in the early 2000s due to diminished fire practices (Aguilar-Martinez, 2007) induced by the protection of the area.

4.3.1. The protection of La Sepultura Biosphere Reserve and its effects

Between 1970 and 1993, among the areas currently protected in Chiapas, the surface covered by La Sepultura Biosphere reserve (REBISE, Figure 4.1) in the north of Sierra Madre, suffered the highest rate of transformation of natural vegetation. Transformations were of 3,848 ha/year and a yearly rate of 2%, driven mainly by slash-and-burn, logging, and agricultural expansion (March and Flamenco, 1996, in Aguilar-Martinez, 2007). In the 1990s in Sierra Madre, both NAFTA and the creation of REBISE posed drivers that pushed forest dynamics in different directions (Valdivieso-Pérez, 2011).

The government of Chiapas declared REBISE a conservation area in 1993. However, this was not made official (Rico García-Amado, 2008) until 1995, when SEMARNAT declared it a Biosphere Reserve—IUCN category VI-Ia with 167,309 ha, of which 13,759 ha are in buffer zone (INE, 1999, Rico García-Amado, 2008). The ejido of Los Ángeles was included within the buffer area defined as *'natural area subject to forest exploitation'* (Figure 4.1). This category allows moderate land use while conserving habitat for wildlife (Aguilar-Martinez, 2007), with the function of minimising impact to the core area (Sanfiorenzo-Barnhard et al., 2009).

Figure 4.1: Location and zonification of La Sepultura Biosphere Reserve in Chiapas, Mexico



Sources: CONANP (2015), CONABIO (2015), and Hansen et al. (2013). Built with QGIS (QGIS Development Team, 2014).

The protection of the area formally limited farming expansion and prohibited fire use for land management. Farmers kept their land with further management restrictions, including the prohibition of hunting, fishing, deforesting, and transforming land-cover in areas of secondary vegetation older than ten years (Valdivieso-Pérez, 2011), although this is occasionally breached (García-Barrios et al., 2009c). The managers of the reserve (from CONANP) are responsible for developing a strategy for sustainable livelihoods, however with limited resources (García-Barrios et al., 2009c). Management restrictions generated some initial tensions with local dwellers (Rico García-Amado et al., 2013) and, although curtailments have been increasingly accepted (Castro-Hernandez et al., 2003, in Rico García-Amado et al., 2013), many farmers still think that the protection is a disadvantage (Jackson et al., 2012).

The declaration of the reserve had a clear impact in land use during the following years because no forest was cleared for maize plots. New plots were established only in areas that had secondary land uses already (Valdivieso, 2008, in García-Barrios et al., 2009a). Slash-and-burn was common practice up to then, and its prohibition further contributed to the shift towards cattle-farming (Aguilar-Martinez, 2007). Cattle was then combined with maize by letting animals browse stubble in cropland after harvest (Galván-Miyoshi et al., 2009).

The area also begun to attract international NGOs and academic institutions with projects to promote conservation and development (Richter, 2000). These projects included organic coffee and palm production (*Chamaedorea quetzalteca*), sustainable timber extraction, community fire control (Speelman et al., 2014), and sustainable cattle-farming.

By the year 2000 in REBISE, agricultural land, secondary vegetation, pasture, and grassland had displaced many forests, mostly conifer, and secondary vegetation had increased overall (Aguilar-Martinez, 2007). As a result, a study detected that, in 2002, 13% of the area was transformed by recent human activities, and 2% of the total area had been modified since 1993 (Figueroa and Sanchez-Cordero, 2008). This rate of change was very high and much higher than that of other protected areas of similar characteristics elsewhere in Mexico (Figueroa et al., 2009).

By 2003, REBISE was considered a non-effective reserve in terms of avoiding land cover change (Figueroa and Sanchez-Cordero, 2008). The same authors categorised it in the lowest quartile in terms of effectiveness among 69 natural protected areas of Mexico. Between 1995 and 2005, a study found that more than 20% of the flammable areas in the protected area suffered fires, which put REBISE second in the ranking of fires in protected areas in Chiapas (Román-Cuesta and Martínez-Vilalta, 2006).

4.3.2. The raise of cattle-farming

The impact of cattle expansion in Chiapas brought two main landscape changes (Aguilar-Martinez, 2007): the displacement of staple crops from the central productive valleys and the expansion of farming towards mountainous forests, causing deforestation and erosion of steep soils.

Since 1980 cattle-farming started to replace maize cultivation in mountain ejidos such as Los Ángeles, however it was not until the 1990s when cattle increased importantly due to raised subsidies and credit for rural development (Aguilar-Martinez, 2007), leading to an inflexion in the importance of maize. Between 1990 and 1995, land for maize reduced and in 1995 the cost of buying fertiliser peaked above the return from selling its product (Aguilar-Martinez, 2007). Maize cropland was then commonly converted to pasture.

Between 2000 and 2005 the national programme PROCAMPO supported cattle purchase, and its twin programme PROGAN now promotes the expansion and improvement of cattle herds. Cattle-farmers got help from *Banrural* (for access to credit), PROCAMPO, COPLADEM and PROGAN programmes (Aguilar-Martinez, 2007).[29] In 2008, the number of cows in Los Ángeles had grown exponentially to 1,970 (PROGAN, 2008, in Valdivieso-Pérez, 2011), twenty times more than in 1980 (Aguilar-Martinez, 2007) and more than twice the number of inhabitants (Trujillo-Vázquez, 2009). Aguilar-Martinez (2007) argues that without the external incentives mentioned above, cattle-farming would have not grown to the current extent, and further suggests that programmes failed to help farmers develop a sustainable management strategy, thus encouraging practices that degrade the ecosystem.

The introduction of cattle meant that fallow was converted into grassland (Sanfiorenzo-Barnhard et al., 2009) and in 2009, rangelands covered 70% of the

[29] See acronyms in page 20.

cleared land in Los Ángeles (García-Barrios et al., 2009c). As practised currently, the impact of cattle-farming on land is dispersed and hard to control because, in contrast to humans cultivating and affecting delimited plots of land, cows may graze freely, precluding tree sapling recruitment, compacting soil, and eroding slopes. Sanfiorenzo-Barnhard et al. (2009) for example, observed low numbers of tree sapling in less dense forests, suggesting that this may be caused by cattle browsing as well as by farmers cutting small and medium trees since the extraction of adult trees is prohibited under protection rules. In the long term, soil erosion and the reduction of saplings may continue degrading the forest, even under the current protection.

4.4. Final words about recent transformations

In synthesis, two main land-use transitions occurred in the last fifty years in the Tablón basin (Valdivieso-Pérez et al., 2012): from mature forest to maize crop, and from maize to pasture. According to a study by Valdivieso-Pérez (2011), the first transformation reduced soil quality mostly in ravines, because their higher slopes favour sediment dragging, while lower slopes in ridges favour accumulation of stubble, manure, and other farming residues that enrich the soil. The impact of the second transition on soil quality is unclear and mediated by geographical conditions; it reduced soil quality in ridges, but no effect was found in ravines, arguably because the former are more accessible to animals (Valdivieso-Pérez, 2011).

Rural dwellers experiment with new activities and diversify in an effort to maintain or increase their earnings and future security. Ongoing land-use transformations reflect this survival strategy (Ribeiro Palacios et al., 2013). The two main land-use transitions are rather recent and arose or intensified owing to the socio-economic factors described above: trade policies, government subsidies, and opportunities for alternative livelihoods such as migration.

García-Barrios (2012) describes current livelihoods as unstable equilibria and with high risk of social and environmental degradation. However, the countryside, rather than being in *"terminal decline"* (Villafuerte Solís, 2005, p.461), is a complex system with multiple slow and fast drivers where large and highly dynamic populations live and swing their livelihoods in a continuous pulse with ecosystems in transformation and with changing macroeconomic and political conditions.

Nowadays, diversity emerges as a livelihood strategy to increase adaptability and resilience in a changing environment, and is common in Mexican rural livelihoods; off-farm sources of income (including subsidies and remittances) are present in 98% of households (de Grammont, 2006, in Galván-Miyoshi et al., 2009). It is argued that this diversification is only transitory while converting from primary to other sectors (Hymer and Resnik, 1968, in Galván-Miyoshi et al., 2009) yet this transition might not apply to Mexico (Galván-Miyoshi et al., 2009).

Within this diversity, the preferred activity in the case study area is cattle-farming and, where biophysical resources are appropriate, also shade coffee. Farmers shaped this strong preference after over five decades in which their livelihoods have wandered, moved by the above drivers. Cattle-farming is thus a rather robust preference currently, which may also stay for a few decades. This is because global meat demand is rising, and cattle is more resilient to variability in prices of external inputs and in weather than agriculture. The drivers of this preference are empirically analysed in Chapters 8 and 9. Prior to this analysis, the case study is described in detail next.

Chapter 5. Case study: silvopasture adoption in La Sepultura Biosphere Reserve, Chiapas (Mexico)

Mexico stands out for its high biodiversity as well as high deforestation rates during the last decades: it is among the top ten in both rankings worldwide (FAO, 2010; World Resources, 2005). In southernmost Mexico and within the neotropical range, the state of Chiapas takes up less than 4% of Mexican land, but is the second most biodiverse state with over 4,500 species of plants and over 1,000 species of vertebrates (Llorente-Bousquets and Ocegueda, 2008). The state presents ecological, geological, and resource extraction patterns that are similar to those of the rest of Central America, and is also the poorest in Mexico, with a high percentage of subsistence farming (Richter, 2000).

Chiapas also suffered one of the highest rates of deforestation in Mexico recently and there is little evidence of a forest transition leading to forest recovery (Galván-Miyoshi et al., 2009; Vaca et al., 2012). Rural areas are not being abandoned, and diverse farming systems are not being replaced by large-scale specialisation (Galván-Miyoshi et al., 2009). The absence of this transition is due, among other reasons, to the lack of employment in urban areas, to the abundance of external payments that reduce the need for migration, and to the strong preference for cattle-farming, as became clear in Chapter 4.

Farmer preferences respond to their vulnerabilities as well as to international demand, and changing these drivers may be a monumental task. Therefore a realistic environmental policy may aim to find ways of making this preference happen in a sustainable manner, and silvopasture emerges as a suitable ingredient for such management (Broom, 2013). One of the main areas where pilot projects to encourage silvopasture are being implemented is in Latin America (Calle et al., 2009; Frey et al., 2012; Pagiola et al., 2007), and with particular emphasis in Central America, to which the southernmost part of Mexico belongs ecologically. The theoretical background in Part I poses that, to understand the impact of perspectives and livelihoods in decision-making to adopt SPS, an in-depth analysis of a case study may provide best results. Thus the thesis now turns its focus to analyse one representative example of such projects.

In order to situate the posterior empirical analysis and to understand the interpretation and discussion of results in the final chapters, next I synthesise the characteristics of the social-ecological system (SES) in the ejido of Los Ángeles in the tropical forest frontier in Chiapas, Mexico. In this location a pilot project to encourage silvopastoral systems (SPS) has been implemented by a regional research centre (El Colegio de la Frontera Sur, ECOSUR) since 2005. The choice of this case study is partially motivated in connection to this project and the adequacy and representativeness of the case is further justified below (Section 5.1). The text below connects the history narrated in Chapter 4 with the contemporary picture (Section 5.2), and gathers suggestions that a number of authors who study this particular area recommend for incentive policies to promote a transition to sustainagile SES (Section 5.3). The aim is to contribute to an optimistic yet realistic prospective that envisions how humans can reshape their livelihoods to keep functional biodiverse ecosystems and simultaneously sustain themselves. This contribution gives foundation to discuss the third main question of the thesis, on how to encourage sustainable land uses. I then explain how the silvopastoral project under study was implemented (Section 5.4), and discuss whether the factors identified in Chapter 3 were favourable in this implementation.

5.1. Why the case of La Sepultura Biosphere Reserve

The pilot project to encourage SPS carried out by ECOSUR is an adequate case to analyse heterogeneity in depth at the micro scale. It is a straightforward intervention where the intended activity to adopt is simple: planting native fodder trees in open rangeland. The level of adoption was appropriately monitored and provides ample variability. Thus it is appropriate to analyse the reasons why the programme success has been variable, focusing on livelihood strategies and on the interaction of subsidies as key factors. This encompasses an appropriate case study to understand hindrances and motivations to adoption, and to discuss how policy could encourage it. The following key reasons support the selection of this case:

(a) The tropical regions in Latin America are a major focus for PES and agroforestry programmes and it is anticipated that these and other voluntary programmes may be a main form of conservation intervention in the following decade.

(b) Mexico is a representative megadiverse country, with a high level of poverty, inequality, and subsistence farming, and its economy is largely based on the exploitation of natural resources. Eighty percent of rural population in Mexico is in tropical and temperate forest ecosystems, mostly concentrated in southern mountainous areas, which are also poorest and most ethnically and biologically diverse (Galván-Miyoshi et al., 2009).

(c) La Sepultura Biosphere Reserve (REBISE; Figure 4.1, p.121) is a typical social-ecological system confronting the dilemma between environmental conservation and livelihoods in rural low-income and biodiversity-rich areas. It is a clear example of the buffer area of a protected tropical forest where intensive, small-scale and non traditional farming land uses lead to forest degradation and risk biodiversity conservation objectives. Buffer areas are at the interface of areas of high natural interest that are kept in reasonable wilderness, and areas of human activity where conservation is a secondary priority.

(d) The history of the community reflects the history of many others in Mexico, affected by important political and macroeconomic changes in the country (as narrated in Chapter 4).

(e) Several external projects for different environmental purposes have been implemented in this location with highly variable success.

Finally, (f) a number of research projects track and document the trajectory of the area in the last decades (Aguilar-Cordero, 2008; Aguilar-Jiménez, 2008; Aguilar-Martinez, 2007; Oleta-Barrios et al., 2013; Ribeiro Palacios et al., 2013; Rico García-Amado et al., 2012; Sanfiorenzo-Barnhard et al., 2009; Speelman and García-Barrios, 2010; Toupet, 2010; Valdivieso-Pérez et al., 2012). This ongoing presence of researchers and the SPS programme at ECOSUR facilitated logistics, contact, and trust with the community during the data collection.

This case study concretises the conceptual framework described in Figure 2.1 (p.48). The ecosystem affected is the buffer area of the tropical forest, where distinct land uses are undertaken as a derivation of livelihood decisions. These land uses are predominantly agricultural (maize, beans, coffee), cattle-farming, and to a lesser extent, extraction of forest products (the full range of activities is shown in Figure 6.3, p.167). Livelihood decisions generate income obtained from a number of sources, including on-farm, and off-farm (commerce, wage labour, migration remittances, and subsidies). For simplicity, it is assumed that livelihood decisions are made by the head of the household. These decisions are affected by internal variables, which mediate external variables such as land tenure, available capital, level of education, etc. Finally, external policies for farm expansion (e.g. PROGAN), for conservation (e.g. PESH), or for development (e.g. *'Oportunidades'*) affect both the income received, and the livelihood decisions of the following year. Thus, in order to comprehend the impact of an external intervention in the adoption of an innovative land use such as SPS, it is important to understand how external and internal factors affect livelihood decisions.

Next in this chapter, I describe the current picture of the case study, which is the result of recent dynamics of environmental and macroeconomic changes, both at local and global levels, whose genesis was explained in the previous chapter. Understanding the origins of this cross-section facilitates the analysis and discussions of actions towards sustainable scenarios.

5.2. The social-ecological system in the ejido of Los Ángeles

Sierra Madre is a forested mountain range in the west of Chiapas that stems off the Andean spine from Central America. A combination of a wide range of altitudes across the range (highest elevation of 4,092 m above sea level in Tacaná volcano) and differences between sea-oriented and inland-oriented faces support a world-class life diversity with over 2,000 plant species (Schroth et al., 2009). Sierra Madre lies mostly over a granite massif with occasional metamorphic outcrops. Further geological and pedological details are given in Valdivieso-Pérez (2011) and Rico García-Amado (2008).

Current environmental changes in Sierra Madre are similar to those in mountainous areas elsewhere in Central America; farming land is being degraded and the provision of ecosystem services reduced. This change is fed by intensifying population pressure polarised between large-scale landowners and small-scale subsistence farmers (Richter, 2000).

Laying in the north of Sierra Madre, REBISE has subhumid temperate climate (Jackson et al., 2012) with rainy season between June and September, annual rainfall of 2,000-2,500mm, and a temperature range of 16-28ºC (Valdivieso-Pérez, 2011). Altitudes range between 40-2,550 m above sea level, and the streams therein pour both to the Pacific and to the Atlantic oceans. The reserve covers a wide range of ecosystems (Jackson et al., 2012; Rico García-Amado, 2008; Sanfiorenzo-Barnhard et al., 2009), including tropical montane cloud forest that provides essential hydrological services, and which is the most threatened ecosystem in Mexico (CONABIO, 2010). Narrow valleys with frequent slopes higher than 45º shape the steep topography and so it is highly prone to landslides and soil erosion (Toupet, 2010).

Within the reserve, 5% of the land is state-owned and the rest is almost equally distributed among *ejido* lands and small private landowners, who total over 23,000 inhabitants (Sanfiorenzo-Barnhard et al., 2009). The core area of the reserve has a population of 8,500 inhabitants, 45% of the land belongs to *ejidos*, and the rest is state owned (CONANP, 2003 and INEGI, 2011, in Rico García-Amado et al., 2013).

In the buffer zone of the reserve, the lower areas and south-oriented slopes are highly deforested and surroundings of human settlements are very transformed (see Figure 4.1, p.121). Land undergoes a process of degradation due to unsustainably managed activities that include annual rain-fed maize and bean cultivation, and cattle grazing in crops, pastures, and forest margins (Jackson et al., 2012). These activities often lead to soil erosion and compaction on cleared steep land (Valdivieso-Pérez et al., 2012), which in consequence lose their capability to buffer wildlife habitat and risk future productivity.

The Tablón river flows from west to east of REBISE between narrow valleys surrounded by highly valuable alluvial soils and a rugged relief that results in abundant microclimates (Trujillo-Vázquez, 2009). The upper Tablón river forms the largest basin in REBISE and provides water for the central valleys of La Frailesca (Sanfiorenzo-Barnhard et al., 2009), the main farming area in Chiapas. The basin has a relatively dense population and its landscape is highly shaped by human activity (García-Barrios et al., 2009b).

Among the various ejidos in the buffer area, Los Ángeles is a representative one. It has a population of 831 people (Trujillo-Vázquez, 2009) distributed in approximately two hundred households and is the largest ejido in REBISE (Sanfiorenzo-Barnhard et al., 2009). It lays in in the upper area of Tablón river watershed, entirely within the buffer area of the reserve, and within the municipality of Villaflores. In this municipality, rural population continues to grow and remains highly dispersed (Galván-Miyoshi et al., 2009).

5.2.1. Land regime and governance

Land property in the ejido of Los Ángeles is a hybrid between traditional communal lands, and tacitly acknowledged private land ownership (see definition of ejidos in Section 4.1.2). Right-holding heads of households gather and vote in the ejidal assembly, which governs land-use matters.

In practice, land is managed as private property that can be rented or sold to anyone—including to non members of the ejido, subject to assembly approval. Land price is often set as the estimated estate price, plus the present and expected earnings from government subsidies for agriculture (PROCAMPO) that correspond to the hectares sold. These two concepts may also be separated in practice, resulting in a plot being sold but the former owner still receiving the agricultural subsidy attached to that land (ejido member, p. c.).

Land distribution has changed remarkably since the ejido was founded in the 1960s, leading to much of it being concentrated in a few families: the declared land owned per family is on average less than 30 ha, but most families have less than 10 ha and about 10 families have more than 100 ha, according to the data collected for this study. The lack of formally documented private land tenure and of precise plot measurements adds further uncertainty to this regime.

The actor context around land use and conservation in REBISE includes small and medium farmers and cattle-farmers congregated in the ejidal assembly and in groups such as the Cattle-farming Association (CFA), national government agencies that promote farming expansion, the municipal authority in Villaflores, conservation NGOs, and CONANP (Brunel and García-Barrios, 2011). CONANP has an office on-site that is responsible for coordinating conservation efforts in the reserve and for distributing public funding via projects. Their activity is mostly focused on fire control.

The main authority in the community in Los Ángeles is the ejidal assembly, composed of heads of household that founded the ejido or their heirs. Heads of households in the ejido are distributed among full-right *ejidatarios* (43%, 9% of which are women); *pobladores* (40%) with no right to vote in the ejidal assembly, no right to communal lands, and who usually purchase or inherit land; and landless *avecindados* (37%) who arrived later to the ejido.[30] A dense associative network includes a number of religious congregations, and a number of groups that participate in farming or development projects, such as coffee-farming or plant nursery.

5.2.2. Livelihoods and cattle-farming

Currently, predominant livelihood activities include the production of maize and beans, cattle-farming, and shade coffee. The latter is highly profitable and maintains forest cover, but is limited to farmers who own land of certain

[30] The assembly decides on issues such as how to distribute external payments provided to the ejido as a whole (including the national scheme of PESH), their participation in projects offered externally, or whether they allow land to be sold to newcomers. Most assembly members are male, and there is an equivalent women's assembly that deals primarily with *Oportunidades* subsidies.

characteristics at the highest altitudes of the ejido. The mountainous topography in the area favours cattle-farming in comparison to agriculture and forestry, for which difficult accessibility and slopes pose a major obstacle (Rosales and Bussink, 2001 in Aguilar-Martinez, 2007).

Although there are remarkable opinion differences among cattle-farmers about the activity itself, this is a preferential activity in the ejido almost unanimously (Brunel and García-Barrios, 2011). If households get better off, the tendency is to increase cattle-farming in absolute and in proportional terms, thus intensifying landscape degradation in the absence of sustainable management.

One of the key reasons for preferring cattle-farming is that it is currently perceived as a less risky activity than cash-crop agriculture. The latter is highly dependent on rainfall and on the price of chemical inputs, although this preference is heavily influenced by international market prices (García-Barrios et al., 2009a). In comparison to agriculture, cattle-farming requires less investment, provides capital to sustain families and to pay for education, it has lower risk, and it may be carried out in less productive lands (García-Barrios, 2012). It is also less dependent on external inputs than modern agriculture (Hernández et al., 2000 in Aguilar-Martinez, 2007). Extensive cattle-farming arguably requires less effort than maize and is more adaptable to variations in labour and capital availability (Galván-Miyoshi et al., 2009), which allows dedication to seasonal labour demands from agriculture. In addition, land is less limiting for cattle-farming than for agriculture in an ejidal context because animals can graze in communal areas (Aguilar-Martinez, 2007).

Aguilar-Martínez (2007) describes in detail the cattle-farming practices in Los Ángeles. During most of the year, cattle graze in pastureland. Maize is sown in June and July after the rain season begins, and is harvested between November and January. Between March and May, cattle enter maize cropland to feed on stubble and to fertilise the land with mulch. Almost half of the cattle-farmers use only natural pastureland, 75% do not give additional feed to cattle—such as ground stubble or maize—and only 5% use fodder bundles (Aguilar-Martinez, 2007). In 2007, it was still relatively common to manage pastures with slash-and-burn (Sanfiorenzo-Barnhard et al., 2009).

The products from cattle-farming in Los Ángeles are calves to be grown for meat and milk products, and they are occasionally used as currency—as savings or investment (Galván-Miyoshi et al., 2009)—or to celebrate important events. According to a 2007 study (Aguilar-Martinez, 2007) young male cows were sold at 18 MXN/kg (~1.5USD), with a weight ranging between 180-200 kg. The sale of such an animal for 3,600 MXN (~300 USD) is comparable to the lowest annual household income level identified in the community in this study. Most cattle-farmers milk their cows only in rain season, providing an average of 5 litres per day. The litre of milk is sold locally at 3 MXN (~0.35 USD), and the remaining milk is used for fresh cheese production, sold at a price of 30 and 35 MXN/kg (~2.5 and 3 USD) in rain and in dry season respectively.

Finding feed in the dry season is perceived almost unanimously as the main problem of cattle-farming, and farmers often address this problem by letting cattle browse freely in the forest (Brunel and García-Barrios, 2011). According to experts interviewed by Aguilar-Martinez (2007), other major problems of cattle-farming in REBISE are the low technical development, inappropriate management of pastureland, and the lack of external support such as credit, training, and technical assistance. The lack of infrastructure and of access to markets may also be seen as a problem (García-Barrios, 2012).

5.2.3. Cattle-farming and land cover

Surroundings of the settlement are a mosaic of pasture, cropland, and forest patches (Aguilar-Martinez, 2007), which reflect the diversity of livelihoods emerged from recent history (García-Barrios, 2012). Current cattle-farming practices involve animals stepping frequently on steep land with little tree cover (see Figure 5.1) and subject to strong seasonal rainfall. Steps cause soil compaction and strong rainfall on uncovered soil causes the loss of organic layers and nutrient lixiviation (Roman et al., 2007, in Valdivieso-Pérez et al., 2012). The stepping and slipping of cattle on slopes also contributes to erosion by generating a slow movement of soil from upper to lower areas, and silt is finally transported by streams into the valleys.

Figure 5.1: View of an ejido in La Sepultura Biosphere Reserve

The lack of vegetation and trails created by cattle in the surroundings of the ejido can be observed.

Lack of vegetation that holds the soil increases the likely magnitude of the impact of extreme natural perturbations, such as floods and landslides. This lack also reduces water availability due to higher evapotranspiration and diminishes shade for cattle.

From all the pastureland in the ejido, 76% is located in steep slopes (Aguilar-Martinez, 2007). The amount of organic matter in the topsoil is significantly higher for forest, lower in maize, and lowest in pastureland (Valdivieso-Pérez et al., 2012). The types of pastureland in the ejido range in a gradient from totally unforested and overgrazed open grasslands, to rangelands with high tree density (Aguilar-Martinez, 2007). The former predominate, covering 41% of the ejido area (Sanfiorenzo-Barnhard et al., 2009).[31] Aguilar-Martínez (2007) reports the analysis of a sample of pastures, of which 80% are overgrazed and/or compacted, and almost one third are eroded.

[31] Sanfiorenzo-Barnhard et al. (2009) also identify four types of pastureland in the ejido according to tree cover percentages: open pastures, shrubby pastures, woody pastures and forested pastures.

More than 70% of the farming plots are surrounded by open vegetation (Aguilar-Martinez, 2007), which indicates some level of degradation. Fodder trees can complement cattle feed and diminish erosion, yet their presence is very low (Trujillo-Vázquez, 2009). The trees found in pastures have the following uses: 28% for wood, 28% for live fencing, and a small percentage of fruit and fodder trees (3%; Aguilar-Martinez, 2007). There is evidence about forest-grazing preventing the growth of saplings (García-Barrios et al., 2009a), suggesting that free browsing in the forest may impede natural tree-replacement, and thus cause future deforestation.

Farmers believe that there is less grass in forested pastures, which are used only when open pastures are exhausted (Sanfiorenzo-Barnhard et al., 2009). According to farmers, various reasons compete for the maintenance or elimination of trees in pasture (Sanfiorenzo-Barnhard et al., 2009). In favour of keeping trees are their value as shade (e.g. *Ficus sp.*, *Enterolobium cyclocarpum*), fodder (e.g. *Guazuma ulmifolia*, *Enterolobium cyclocarpum*, *Gliricidia sepium*, and *Erythrina goldamanii*), and wood and fences (e.g. *Quercus sp.*, *Gliricidia sepium*). Reasons against keeping trees are that these are cumbersome (e.g. *Acacia sp.*, due to its spines) or provide excess shade that reduce grass growth (e.g. *Vernonia leiocarpa*). A number of conservation programmes have been implemented that pay farmers to grow specific species of trees (e.g. *Jatropha sp.*).

5.2.4. A complex setting of external payments

The Mexican case of subsidies and market-based conservation instruments is complex because of the high diversity of government programmes directed to a wide range of purposes, both for development and for sustainability. The last few decades brought a period of subsidy abundance (Chapter 4), which poses two general livelihood options: using the subsidies for developing self-sustaining livelihood businesses, or for immediate consumption with no behavioural change.

In the case study many schemes are available, such as for cattle and agricultural extension, carbon capture projects, and hydrological services (PESH; data from Chapter 6). All but carbon-capture projects are government-led nationwide programmes, and the payment distribution and conditionality are variable, although these are generally homogeneous within each programme. The following are subsidies regularly received in Los Ángeles:[32]

— '*Oportunidades*', from the national secretariat for social development (SEDESOL) separated into '*70 y más*' for the elderly, '*Amanecer*' for the youth.
— *'Aconcafé',* for ~30 coffee producers.
— '*Maiz Solidario*'
— PESH,[33] PROARBOL, for forest conservation; both from the national commission on forestry (CONAFOR).
— *'Ambio'* for carbon capture credits, private organisation.
— PROGAN, PROCAMPO, for farming development; both from the department of agriculture, livestock, rural development, fisheries, and food (SAGARPA; see their introduction in Sections 4.2.1 and 4.3 respectively).
— City council programmes (Head of CONANP at REBISE, p.c.).
— PROCODES, national programme for conservation towards sustainable development; managed by the national commission on protected areas (CONANP; see Section 4.2.1).

In Los Ángeles, 57 cattle-farmers benefited from PROGAN in 2007 (Aguilar-Martinez, 2007) and in 2010 there were 59 cattle-farmers recorded in the census with nearly 2,000 heads of cattle (compared to 83 out of a sample of 103 heads of households, about half of the community, declared having cattle; own data). This programme is managed by SAGARPA and it pays 375 MXN (~30 USD) for adult female cows per year to individual farmers, with a minimum of 5 and a maximum of 60 head. It requires that beneficiaries participate in support programmes, such as parasite-treatments and vaccines (CFA president, p.c.). The programme uses the same

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32 See acronyms in page 20.

33 The ejido has 916 ha included in the PSAH programme (approximately 20% of the area), which pays 281,100 MXN annually (Rico García-Amado et al., 2013). The ejido assembly receives the payment and decides how to distribute it. In the case of Los Ángeles, PESH are distributed to all households based on their status: *ejidatario,* 2,000 MXN/year; *poblador,* 1,000 MXN/year; and *avecindado,* 400 MXN/year (Chair of the ejidal assembly, p.c.). Surveillance rounds to monitor and comply with PSAH requirements are allocated to everyone. The quantity of land owned, forest cover, or the participation in surveillance are not criteria for distributing the payments in this ejido.

rules uniformly across Mexico, including within protected areas thus it does not formally adapt to local conditions (Aguilar-Martinez, 2007). PROGAN promotes mostly extensive cattle-farming and reportedly, its main purposes are health control and keeping an up-to-date census of herds, production, and commercialisation (Aguilar-Martinez, 2007).

Programmes for environmental conservation vary in their market orientation, for example: established markets for carbon capture, programmes with indirect benefits such as fodder trees, and those exclusively for conservation that do not provide benefits in conventional markets. Most of these are managed by CONAFOR (Rico García-Amado et al., 2013). There are frequent misconceptions among recipients about the real terms of conservation programmes that provide income. For example, a participant of a carbon capture programme to plant *Jatropha sp.* expressed that he hoped that the programme managers would let him cut down the plants after five years in order to sell them as wood posts (Head of household, p.c.). This illustrates the more general concerns about permanence of these programmes (Palmer, 2011).[34]

5.3. Prospectives to transition towards a sustainable social-ecological system

The future of Sierra Madre under climate change is expected to be warmer and drier, with more irregular precipitations and higher evapotranspiration, consequently increased water stress (Schroth et al., 2009). The same authors describe climate scenarios for the period 2040 to 2069, predicting an increase of over 2ºC and a decrease of precipitation of 2-5% in the coffee area of the mountain range. Potential

[34] Corruption in payment programmes is also a concern. Klooster (2003) describes corruption in Mexico in two forms: the signature of agreements under highly asymmetric power or capacities, and the mismanagement or appropriation of money by intermediaries. Despite limited investigation of the impact of corruption in the Mexican forestry and conservation context, a number of interviewees alluded to the latter form of corruption with regards to some external projects. This undermines the reliability of future projects and the trust of locals towards external agents.

changes in plant phenology could affect crops and pest and disease development (Schroth et al., 2009).

These changes might lead to further land-use transformations in detriment of forest, such as the abandonment of shade coffee or the expansion of pasture towards higher altitudes. Land transformations may be mediated by property regimes and conjunctural regulations, for example, if some land uses are hindered from moving to higher altitudes. In the challenge for adaptability, the vulnerability of small farmers can aggravate and further diversification of livelihoods could possibly occur (Schroth et al., 2009).

Several studies about the area suggest actions for improvement and adaptation towards sustainable systems. I present these recommendations in order to contextualise the role of SPS adoption programmes, like the one described in the next section. I group the suggestions into landscape level agroecological actions, the coordination of subsidies and programmes, and boosting social and human capacities (Table 5.1).

Table 5.1: Recommendations for a transition towards a sustainable social-ecological system in La Sepultura Biosphere Reserve

LANDSCAPE-LEVEL ACTIONS

— Reduce the accelerated trend of frequent land conversion derived from increasingly unstable livelihoods (Lambin and Meyfroidt, 2010; Ribeiro Palacios et al., 2013).

— Transform the landscape mosaic into **agrosilvopastoral systems** that suit the goals of the buffer zone (Sanfiorenzo-Barnhard et al., 2009).

— Undertake **specific ecological actions**: secure corridors, stabilise soil erosion (Jackson et al., 2012), and address the lack of sapling recruitment observed in pastureland and in grazed forests (Sanfiorenzo-Barnhard et al., 2009).

— Adopt **strategies to adapt to climate change**, including the use of varieties adapted to heat and drought, development of water-efficient systems, and abandonment of areas prone to floods and landslides (Schroth et al., 2009).

PAYMENTS AND SUBSIDIES

— **Coordinate** the range of **subsidies** to increase their consistency and compatibility, so that they lead towards the same direction of constructing sustainable landscapes in the buffer area (Jackson et al., 2012).

— Adapt or **redesign payment** programmes that encourage cattle-farming, in order to include sufficient resources to help farmers develop sustainable management strategies (Aguilar-Martinez, 2007).

SOCIAL AND HUMAN CAPACITY

— Strengthen **social networks** to encourage knowledge exchange on landscape practices and cattle-farming (Schroth et al., 2009), and to favour local resource management institutions rather than imposing new forms of economic restrictions (Bray and Klepeis, 2005).

— Understand and build **capacity among local stakeholders** to manage the landscape in an autonomous manner, and to engage in deliberations on development and adaptive land management with external agencies and NGOs (Brunel and García-Barrios, 2011; Jackson et al., 2012; Sanfiorenzo-Barnhard et al., 2009).

Literature about this local context also identifies several opportunities in terms of targeting policies to encourage transitions towards agroforestry systems, by focusing on farmers with highest impact, and/or with highest interest. For example, the impact of a farmer on soil erosion depends on cattle density, and on the area of pasture upstream and of water capture—areas that have more influence on the amount of surface water run-off (Toupet, 2010). However, those with highest impact are not necessarily the most interested. Some farmers show interest in innovative sustainable practices, and their active participation can be instrumental for transition policies (Sanfiorenzo-Barnhard et al., 2009).

5.4. The pilot project for planting fodder trees

In 2005, ECOSUR, a research institution based in San Cristobal de las Casas (about 120 km away from the case study), began a pilot voluntary and participatory programme for farmers to experiment with planting native fodder trees in small pasture plots of their own (see García-Barrios, 2012), and with monetary and non-monetary incentives (see chronology in Table 5.2).[35] This study is framed within an ongoing research agenda about implementation of SPS in REBISE (García-Barrios et al., 2009c; Speelman and García-Barrios, 2010). The silvopastoral project has been described and documented in detail (Trujillo-Vázquez, 2009), from which the following explanation largely draws. The aim of the project was to evaluate whether fodder-tree cultivation is ecologically and socially viable, the latter measured in terms of the interest and social and individual capacities of cattle-farmers, and of the institutions involved (Trujillo-Vázquez, 2009). The project was designed using participatory action-research, in which researchers facilitated organisation, but farmers themselves took the decisions.

[35] The study title is *"Participatory Project for the Development of Sustainable Silvopastoral Strategies in the Buffer Zone of La Sepultura Biosphere Reserve"*. Original title in Spanish: "*Diseño participativo y establecimiento de Sistemas Sustentables de Producción Agro-silvo-pastoril para la Conservación de suelo, agua y especies arbóreas*". The project is led by Luis Garcia-Barrios and assisted by Romeo Trujillo-Vázquez.

Table 5.2: Fodder tree planting project timeline (based on Trujillo-Vázquez, 2009)

2005 (end of): first visit and presentation.

2006:

- March: formal introduction to the community; expert talk about agroforestry.

2007:

- March 8-10: workshop on *"Participatory design of silvopastoral plots"* (26 producers attended), including raising awareness about soil degradation.
- March 26-30: workshop on *"Production of tropical tree seedlings in a communal nursery"*.
- June:
  - Evaluation of the performance of the nursery, distribution of seedlings and planting.
  - Practical workshop on "*Setting and monitoring agroforestry plantations in experimental silvopastoral modules*". 23 producers and another 22 producers organised by CONANP with the PET programme attended.
  - Workshop on "*Methods for assessing the ecological and social viability of silvopastoral modules*" to train staff for monitoring.
- November: First monitoring.
- November: Performance evaluation workshop based on the commitments set (58% of participants attended).

2008:

- January: Second evaluation workshop convened by the low turnout, includes also the programme of activities for the year 2008 (54% of participants attended).
- November: Second monitoring.
- December 4: Evaluation session of the second measurements (67% attendance).
- December 8: Meeting of the group without the technical staff.

In the first phase of the project, 22 individuals volunteered after an open call to the community. ECOSUR provided incentives in the form of training and fencing material without financial remuneration for participants. In the second phase, 68 farmers formally participated with 44 individual plots of up to three farmers per plot, and CONANP supported these efforts with additional material and cash payments.

5.4.1. Process

Between 2005 and 2006 at least two introductory events were organised: one to present the project, and a talk about agroforestry with an invited expert. In January 2007, ECOSUR obtained funding from the *Fondo Mixto-Chiapas* for the voluntary scheme. Participants decided on the species to grow—*Leucaena leucocephala*, *Guazuma ulmifolia* and *Erythrina Pithecellobiun goldamanii*—and organised a communal nursery to obtain seedlings. They also proposed *Gliricidia sepium*, which afterwards would give the best results. Seeds were collected locally between February and May 2007. Later on, only *L. leucocephala* and *G. sepium* were used. Participants selected plots of 20x20 m and in many cases, more than one participant shared one experimental plot. In May 2007 there were 22 plots, and in June the seedlings from the nursery were distributed and planted.

In August 2007, two months after the first group of 22 volunteers had planted the saplings, the CONANP officers entered the project. They considered the participatory implementation of silvopasture an appropriate model to incorporate in their strategy with livestock issues. Under joint institutional coordination, CONANP provided budget for fencing material for additional 22 farmers. CONANP encouraged the expansion of the project and the financial reward of participants, using funding from PET-PROCODES for temporal employment. They got the support from the ejido authority, which summoned producers urgently, and seedlings were distributed directly from other nurseries in the state. In sum, additional 22 plots were planted in August 2007 by a second group promoted by CONANP. In 2007, a total of 68 farmers grouped in 44 plots were participating.

Payments in cash were distributed at the participants' criteria. Farmers were required to plant the trees in order to receive incentives, but there was no real conditionality since the outcome in establishing fodder-tree plots did not influence the reward received. This was so because the project was intended as a pilot experience to be further developed afterwards.

At the beginning of 2008, the joint group organised a new nursery to replant trees where necessary, though participation in communal work was perceived unequal and many seedlings did not germinate or were defective. Some alternative species with different functions were also discussed, such as fruit trees, timber trees, or fodder grasses. Participants had to address two issues that emerged during tree growth: fertility problems were corrected with chemical fertilisers, and defoliating ants affected particularly *L. leucocephala*, which were controlled by means of limited application of insecticide.

5.4.2. Funding and monitoring

Funding distributed by CONANP was provided by two national programmes: PROCODES for conservation and development, and the Temporary Employment Programme (PET; Head of CONANP at REBISE, p.c.). The key figures of the project are shown in Table 5.3.

Table 5.3: Budget from CONANP for the fodder tree planting project

Project name	Soil rehabilitation for the productive use of silvopastoral systems*	Establishment and rehabilitation of agroforestry systems*	
Year	**Funding by PROCODES**	**Funding by PET**	**Number of beneficiaries**
2007	Unknown	Unknown (CONANP distributed this in Sept-Oct, two months after ECOSUR started the project)	ECOSUR, volunteers................22 CONANP, after monetary payments were introduced........22
2008	70,000 MXN *~6,000 USD* Divided equally among participants	Total.......................148,993 MXN *~12,500 USD* Distributed as: Wages (among the 44 people) ....104,000 MXN *~8,000 USD* Material..................37,493 MXN *~3,200 USD* Operation expenses....7,500 MXN *~635 USD*	44 (All from the previous year, managed as a single group)
2009	152,726 MXN *~10,800 USD* Officially for 17,5ha, although work was carried out in approximately 50ha.		68 (All managed as a single group)
2010	45,000 MXN *~3,500 USD* Reduced due to budget cuts in REBISE.		36+10 For a new volunteer project of ECOSUR. Another CONANP group was still to establish at the time of fieldwork.
TOTAL	**267,726 MXN** ***~20,300 USD***	**~150,000 MXN** ***~12,700 USD***	

Sources: Head of CONANP at REBISE, p.c., and Head of fodder tree project group, p.c. Approximate average exchange rate MXN/USD is used for each year.
** Original title in Spanish: "Recuperación del suelo para uso productivo de sistemas silvopastoriles" and "Establecimiento y recuperación de sistemas agroforestales" respectively.*

The initial project was on a voluntary basis without payments. CONANP assessed the budget available and later they estimated how much could be covered. In 2009 most of the budget was spent in fencing material and wages. Also in 2009 some farmers attended an exchange of silvopasture experiences outside of the ejido, with an additional budget of 40,000 MXN (~3,360 USD; Head of CONANP at REBISE, p.c.).

The process and results for each plot were monitored four times from June 2007 to November 2008, at the beginning and at the end of the rainy season of both years. The actions carried out to cultivate trees, the resulting number of trees, and their height and quality were monitored for each of the plots (Garcia-Barrios and Trujillo-Vázquez, Unpublished results). The involvement activities measured were: planting, fencing, and weeding (to protect saplings against weeds, desiccation, and cattle browsing). Tree growth was monitored during and at the end of the first year, thus within an early testing phase of the adoption process.

In the first detailed monitoring in November 2007, 2,093 trees were measured and the comparison between plots showed that performance was highly variable yet lower for the second group (Trujillo-Vázquez, 2009). In the second detailed monitoring in November 2008, 2,929 trees were measured. The specific micro environment in which plots were located significantly affected tree growth only in the case of the three plots in river valleys in shade (Trujillo-Vázquez, 2009).

In 2008, two new producers requested to participate, driven by fodder scarcity in dry season and arguing that they saw the benefits of the group in the previous year. They did not require any financial or material compensation.

The results of each producer were publicly presented in an evaluation session in December of 2008. During the same meeting, it transpired that the group decision-making was perceived difficult, thus the expansion of the group was deemed impracticable and further people could be integrated only if any current participant withdrew. New participants would be trained by the participants themselves. They argued that they had greater trust in their own nursery seedlings and that there was a remarkable difference in group trust over the previous year. However, in a later meeting in the same month, the group agreed further expansions: to include 25 more people, to increase the number of plots from 45 to 70, and to increase the size of the plots from 4.5 to 30 ha.

5.5. Final remarks about the fodder tree planting project

The implementation of this project thus fulfilled a number of the preconditions identified in Chapter 3 (Figure 3.2, p.80), from the factors influencing adoption. The project was participatory, and was developed with the aim of ensuring that factors related to the technology were favourable. These factors are technical feasibility, logistics and material incentives, and factors related to knowledge and information. Other factors present were the existence of networks and communication channels. The economically rational motives were made clear, but had the drawback of the time-length required for fodder trees to provide benefits, which contrasts with the short-term planning typical of low-income farmers. From the individual subjective characteristics, problem awareness was worked out through workshops, but not issues of risk, self-efficacy, or values. Certain social pressure was exerted through the group work in the nursery, and seemed to result in some game theoretical situations which are left aside of this study. Due to the ejido status, there were no major issues of land security at the time. The remaining factors vary across farmers: objective individual characteristics, perspectives, livelihoods and livelihood pathways, household income and labour, land endowment, and biophysical conditions of individual plots.

Thus far this and other fodder tree implementation projects in the area have had highly variable success in the involvement of participants, and tree outcomes are poor to date (Trujillo-Vázquez, 2009). There were contradictions between the height of *G. sepium* and the producers' view of the status of their plot. A farmer suggested that, had the two groups remained separated, results would have been better because that could have eased management and created certain sense of competition. The reasons behind the highly variable degree of involvement are unclear and scarcely related to standard socio-economic variables (Trujillo-Vázquez, 2009).

Studying a pilot project allows to approximately control for some of the cost-related factors considered important in determining adoption (Mercer, 2004), such as access to markets, credit, or market-prices. Even though these costs can be considered rather uniform in this case, the success level was still highly variable, and this variability enables studying other underlying factors influencing behaviour. A prior assessment of this project suggests that a number of conditions from those identified in the literature are already in place, thus the variability in adoption could be explained by individual characteristics, which makes it an appropriate study-case. The next part presents the methods employed to empirically understand livelihoods and adoption of SPS in order to help us explain this varying degree of adoption.

Summary of Part II

This part of the thesis provides details about the case study and its recent social-environmental history, following the theoretical background provided in Part I and in order to design and understand the posterior empirical study. Chapter 4 explains the recent transformations at the national and local levels that originate the current picture of the case study, described in Chapter 5. Decisions are pathway-dependent, a pathway that is narrated and which sets the background to understand the causes of the current situation, its trends, and plausible futures.

In the last half of the century, two main land-use transitions took place in forests of the southern frontier in Mexico (many of which were similar in forest frontiers across Central America): from primary forests to maize crops, and from maize to pasture. The first one occurred after the 1950s, when the frontier was populated through ejidos. The change was driven by national policies oriented to food production and self-sufficiency first, which led to a commodity boom fuelled by subsidies and agrochemical inputs. The productivity gap increased between traditional subsistence agriculture and modern farming. In the latter, the (ab)use of external inputs led to soil degradation due to draining of nutrients and to exploiting poorer soils. Increasing dependence on external inputs also introduced a new source of vulnerability to local livelihoods, in the form of debt when the yield was scant.

In the 1980s, a shift in the national focus (from food production to paying external debt) brought radical changes to livelihoods; subsidies for agriculture vanished and food imports increased. Soon after, maize ceased to be a safe choice and livelihoods started to incorporate other activities (including more off-farm) and to diversify, seeking resilience.

The second major land-use transition came: from maize to pasture. Cattle farming boomed in the late 1990s, driven by increased demand, higher resilience of the output to both climatic and macroeconomic perturbations, and substantial temporary migration to the US that provided capital for the initial investment. Approximately at the same time, a *subsidy boom* began, with no clear coordination across their miscellaneous goals.

At the local level, livelihoods drifted and ecosystems transformed, following these forces from the macro scale. To illustrate these, Chapter 5 justifies and describes the social-ecological system chosen for this study, covering the main topics in the conceptual framework depicted in Figure 2.1 (p.48). These are the social-ecological system, land regime and land uses, livelihoods and their environmental impact, and the context of subsidies.

Los Ángeles is a representative ejido in a mountainous protected tropical forest in Chiapas, southernmost Mexico. Land property regime is hybrid between traditional communal lands, and tacitly acknowledged private ownership. Unsustainably managed farming and cattle-farming—free animals grazing in steep deforested slopes—risk the buffering capability of the ecosystem. Since 2005, a regional research institution, ECOSUR, implemented a pilot participatory project to encourage volunteers to plant native fodder trees in small plots of their own. They provided incentives in 2007 in the form of fencing material and training to 22 initial participants. Later, CONANP supported these efforts with additional material and payments, and in 2009, 68 farmers grouped in 44 plots participated. Rewards had no ex-post conditionality. Researchers at ECOSUR measured tree outcomes and found highly variable results.

If—according to the goals set in Chapter 2—the SES under study is to become *sustainagile*, it is imperative that the core ecosystem functions are maintained. Given current preferences and practices in favour of cattle-farming, the fundamental functions of the soil are at risk (Section 4.2) and a policy intervention could help transitioning towards more sustainable land management (Section 4.4). Such an intervention requires a deeper understanding of livelihood decisions and the rest of the thesis is concerned with this endeavour. The diversity of livelihoods and subsidies, and the trends learnt in Part II shape the design and implementation of the empirical research, which is explained in Part III.

PART III: DATA COLLECTION AND ANALYTICAL METHODS

To understand what motivated and hindered farmers to perform in the pilot project to adopt silvopasture, and to be able to discuss how to encourage participants in similar projects, an in-depth empirical analysis of perspectives and livelihoods is undertaken. The following two chapters describe the data and methodology used for this analysis. Chapter 6 gives details of most of the empirical procedure, whereas Chapter 7 develops an analytical innovation to enhance the results obtained in the analysis of perspectives. The empirical procedure applies Q methodology to understand perspectives, and quantitative methods to understand livelihoods and their impact on participation and adoption within the pilot project. Data on livelihoods for the quantitative approach was collected via an original design of board and tokens inspired in role-playing games for research. The analysis of this data uses cluster analysis to define livelihood strategies, and econometric modelling to devise the effect of livelihood variables on participation and adoption. In scrutinising the analysis in Q methodology, a major drawback is identified, with reference to the lack of levels of confidence of the results. To overcome this, Chapter 7 presents a bootstrap approach that provides more detailed results, which contribute to a more accurate interpretation of the results. While this part provides all the methodological details, the results are presented and discussed in Part IV.

Chapter 6. Data collection and methods to understand the links between perspectives, livelihoods, and adoption

Part II introduced the general trends that may be shaping individual decisions about livelihoods nowadays in La Sepultura Biosphere Reserve. In recent decades, livelihood strategies drifted in complex pathways driven by macroeconomic changes and by the appearance and disappearance of external payment programmes, for maize and agriculture in the 1970s and 1980s, and for conservation and cattle-farming in the 2000s (Chapter 4). Land cover is a mosaic that reflects these changes in livelihood activities.

In order to assess how policy can encourage the implementation of silvopastoral systems (SPS) in this mosaic, I conduct an empirical analysis of the motivations and hindrances for adoption. This chapter explains the methodological strategy undertaken to collect and analyse primary data and justify this choice against other plausible approaches. The explanation includes a methodological innovation in the livelihood data collection.[36]

As emerged from Part I, the literature on SPS adoption—and on agroforestry in general—overlooks the following factors that are important to understand decisions

[36] Another methodological enhancement, in the study of perspectives, is explained with the necessary detail in Chapter 7.

to uptake according to the conceptual framework: contextual subsidies, internal variables, and livelihood strategies (including diversification), and the heterogeneity thereof. To analyse these sources of heterogeneity in depth and generate adequate knowledge to discuss plausible incentives, I use a combination of semi-qualitative and quantitative methods: Q methodology to uncover perspectives (internal variables), cluster analysis (CA) to define livelihood strategies, and econometric modelling to explore the relation between livelihoods and SPS adoption.

Q methodology (Section 6.1) is appropriate to understand heterogeneity of subjective perspectives (McKeown and Thomas, 2013). This approach uncovers perspectives in a more systematic manner than other qualitative methods and, compared to psychometric tests for similar purposes, provides a more integral explanation of perspectives by making explicit the trade-offs and the relative engagement of respondents with related topics. The methodology is also focused on diversity of perspectives, rather than on predominance. The next section explains the purpose of this methodology and describes the essential steps and criteria for designing this research.

The study of livelihoods also takes a holistic approach. I transform the conventional livelihood questionnaire into a game-like survey, which purpose is to obtain the proportion of assets and effort that individuals assign to each livelihood activity. This data collection approach uses tokens and a visual representation of livelihood strategies, which triggers a cognitive elaboration of the response that differs from that of responding absolute assignations independently (see Section 6.2). Through this game, respondents make explicit the choices they confront in the allocation of their resources, therefore detaching from prejudices about expected responses. The questionnaire gathers data about land, effort, investment, and benefits, providing appropriate information to understand livelihood diversity and the role of subsidies.

The study of livelihood strategies tends to be either qualitative, or use descriptive statistics (Murray, 2001). Some studies have used CA (e.g. van den Berg, 2010) and I choose this option for it provides a way of formalising and quantifying livelihood strategies. The method and variables used for the analysis are explained in Section 6.4.

In terms of modelling adoption, from the conceptual framework and literature review it emerged that process-based explanation may be more appropriate to explain adoption of innovative farming practices. Accordingly, a model allowing integration of more than one outcome in time is selected (Section 6.5).

Data on livelihoods was collected between 29 April and 22 June 2010, and four fieldwork assistants helped during a more intensive period between 8-18 June. Data on Q methodology was collected in August 2010 by the author, and in January 2011 by a fieldwork assistant. The author, research assistants, and respondents are all native Spanish speakers, thus all data collection was conducted in Spanish. The support from researchers based with ECOSUR was fundamental and helped to build trust with respondents, consequently the rate of non-response was very low.

This combination of semi-qualitative and quantitative methods is chosen because it provides the benefits of both approaches: the robustness of quantitative results and the depth and richness of qualitative interpretation. It improves with respect to previous empirical studies on adoption because it integrates the analysis of perspectives in a holistic manner (as compared to regression studies), and it provides structured and quantifiable results to support the qualitative analysis. The exploration of the wide database on livelihoods collected requires intense analysis. However, the actual investigation on perspectives, livelihood strategies, and adoption can be implemented in a precise and straightforward manner in order to study the same factors in other contexts, and for purposes such as target identification for policy design.

Next in this chapter, Section 6.1 explains and justifies the use of Q methodology. Section 6.2 describes the development and the protocol to collect livelihoods data, and explains the complementary survey about demographic, economic data, and multiple-choice opinion questions. Section 6.3 provides theoretical background to compute two important indices from the raw data: adoption of SPS and livelihood diversity, and justifies the choice made for this study. The final two sections summarise the quantitative methods to model livelihood strategies and adoption levels respectively: CA (Section 6.4) and the Heckman selection model (Section 6.5).

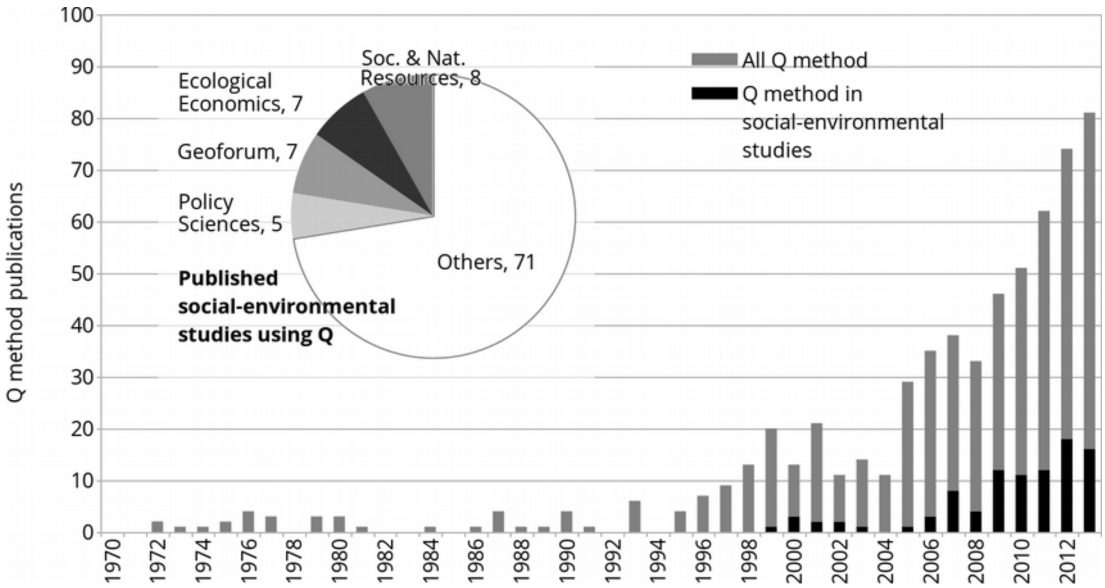
6.1. Q methodology to understand heterogeneous perspectives

Q is a powerful methodology (also known as Q technique or Q-sort) to shed light on complex problems in which human subjectivity is involved, by identifying different patterns of thought existing within a group on a topic of interest. Subjectivity is understood as how people conceive and communicate their point of view about a subject (McKeown and Thomas, 2013). Q is systematic, and the analytical process is clearly structured and well established (Brown, 1980; Stephenson, 1953). The method originated from a 1935 proposal to correlate respondents instead of variables in factor analysis (FA) by Stephenson (1935), an assistant to Spearman—the developer of FA.

This methodology is designed specifically to uncover perspectives on or attitudes towards topics of public concern (Barry and Proops, 1999; Watts and Stenner, 2012). It is aimed at exploring perspectives, discourses, or decision-making styles in order to address practical matters such as the acceptance of new policies and technology. Q was used initially in psychology, then in political science, and later in several other fields. Further history of the methodology is given in Stenner et al. (2008) and Brown (1999).

Q is increasingly being used across disciplines and for different purposes, such as policy evaluation, or participatory processes. Its use is growing particularly in environmental studies (see Figure 6.1). It is used to identify typologies such as conservationist attitudes towards markets (Sandbrook et al., 2013, 2011), farmer environmental perspectives (Davies and Hodge, 2012), opinions about new environmental legislation (Buckley, 2012), sustainability discourses (Barry and Proops, 1999), stakeholder views on energy from biomass (Cuppen et al., 2010), discourses on forest management (Swedeen, 2006), or citizen views on climate change policy (Lo, 2013).

Figure 6.1: Trends in publications using Q methodology in all fields (670 approx.) and in social-environmental studies (98)



The pieplot shows the approximate number of Q studies published by social-environment journals. All social-environmental studies using Q were published after the publication of Barry and Proops (1999). Data exclude the journal 'Operant Subjectivity', which specialises in publishing on Q methodology. This journal is not indexed, which complicates its introduction into the analysis. Source: Scopus (keyword search, June 2014).

The following characteristics of the methodology make this a suitable approach to understand perspective heterogeneity in the case study. It is versatile due to its compatibility with small samples; it is not focused on estimating the frequency and distribution of perspectives within a population, but rather on mapping the plurality of these perspectives, whether or not they are minority ones. It is predominantly exploratory because the patterns of views emerge from the study and thus prevent the researcher from imposing a frame of reference or pre-determined assumptions and definitions (McKeown and Thomas, 2013; Stenner et al., 2008). It is a mixed (semi-qualitative) methodology because, although the data collected are quantitatively analysed, their interpretation is extensively qualitative (Ramlo, 2011) and makes thorough use of theory. Results can be used in combination with other methods. For example, Q can be used in regression models to examine how perspectives influence behaviour, to develop a test to identify perspectives in larger populations, or to understand evolution of perspectives over time.

The study of attitudes is done across disciplines, by using qualitative methods such as focus groups or interviews, and psychometric methods from social psychology. Most frequently, the quantitative analysis of attitudes is done using variations of Likert scales (Cross, 2005). These include Semantic Differential (Cross, 2005), and specifically on environmental attitudes, the Ecological Attitude and the New Environmental Paradigm scales (Fransson and Gärling, 1999). All these consist of a set of items to which respondents give a value in an ordinal scale, and each item is valued independently. The advantages of Q methodology are that it provides quantitative measurements (in contrast to focus groups or interviews), it uncovers heterogeneous perspectives, whether or not they are predominant (in contrast to methods that emphasise random samples), and it portrays perspectives in a rich manner that interrelates the different topics that construct and individual's perspective (in contrast to Likert and other scales where items are measured independently).

Q methodology does not have the generalisability of other psychometric methods due to the sampling method, and the data collection is somewhat time-intensive, which hinders from collecting large samples. In contrast, it yields very rich descriptions of attitudes and broader perspectives, and is highly suitable to uncover heterogeneity, a point in which other quantitative psychometric methods are not focused. To uncover heterogeneity, purely qualitative methods tend to be used, such as discourse analysis. These qualitative methods however, lack the structure of Q, and can hardly be compared to quantitative data. Q thus combines benefits of both approaches: the structure of quantitative data and the richness of qualitative data.

6.1.1. Research design: statements and their structure

In essence, data collection in Q methodology typically consists of selecting a set of statements and asking respondents to sort them according to their views. Most studies that use the method also explain it (concise yet comprehensive summaries are those of Davies and Hodge, 2007; Sandbrook et al., 2013). A succinct description of the research design can be found in van Exel and de Graaf (2005), Watts and Stenner

(2012) offer a detailed reference manual, and a key and extensive work is that of Brown (1980). Dziopa and Ahern (2011) provide a structured outline of the key elements to be reported in a study in order to facilitate its assessment and replication.

The set of statements is a representative sample of the *concourse*: the whole set of possible expressions on a topic, gathered from all possible points of view (in theory, a concourse would be infinite), and contains multiple discourses (Dryzek and Berejikian, 1993). To create this set, the researcher collects a large number of statements from interviews, reviews of literature, mass media, expert consultation, participant observation, etc. This collection is reduced to a final representative selection that usually ranges between 40 and 80 statements (Watts and Stenner, 2012). Statements can express understandings or behavioural preferences relating to the topic. Photos, sounds, or other types of stimuli may be used instead of statements.

Statements are written on one card each and respondents sort them on a grid,[37] commonly from *most agree* to *most disagree*, although there are other possible conditions of instruction—different ways in which participants are asked to sort the statements (McKeown and Thomas, 2013). The grid represents a prearranged frequency distribution, which shape is up to the researcher. This grid is usually bell-shaped, assuming that fewer statements generate strong engagement (Brown, 1980), although there is much flexibility with regards to its shape and size. An example of such a distribution (or grid) used for the present study can be seen in Figure 6.2.

Figure 6.2: Q methodology distribution and example response

			4			
		23	22	5		
		20	11	9		
	17	19	13	6	2	
16	12	24	25	1	3	15
8	7	26	18	14	10	21
−3	**−2**	**−1**	**0**	**1**	**2**	**3**

Most disagreement Most agreement

[37] The sample of respondents consists usually of many individuals, but can also be a single respondent using different conditions of instruction in each of the responses.

Numbers in bold indicate the gradient from disagreement to agreement. Numbers in italic correspond to statement numbers, as ranked by a sample respondent.

For this research, a comprehensive concourse has been built based on expert consultation and after extensive fieldwork gathering quantitative and qualitative data on livelihoods, as well as qualitative questionnaires about stated preferences on silvopastoral practices to 103 heads of households (see details in Section 6.2). The statement selection follows a hybrid approach, by including both naturalistic (directly from respondents' communication) and ready made ones (expert formulated; McKeown and Thomas, 2013). Twenty-six relevant statements are selected, referring to their attitudes, preferences, perception or trade-offs; to the present and the future; and to themselves, their descendants, and other forms of life. Statement wording is shown in Table 6.1.

Table 6.1: Q methodology statements

Topic	ID	Statement	Original statement in Spanish
A. External payments	3	What is of most interest to me from external programmes is what I learn to earn more money	*Lo que más me interesa de los programas es lo que aprendo para ganar más dinero*
	4	I can maintain my family with my own work, external payments are just an aid	*Puedo mantener a mi familia con mi propio trabajo. Los subsidios sólo ayudan*
	8	I participate in all external programmes that bring income	*Participo en todos los programas que traen recurso*
	15	We need more external payments so that my children do not need to go to live elsewhere	*Es necesario que me den más subsidios para que mis hijos no tengan que ir a vivir a otro sitio*
	21	If the government does not give me external payments, taking care of the forest does not benefit me	*Si el gobierno no me da subsidios, no me beneficia cuidar el bosque*
	23	I rather live from external payments than from working my lands	*Prefiero vivir de los subsidios que del trabajo en mis tierras*
B. Conservation and environment	10	Conserving the forest is responsibility of the landowner	*Conservar el bosque es responsabilidad del dueño del terreno*
	25	I can earn more as a cattle-farmer if I let live other wild animals	*Puedo ganar más como ganadero si dejo vivir a los otros animales del bosque*
C. Attitude and personal behaviour	1	My children and grandchildren will work the same land that I cultivate now	*En las tierras que trabajo, trabajarán también mis hijos y nietos*
	9	It is more convenient for me to cultivate my own food than buying it	*Me conviene más producir mi propia comida que comprarla*
	11	I analyse my costs and benefits and thereafter I work on the most beneficial activity	*Hago las cuentas de lo que mejor me sale y me dedico a ello*
	22	I try new things in my job	*Pruebo cosas nuevas en mi trabajo*
D. Cattle-farming preferences	6	I could increase my benefits in cattle-farming without degrading the land	*Podría obtener más ganancias de criar ganado sin por ello estropear la tierra*
	12	My land is 'getting tired'	*Mis terrenos se están cansando*
	13	What cattle produces is much more than what land loses	*Lo que da el ganado es mucho más de lo que pierde la tierra*
	16	It is more convenient for me to invest money in improving my pastures than in buying cows	*Me conviene más invertir dinero en tener mejores pasturas que en tener más vacas*
	18	In dry season there is no alternative other than releasing my cows free into the mountain	*En secas no hay otro remedio que soltar las vacas al monte*
	19	With more training I could improve very much my work in cattle-farming	*Con más capacitación, podría mejorar mucho mi trabajo con el ganado*
	24	I need to improve my pasture, otherwise cattle-feed will run out in a few years	*Necesito mejorar mis potreros porque si no se acabará el alimento para mis vacas en unos años*
E. Preferences about fodder-tree planting	2	I prefer two hectares of pasture than one hectare of fodder trees	*Prefiero 2 hectáreas de pasto de corte que 1 hectárea de mataratón o guash*
	5	With tree planting programmes I receive more money in return for my work	*Con los programas de plantar árboles recibo más dinero por mi trabajo*
	7	Cultivating fodder trees involves a lot of effort and little benefit	*Sembrar bastante mataratón o guash significa mucho esfuerzo y poco beneficio*
	14	It takes long for fodder trees to grow	*El mataratón y el guash para forraje tardan demasiado en crecer*
	17	If I had more money, I would plant fodder trees instead of increasing my cattle	*Si tuviera más terreno, le sembraría mataratón o guash en lugar de aumentar mis vacas*
	20	It is convenient for me to clean my fodder tree plot from weeds even if I have other tasks, in order to produce more fodder	*Me conviene deshierbar mi parcela de mataratón o guash aunque tenga mucho trabajo, para tener más forraje*
	26	In order to dedicate one hectare to fodder trees during two years, I would need more land than what I have	*Para excluir una hectárea de mataratón o guash por dos años, necesitaría más terreno del que tengo*

Statements cover the topics of most relevance in explaining farmers' perspectives with respect to practising silvopasture: (A) the relative importance that external payments have in their livelihoods; (B) environmental and conservation values; (C) personal attitudes towards work and livelihoods; (D) beliefs and preferences about cattle-farming and land use, including benefits, resource use, and perception about the need to improve farming practices; and (E) preferences and trade-offs between planting fodder trees and other livelihood activities, including the perception about potential benefits of fodder trees.

These topics join the subjective individual characteristics shown in Figure 3.2 (p.80), with the livelihood practices that an external policy aims to affect, as illustrated in Figure 2.1 (p.48). The statements cover values, attitudes, beliefs, and preferences, all identified as relevant internal variables according to the review on decision-making in Section 2.4. The specific livelihood topics are land use, cattle-farming, fodder trees, and subsidies, topics that emerge as key throughout the description of the case study in Part II.

The wording of statements has been adapted after pilot testing with experts of the local context, and with trusted members of the community. This ensures that the statements are concise, clear, and that their meaning does not overlap, unless they are purposely included to validate the coherency of individual responses. The total number of statements is low in comparison to other Q-studies, a decision made to ease the process of sorting by respondents, some of whom have little reading skills.

6.1.2. Respondent selection and administration

The sample of respondents needs be neither large nor representative of the population, but it must be diverse. The aim is to get the widest possible range of opinions, regardless of whether they are minority ones. The group of respondents is a representation of the population diversity rather than a representative sample of the population. This purposive sampling approach enables us to uncover patterns that may not be detected otherwise because they may be unrelated to explicit demographic characteristics (Brown et al., 1999). Identifying all perspectives notwithstanding their proportional representation, may be particularly important in research questions where highly influential individuals have a strong effect on others' opinion or behaviour, such as in the diffusion of innovations.

The method was individually administered to 32 heads of households, all participants in the fodder tree planting project, for whom secondary data on involvement and success are available. Respondents are selected through maximum-variability sampling, by using a factorial design based on observed variables, in order to select a wide range of levels of involvement and livelihood variables. From the 68 individuals who participated in the project, I short-list individuals with highest, lowest, and median values of a subset of key variables: cattle specialisation, income, land, success, and diversity. Respondents were interviewed between August 2010 and January 2011. From those approached (36), one decided to stop sorting the statements after the survey had started (due to fatigue), and three were not found at home.

Each respondent divided the statements into three piles of agreement, disagreement, and neutral. Statements in each pile were counted, and then farmers placed the statements in the board with a standard pyramidal shape of seven columns representing different levels from *most agree* to *most disagree* (Figure 6.2). This Q sorting prompted respondents to explicitly express their preference of each statement relative to all other statements. A brief explanation by the respondent followed.

6.2. A novel method to collect livelihood data

Moving on to the investigation of livelihoods, in order to study decision-making about participation in the project and level of adoption, 103 heads of household responded to a comprehensive survey, which accounted for half of the ejido. The sample includes most participants in the project (58), as well as non-participants. The latter have been selected through a stratified random sampling based on information from two sources: the community census of members of the ejido assembly and the list of members of the Cattle-farming Association (CFA). From those approached, only one person refused to respond the questionnaire, and 15 were not found at home after several visits, due to temporary migration.

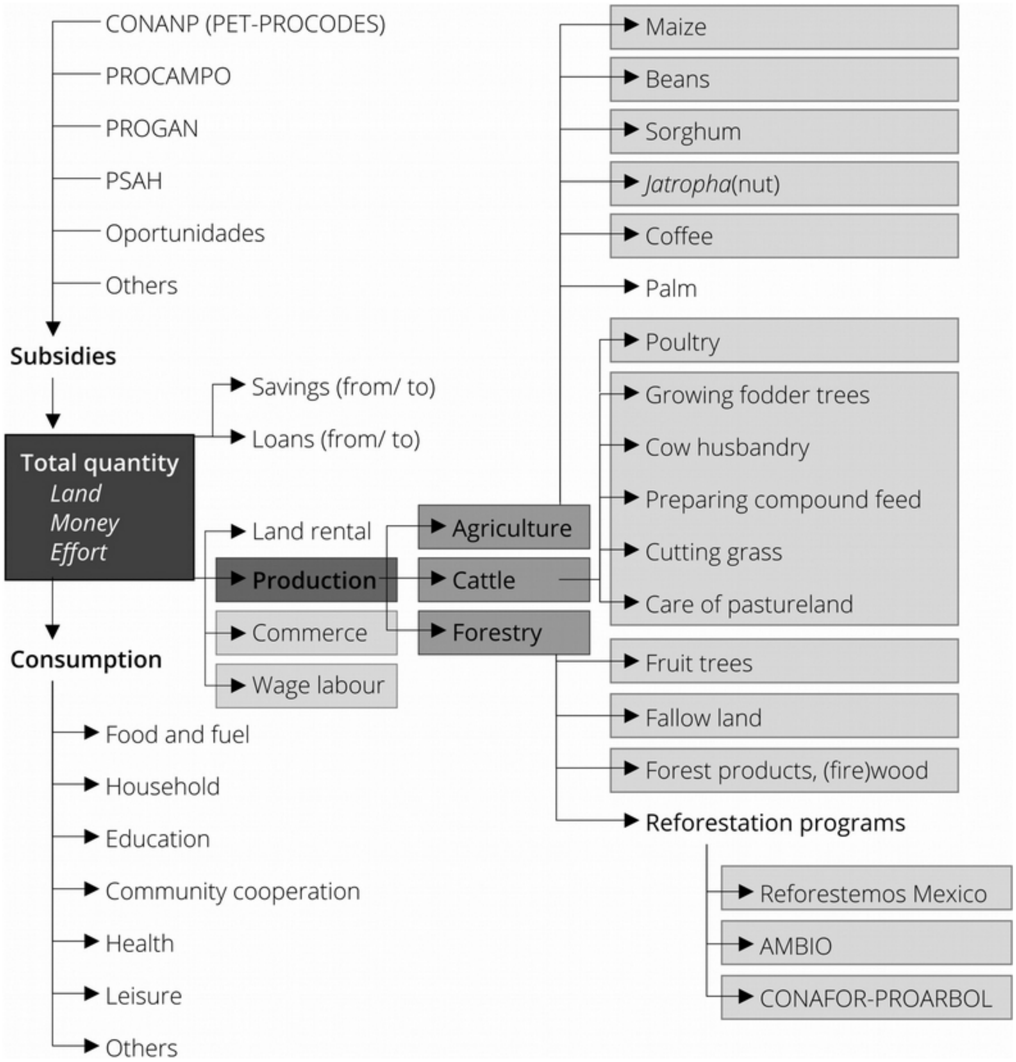
The survey comprises three parts: a baseline questionnaire covering demographics and wealth level, a game to ask about livelihood strategies, and an opinion questionnaire.

6.2.1. Design of the data collection method

The design of the data collection survey on livelihoods is inspired by role-playing game research, in which boards and tokens are used to obtain information about people's behaviour (e.g Etienne, 2003; García-Barrios et al., 2015). Such games portray a reality simplified to a degree at which respondents still feel identified with the topics observed, but facilitates responses and avoids some of the drawbacks observed when using traditional survey methods of self-reported information, such as the lack of sincerity or fatigue. The approach taken here keeps similarities with the Livelihood Matrix Scoring, which uses tokens to represent strength of preferences and trade-offs for livelihood activities (Cramb and Purcell, 2001). The token approach demonstrates to be more time-efficient than seasonal calendars to understand the allocation of effort.

The novel approach to gather livelihood data represents the peasant economy, and resembles a board game synthesised in Figure 6.3 (see the diagram as presented to respondents in the Appendix, Figure A1, p.314). This structure portrays the livelihood universe in the local context and it has been designed based on secondary data and on consultation with experts and key informants in the community.

Figure 6.3: Diagram of the peasant economy in La Sepultura Biosphere Reserve



The board-questionnaire is designed to provide data on the allocation, across livelihood activities, of the following: land, effort, source of benefits (from the previous year), money expenditures (investment and consumption), all for the previous year $(t-1)$ and the resulting benefits in the current year (t). Fifty tokens representing each asset and effort were distributed by respondents across the 36 livelihood activities on the board (the protocol is provided in the Appendix (Figure A2, p.315).). First, respondents distributed land tokens.[38] Then they distributed effort, they indicated the source of benefits in the previous year, and how they spent this available money between consumption and investment activities. Finally, they were

[38] Prior to responding to the land allocation question, respondents were asked whether they preferred using hectares or tokens, and all but one respondent provided responses in hectares.

asked to choose a number of tokens to represent benefits, and to distribute them according to those obtained from the land, effort, and investment allocated in the previous year.

These allocations were asked to heads of household (or to the adult responsible for managing household assets, where the formal head of household was too old). These individuals are assumed to decide on how to distribute the assets of the household. Their response about land corresponded to that available to the household. Effort would be understood as individual. Financial investment and benefits would have been the money they managed (thus likely excluding the money that the spouse would make in their own activities, such as selling food, etc.). For this reason, decisions in the empirical analysis are understood as individual decisions (although these decisions from the head of household are determinant to the household livelihood).

This board-based approach for data collection was designed to reflect the decision tree of farmers when confronted with limited assets. Despite that this data misses absolute values, such representation of the allocation of available land, financial capital, and effort provides an integrative perspective; it makes respondents explicitly think about trade-offs among activities, and integrate decisions about consumption and investment. In a normal survey where each livelihood activity is asked separately, the respondent need not be aware of such limits, a situation that does not accurately reflect reality and that can mislead the comparability of values between activities.

Ensuring comparability is particularly important in the calculation of livelihood diversity. This approach provides adequate information to understand livelihood strategies that can be devised as a highly specialised one, or as a combination of many activities. Using proportions allows a clear comparison of the allocation of assets of respondents with different total land and capital (Isaac-Márquez et al., 2005). In addition, in contexts of subsistence agriculture, it is also suggested that household models that jointly represent consumption and production decisions, explain the dynamics of decision-making better than more simplistic models that assume separability (Douglas, 2008).

The approach has also advantages for administration and reliability of responses. By using an illustrated diagram-board with tokens, the survey became synoptic, clear, and attractive for respondents. By focusing on relative rather than absolute measures of assets and effort, it was less compromising and reduced bias caused by potential unwillingness to disclose private information. A board with tokens may capture respondents' attention with more ease, thus making them more focused on the response itself rather than on internal deliberations such as reflexivity towards the researcher, or whether to trust personal information, which can distract the respondent in a standard survey.

6.2.2. Additional questionnaire and secondary data on adoption

Livelihood strategy data has been complemented with a demographic and wealth-level questionnaire, and with qualitative questions about farmers' livelihood strategies and, in particular, about their attitude and constraints towards planting trees in their plots, based on the decision making theories explained earlier (see questionnaire in the Appendix, Figure A3, p.316).

Secondary data on involvement and tree outcomes were collected by García-Barrios and Trujillo-Vázquez in 2008 (Unpublished). This includes observations about the caring activities, the number of saplings encountered in each plot, their height, and a qualitative observation about their health quality (*good*, *medium*, and *dead*). Table 6.2 synthesises the primary and secondary data collected.

Table 6.2: Summary of primary and secondary data on livelihoods and adoption

Adoption (secondary data)	— Participation/ non-participation (binary) — * Tree outcomes — * Ordered categories of tree outcome: no participant, participant but no plants, few plants, many plants — Involvement in caring activities: categories of planted/ not-planted, fenced/ not-fenced, weeded/ not-weeded ** calculated as per Section 6.3.2*
Demography (own data)	— Family size — Age and gender of respondent and of members of the family — Level of studies of family members — Position in the community (*ejidatario* full rights, *poblador* partial rights, *avecindado* newcomer)
Economy (own data)	— Wealth proxies (characteristics of the house) — Income level in five categories — Land quantity in five categories — Years of experience in cattle-farming
Livelihood (using board and tokens; own data)	— Number of hectares dedicated to each farming activity (L) — Allocation of effort to each livelihood activity (W) — Allocation of expenses into consumption and investment (I) — Share of benefits from each activity in the previous year (O, including subsidies) — Share of benefits from each activity (B)

	Range	Description
L	[0, 1]	allocation of land
W	[0, 1]	allocation of effort
O	[0, 1]	distribution of sources of benefits (previous year)
I	[0, 1]	allocation of investment
B	[0, 1]	distribution of sources of benefits
Lha	[0, unlimited]	number of hectares for each activity (unbounded)
Btot	[0, unlimited]	tokens of benefits for each activity (unbounded)

In preparing the data for analysis, all values of allocation of assets, effort, and benefits are standardised to a range of 0 to 1. Thus these values are both fractional (bounded between 0 and 1) and compositional (sum up to 1). This data are synthesised into livelihood diversity indices (Section 6.3.1).

Opinion questions (own data)	— Reported self-performance in the fodder tree project — Limiting factor(s) for planting fodder trees — Level of difficulty found in planting the trees — Perceived benefit — Perceived time lapse until trees mature

6.2.3. Data entry and validation

Token allocations have been recorded in photographies (see an example in the Appendix, p.314), and complementary survey results noted on paper. Data was entered by the author and four research assistants, and compared twice by the author with the original records.

Data on livelihood strategies have been internally validated by inspecting the allocation of resources across activities for each respondent, in search for inconsistent responses. Criteria to define inconsistencies are based on the assumption that if the respondent had allocated some of one resource to an activity, he would allocate some of all other resources to the same activity, with some logical exceptions such as no land needed for off-farm activities. Each type of inconsistency has been assessed case by case and for some of them, plausible explanations have been found in the survey notes or in posterior questioning. For some other inconsistencies, no plausible explanation has been found and those respondents with more than three of such unexplained inconsistencies are excluded from the sample. The sample size is thus finally reduced to 97 during data validation due to excess inconsistencies or to survey incompleteness.

6.3. Computation of composite indicators

Raw data on fodder-tree planting consist of number and height of trees per plot, and data on livelihoods are the shares of assets, effort, ad benefits for each livelihood activity. In order to operationalise the concepts of livelihood diversity and adoption for posterior empirical analysis, I encapsulate the data into indicators. There are a number of options to compute these two indicators, which I discuss to justify the choices for this study below.

6.3.1. Livelihood diversity

I assess the most recent proposals on how to measure diversity as an abstract, cross-disciplinary concept, in order to inform the selection of a livelihood diversity indicator. Diversity is composed of three concepts: *richness* (number of types; e.g.

number of livelihood activities carried out), *evenness* (proportions; e.g. proportional allocation of an asset across activities), and *disparity* (distance between types of elements; e.g. differences between the activities carried out) (Stirling, 2007). A review of the most common diversity indices (Shannon, Simpson, and richness) (Keylock, 2005), reveals that these three are specifications of two general equations: Tsallis entropy that includes richness and evenness (Patil and Taillie, 1982; Tsallis, 1988) and Ricota & Szeidl that unifies the former by adding also disparity (Ricotta and Szeidl, 2006). The final choice is a livelihood diversity index that is a standardised version of richness, for the reasons explained below.

The application of disparity to the livelihoods data demands that values are assigned to distances between activities. For example, the distance between maize and beans would be shorter than the distance between maize and cattle. However, assigning precise values in the absence of other measures involves a great deal of judgement, and arguably, of arbitrary or subjective decisions. Disparity is thus left aside.

a. Livelihood diversity in the literature

The earliest basis for the few studies that quantify livelihood diversity comes from literature on rural income diversity, which is mainly focused on the effect of off-farm income on rural households (Evans and Ngau, 1991). Literature in economics and development studies that quantifies livelihood diversity uses primarily income sources (Perz, 2005), and only rarely other assets. Most examples calculate income diversity (Vedeld et al., 2007) and livelihood portfolio. The term *'livelihood diversity index'* is used in a number of studies (Hahn et al., 2009; Murray, 2002; Perz, 2005; Wang et al., 2010), but those that quantify it employ different measures.

Several indices have been used to quantify livelihood diversity, most of which are mathematically equivalent to the Simpson index:

Equation 6.1: Simpson diversity index

$$S_2 = 1 - \sum_{i=1}^{n} p_i^2$$

Where p_i proportion of elements of class i, and n number of classes in the system

These variations include the Hirschman-Herfindahl index (HHI = $1 - S$) for market competition, a computation of $1 - S$ (Wang et al., 2010) or inverse Simpson ($1/S$) (Illukpitiya and Yanagida, 2008). Tesfaye et al. (2011) use an inverse HHI for income diversity of households, initially proposed by Chang (1997, in Ellis, 2000b). Hahn et al. (2009) calculate an ad hoc *'Average Agricultural Livelihood Diversification Index'*, based on the number of activities carried out. At the other edge of complexity, Cinner & Bodin (2010) use a network-based approach to analyse what they term *'livelihood landscapes',* abstract maps of occupations and their interrelationships.

Income is heavily dependent on exogenous factors in addition to an individual's decisions, and the extensive literature on sustainable livelihoods also shows that capitals other than financial are critical (Scoones, 1998). Other capitals that may be defined at the individual level (in contrast to social and physical capital) are natural and human capital. These capitals could be approximated by land and effort respectively. I argue that effort is the asset that most clearly reflects one's own decision, because its distribution is more directly dependent on individual factors than the distribution of income and to a lesser extent, of land, the use of which is heavily dependent on the type of activity carried out.

b. Application of a diversity index to the case study

A richness index of effort, standardised by the maximum possible activities, is finally chosen. A measure of how many activities a person undertakes is a sufficient approach to measure his or her tendency towards trying new activities.

Effort is chosen as the resource to account for livelihood diversity. I argue that this is the most intrinsically attached to a person's decisions than land or investment allocation. Consequences of allocating effort are fully experienced and internalised by the individual. In contrast, how land uses are allocated, for example, is closer to a one-off decision, a fixed distribution (at least in the short-term) that does not require constant pro-activeness. Whether the activities receive allocation of land or financial investment, or produce a given income share depends more on causes beyond the individual decision than in the case of effort, such as activities inherently requiring assignation of land, or activities that do not require financial investment, or that do not give benefits due to unexpected events.

It is argued that, beyond richness, diversity indices provide no intuitive interpretation because they have to be transformed to their number equivalents[39] in order to be in units that are meaningful for real subjects. Richness is *"its own numbers equivalent"* and therefore provides straightforward interpretation (Jost, 2007, p.2429). As a test of robustness of this choice, I computed for each respondent and each asset the Shannon, Simpson, Gini, and richness indices, and explored their correlations and distributions, observing very high correlations.

All the previous indices do not account for a valuable piece of information that is naturally uncommon in biodiversity studies, but which this study provides. This information is the maximum possible number of activities, a limit defined by the board. In biodiversity measurements, the maximum value of an index, if calculated, is based on maximum evenness because there is no information about maximum richness. In addition to maximum evenness, livelihood data in this study include knowledge about the maximum richness. This maximum corresponds to the number of activities on the board, including those to which the respondent did not allocate any asset. The consequent range of livelihood diversity therefore provides a straightforward interpretation in the given context.

6.3.2. Silvopasture adoption

Based on secondary data about plant counts and heights, I calculate a continuous variable of adoption for each plot, which is then assigned to each individual participant.

Empirical studies that monitor reforestation rates on the ground tend to use a variety of indicators (Le et al., 2014), and forestry studies use measures of living biomass or wood density (tones/m^3). This is usually based on the diameter of the tree at a height of 1.5 m (or other standard value), and multiplied by a parameter specific

[39] *Numbers equivalent* is the *"effective number of elements"* (Jost, 2007, p.2428), which is the value used to report comparative variations in diversity.

to each species. Another common measure is forested land-cover measured through satellite images, but this is still unsuitable for detecting small trees.[40]

The secondary data of tree-monitoring performance contains several variables of relevance for an index of adoption: size of the plot, number of people working in the plot, number of plants initially delivered, count of plants per plot, and plant height and quality (*good*, *regular*, and *dead;* see distribution of heights in Figure 6.4). Two variables are essential, the plant height (h) and the number of plants per plot (n).

If the plant quality were to be integrated, a weighting should be added. For example, either giving a value of 1 for *regular* and 2 for *good*, or transforming the values, such as with square root of *regular* plants. However, this is discarded due to the arbitrariness of assigning weights, since the choice of a given pair of values would affect parameters in posterior modelling.

The geographical location and ecological characteristics of each plot (orientation, slope, etc.) can also introduce biases in the potential to grow fodder trees. This was found to be significant in three plots only (Trujillo-Vázquez, 2009). There is also a height threshold above which there is an inflexion in the rate of growth; plant growth decelerates because trees stop their initial fast development. However, this is not relevant because the period between planting and measuring was short and far too early for this inflexion.

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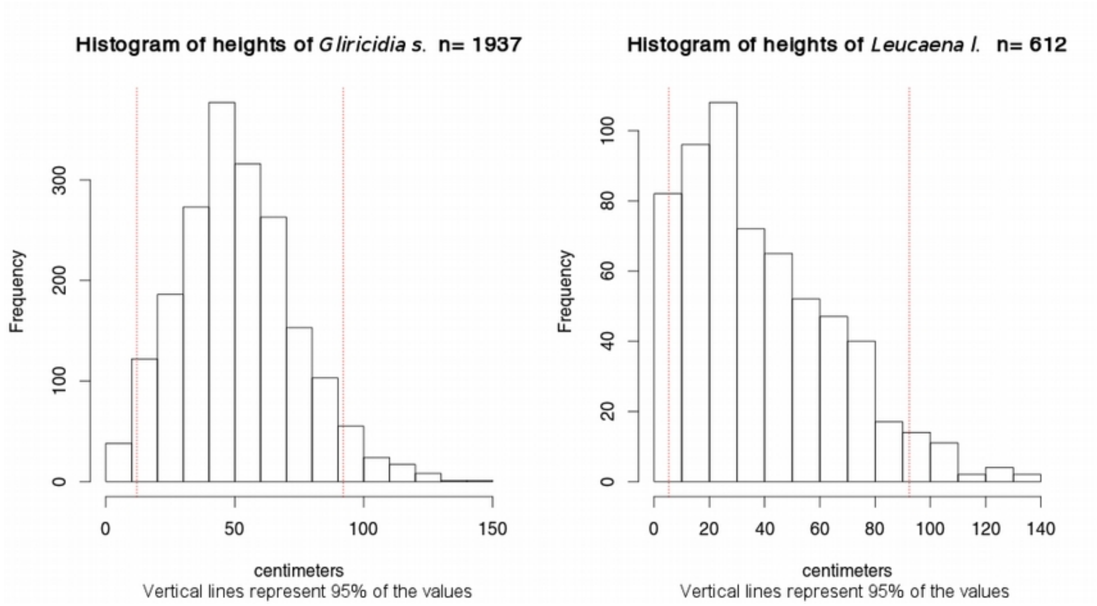
[40] Successful reforestation more broadly may be measured in terms of establishment of trees (as measured in this study), forest growth or re-vegetation, changes in ecosystem services and functions, and socio-economic benefits (Le et al., 2012).

Figure 6.4: Distribution of tree heights for the two species planted



The survival ratio of the plants delivered at the beginning would be another plausible estimate of early adoption. This has the advantage of measuring success with respect to the initial compromise of the individual. However, in some cases participants grew their own plants, thus this ratio on occasion takes a value higher than one. There is neither information about the number of plants that each participant grew, nor would this ratio include information about plant height.

I suggest an index of length of plant per plot (Equation 6.2), where *i* is a plot and *j* is a given tree. I select only those plants of quality *good*, assuming that these have a considerably higher viability potential than *regular* plants, which might have died soon after or be more susceptible to pests. Growth rates of *Gliricidia s.* and *Leucaena l.* are slightly different (Ferdousee et al., 2011) and thus they cannot be directly aggregated, therefore a standardisation of heights by the maximum height observed for each species is performed ($h_{max\text{-}Gli}$ = 1.43m for *Gliricidia s.,* $h_{max\text{-}Leu}$ = 1.33m for *Leucaena l.*).

Equation 6.2: Adoption index, in standardised metres of tree per plot

$$S_i = \sum_{Gli} \frac{h_{ij}}{h_{max_{Gli}}} + \sum_{Leu} \frac{h_{ij}}{h_{max_{Leu}}}$$

This index is the total sum of standardised height of trees for each plot, and is a proxy for biomass. Because the trees at the time of monitoring were still very young, the diameter variability can be expected to be low. Thus it is safe to assume that height and biomass are highly correlated in this situation.

6.4. Cluster analysis

To understand the key factors influencing livelihood decisions, it is important to profile what are the main livelihood strategies (see definition in Section 1.3) in the case study. With that goal, I classify livelihood strategies using CA with the data collected as per Section 6.2.

Livelihood strategies may be analysed using a diversity of methods (Murray, 2001): participatory techniques, livelihood trajectories, vertical transect, life histories, CA, quantitative surveys, or a combination of these. The goal of understanding livelihoods in the case study is to obtain a picture of current livelihoods, for which chronological methods (such as trajectories or life histories) are discarded. CA has low data requirement in contrast to more qualitative and participatory techniques, and provides a structured and quantified picture of existing livelihoods. Thus I consider it most appropriate. A review of empirical studies using CA to analyse livelihood strategies is provided below, followed by the essentials of the method and the analytical decisions taken to apply the method in this case study.

6.4.1. Cluster analysis to research livelihood strategies: a review

Quantifications of livelihood strategies in the literature are scarce and focused on variables related to income (Brown et al., 2006; Ellis, 2000a). A few studies use CA to define livelihood strategies in low-income communities in developing countries (Ansoms, 2010; Brown et al., 2006; Soltani et al., 2012). For example, an asset-based approach of CA was used to model the determinants of distinct livelihood strategies, based on household attributes and endowments (Brown et al., 2006). I look at the following aspects in these studies: clustering method, definition of livelihood strategy (variables used), and purpose of these definitions.

On the clustering methods (explained below), various authors use hierarchical agglomerative cluster analysis to define the centroids that will then be used in a final k-means (Ansoms, 2010; Soltani et al., 2012; van den Berg, 2010). Other use simply k-means (Brown et al., 2006).

Livelihood strategies are usually operationalised as the shares associated with different livelihood activities. These shares most frequently correspond to income (Oumer and de Neergaard, 2010; Soltani et al., 2012), and also land (Brown et al., 2006; Oumer and de Neergaard, 2010), or land and effort (van den Berg, 2010). Variable selection differs according to the research purpose of each study. If the aim is to correlate certain variables with the choice of a given livelihood strategy, then those variables are not included in the CA. Therefore, following distinct research purposes, livelihood strategies can be broadly defined around variables other than the allocation of assets, such as household characteristics, wealth, and demographic variables (Ansoms, 2010). The reviewed studies use between 11 and 24 variables (in some cases, factors or components aggregating variables) to identify from four to seven clusters.

With respect to the purpose of classifying livelihood strategies, multinomial logit models are applied to learn which household characteristics affect the choice of livelihood strategy (Brown et al., 2006; Soltani et al., 2012; van den Berg, 2010). Some also compare livelihood strategies with specific explanatory variables such as consumption (van den Berg, 2010) or income. Brown et al. (2006) for example, compare the cumulative curves of income of each livelihood strategy to see wealth differences. Another goal is to investigate mobility and transitions between livelihood strategies by using panel data (van den Berg, 2010). Oumer and de Neergard (2010) explore the relationship between resources management, livelihoods, and poverty, by performing three multivariate exercises over the same sample: two cluster analyses (on income sources and levels respectively) and one PCA (on land-use portfolios). Then they look at the relationship between the three sets of results and suggest policy interventions specific for the heterogeneity of livelihood strategies found.

6.4.2. The method

CA groups observations by their similarity. It distinguishes from FA because the latter is a data-reduction technique based on variable correlation, whereas CA classifies observations based on distances between variable values (Everett et al., 2011). CA has the following main steps: select the variables, choose the method to associate variables, find the groups using one of three main methods described below, compare the variables that define each group, and interpret the groups (Burns and Burns, 2008).

There are three main clustering methods: partitioning (k-means), hierarchical, and model-based (Everett et al., 2011). The k-means method begins with a random or pre-defined set of centroids, then it moves elements among groups and leaves those changes which result in groups with lowest internal (intra) variability and highest external (inter) variability. Hierarchical agglomerative methods group those observations which are closest from each other according to a distance matrix (typically of Euclidean distances). Then the next-closest elements are assigned into existing clusters until all the elements belong to a cluster. Hierarchical divisive methods proceed the inverse way. The model-based or distribution-based clustering method (less commonly used) tests different models for clustering and selects the most likely model and an optimal number of clusters (Fraley and Raftery, 2002).

In contrast to hierarchical methods, in k-means the clusters depend upon the centroids initially selected, therefore if the starting point is selected at random, the results are different each time (when three or more clusters are selected). A bootstrap of hierarchical clustering can also be done to calculate p-values for each cluster (Suzuki and Shimodaira, 2006), which recommends a number of clusters based on the clusters that have a high probability of being obtained (with p-value > 0.95).

Once defined, the clusters are described by calculating centrality values of each variable for each cluster. An ANOVA test (or a non-parametric equivalent) followed by post-hoc tests may be used to find which variables distinguish clusters significantly (Burns and Burns, 2008).

6.4.3. Application of cluster analysis to distinguish livelihood strategies in the case study: analytical decisions

The main analytical decisions made to obtain the clusters are the variables to be included in the analysis, the method to compose the clusters, and the number of clusters to obtain.

I use 25 variables to run the CA. These are incorporated primarily according to whether the variable is important to distinguish and interpret livelihood strategies as explained through the livelihood map in Figure 6.3.[41] This criterion is complemented with the following ones: variables used in relevant empirical literature, the three variables identified as key to understand how livelihood variability may affect SPS adoption—cattle-farming, diversification, and subsidy dependence, and data completeness and variability.

Three further criteria are used for exclusion: those variables for which variability is captured by other covariates (identified through the correlation matrix shown later in Section 9.1.1), those which may determine the choice of livelihood strategy (such as wealth or demographic variables, likely to be included as predictors), and those which may be consequences of the livelihood strategy. A sensitivity analysis to test different sets of variables further aids the selection of the combination below.[42]

Because benefits (income) may be a consequence of livelihood strategies or a predictor of the next livelihood choice, rather than descriptors, a combination of effort and land is selected (Table 6.3). Published papers more frequently use land or income, and in one instance land and effort are used (van den Berg, 2010). Land could be included either in absolute or in proportional terms. The latter option is selected because the total quantity of land may also be a predictor of the choice of livelihood strategy.

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[41] Some studies perform a previous FA or PCA in order to reduce variables and to eliminate distortion in clusters due to high correlations among variables, and they run CA directly with these components (Ansoms, 2010; Soltani et al., 2012). However this requires large samples, and the interpretation of components can obscure the interpretation of CA.

[42] To aid the selection of variables, CA was iterated with subsets of variables in four iterations. Six clusters are selected in all iterations, which are compared using a correlation matrix.

Table 6.3: Variables included in the cluster analysis of livelihood strategies

Binary variable	Share of: L, land	W, effort	I, investment	O, previous year benefits	Description
■		■			Off-farm effort (binary)
	■	■			Livelihood diversity
	■	■			Coffee
	■	■			Beans
	■	■			Maize
	■	■			Poultry
	■	■			Agriculture
■	■	■			Cattle-farming (presence/ absence)
	■	■			Forestry
		■	■		Commerce
		■	■		Wage labour
		■		■	Subsidies

The key livelihood activities are included.[43] Agricultural activities are both aggregated as well as disaggregated into the main crops: coffee, maize, and beans. All forest activities are aggregated into forestry because they correlate highly. Off-farm activities are separated into commerce and wage labour. Land is not assigned to these two activities, and most activities are represented by two variables. Thus the investment in off-farm activities is also added for representativeness. An additional binary variable of presence of off-farm activities is integrated, as well as the share of income from subsidies, because these are theoretically important for the study.

With these variables, I use k-means to compose five clusters. I expand the sensitivity analysis performed with different sets of variables in order to inspect whether there is important variation when selecting different numbers of clusters or using alternative clustering methods.[44] This analysis is used to decide upon using k-

43 Palm and *Jatropha* are excluded because they have few non-zero observations and they are considered less relevant in this context. Sorghum is excluded because it is narrowly related to cattle-farming variables.

44 I perform the iterations using k-means and hierarchical (complete) methods, and selecting different number of clusters (k = 2, 4, 6, or 8). For each method and number of clusters, variable boxplots were built to assess differences between choosing different numbers of clusters. For smaller

means, which provides more clearly distinguishable clusters than hierarchical clustering, and selecting five clusters, which is an appropriate compromise in terms of interpretability.[45]

In order to select the initial centroids for k-means, it is suggested to group observations randomly into equal numbers, and to select the observation from each group which most approaches the average value of the variables. In this study, a variation of this is implemented, which includes the information obtained from hierarchical clustering (van den Berg, 2010) using the complete-linkage method: the initial centroids considered correspond to the five clusters obtained with hierarchical clustering. The observation within the cluster which is closest to the average of the cluster is selected as a centroid. Prior to clustering, variables are scaled and centred.

The robustness of the clusters was tested through a repeated split-half procedure (Field et al., 2012). Results support this robustness very clearly for all the clusters in the case of one half and for three clusters in the case of the other half (correlations >.9). These clusters are presented in Section 9.1.2 and subsequently discussed. Prior to the results, this chapter continues with the description of the last standard analytical method used in this thesis.

6.5. Econometric model of participation and adoption

To understand how livelihoods and other factors influence adoption of SPS in the case study, a multivariate regression model is appropriate, as is done in most of the adoption literature (see Chapter 3). Two issues may be considered in the choice of an appropriate model. First, the dependent variable of interest—*adoption*—is only observed for those participating in the project. Second, adoption may be better explained as a process with different steps.

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number of clusters, k-means provides slightly lower p-values overall in the post-hoc tests for differences between variables and clusters.

[45] The screeplot from k-means is clear up to four clusters. A clustergram indicated that a choice between five and seven would capture those groups that are most stable. The hierarchical bootstrapping method suggests very high number of clusters—over nine, which is hardly interpretable. Model-based CA suggests two clusters.

I follow a theoretical model of behaviour as a decision process where independent variables influence the decision at each stage differently (Morris et al., 2000). If that is the case, then the factors that influence decisions to participate may be different from (or have different effect to) the factors that influence posterior adoption (measured a year after, as explained in Section 5.4). Consequently, the probability of participating can be assumed to be independent from the adoption function. If that is the case, then the sample for which adoption is observed is biased. The truncation of observed values of adoption is non random, as it would be the case if the data were truncated or censored (Greene, 2008). In this case, the sample selected is biased, and the coefficients for the parameters influencing adoption may be biased in the direction of the factor that determines participation. Given these conditions, a selection model is deemed adequate (Giovanopoulou et al., 2011; Heckman, 1979).

The Heckman approach is appropriate for cases in which the sample obtained is not random, but is selected upon a previous decision (Greene, 2008). This model is highly compatible with the consideration of adoption as a sequential process (Section 2.4.2). The sample selection implies that the situation has two decisions: whether to participate, and how much to adopt (Greene, 2008). Each decision is represented by an equation in the model:

Equation 6.3: Sample selection equation (probit model; participation)

$$z_i = w_i \gamma + u_i$$

Equation 6.4: Outcome equation (regression model; adoption)

$$y_i = x_i \beta + \varepsilon_i$$

The parameters γ and β are sets of coefficients for the vectors of explanatory variables w_i and x_i respectively (these variables are defined later in the implementation of this model in Section 9.3.2). In the selection model, y_i is observed only if $z_i > 0$. The error terms in both equations, u_i and ε_i, are assumed to have a bivariate normal distribution with mean 0, and a correlation ρ. The model assumes that $\rho \neq 0$ due to the sample selection bias. If u_i and ε_i were independent, then the data missing in y_i would be missing randomly, and a least squares regression would provide unbiased (though inefficient) estimates (Heckman, 1979). Because $\rho \neq 0$, an OLS estimation of the second equation would produce inconsistent estimates of the coefficients and heteroskedastic disturbance (Greene, 2008). This means that the nonrandom sample used to estimate the outcome equation, biases the estimated coefficients in the direction of ρ (Greene, 2008).

This bias is corrected by introducing another covariate in the estimation of the outcome equation, the Inverse Mills Ratio (IMR). The IMR is *"the probability that an observation is selected into the sample"* (Heckman, 1979, p.156). Therefore, the model uses information from the full sample for the estimation, not just from the selected sample. The selection model is described as an omitted variable problem, where IMR is the instrument that approximates the omitted variable (Heckman, 1979; Toomet and Henningsen, 2008).

For estimation, a two-step method is most commonly used (Greene, 2008) and more robust than maximum likelihood (Toomet and Henningsen, 2008). First, the selection dependent variable (participation) is modelled using probit analysis, using the complete sample. Then, the IMR is calculated and used as a predictor in the model of the outcome of interest (adoption), using only the selected sample for which y_i is observed (Heckman, 1979). If IMR is significant, then the selection model is a better estimation of the outcome than a standard multivariate regression of only the selected sample. This model is implemented in Section 9.3.2.

6.6. Synthesis of the data collection and methods

This chapter introduces the methodology and data used to understand adoption of SPS in the case study described in Part II, and focusing on variables that are important according to the theoretical background of Part I. The methods used are Q methodology to explore perspectives (about conservation, SPS, and livelihoods), cluster analysis to identify livelihood strategies, and a Heckman selection model to find what influences adoption. The core questions of the thesis are responded through the discussion of perspectives and through the econometric model. The study of livelihood strategies is instrumental to understand and explain the numerical results obtained through modelling, and to discuss their implications.

The design of data collection and of the decisions taken for standard analytical approaches are also explained. This data collection includes a novel board and token design to obtain proportional data on the allocation of assets and effort into different livelihoods and the income portfolio.

In addition, after the collection of Q methodology I identify an important shortcoming of the analysis, related to the lack of levels of confidence for the results. Therefore I develop an approach to overcome this shortcoming. Details that lead to the identification of this gap and the additional methodological innovation for the analysis of Q methodology data is explained in more detail in the next chapter.

Chapter 7. Enhancing the accuracy of Q methodology to uncover perspectives with the bootstrap

The previous chapter explains the research design and data collection developed to understand perspectives towards silvopasture (Section 6.1). With the aim of fully understanding the reliability of results, this chapter contributes to Q methodology by providing means to enhance the accuracy of the interpretation. It outlines how Q methodology data is analysed and highlights an important shortcoming of the procedure, referred to the lack of precise information about the spread values of results. To overcome this issue, it introduces a novel approach to calculate specific levels of confidence for important results which the standard analysis does not offer, thus helping to elaborate more robust and reliable Q studies. This provides deeper insight from the data, in order to better understand perspectives towards the adoption of SPS.

While the methodology is predominantly qualitative in its construction of the perspectives, it is grounded on quantitative data and the analysis is a sequence of equations. The analytical method remains unchanged since it was detailed in 1980 (Brown, 1980) and provides arguably rudimentary measures of variability. These measures are based principally on the number of respondents that are representative of a factor (as explained below in Section 7.1.2), and are not specific for each statement and factor. This shortcoming poses a handicap to understand the reliability of results, and signifies that the data collected are not exploited in full through the analysis; further information could be yielded from the data to aid a more nuanced interpretation.

Even though the use of Q is increasing (see Section 6.1), the analytical process has received little attention in recent decades. In the standard analysis, the standard error (*SE*) is estimated as a unique value for all the statements within a factor, no confidence intervals (*CI*) can be calculated, and there is no measure of variability for the factor loadings—which relate respondents with factors. This lack of uncertainty levels for all the results can be an area of concern, especially for researchers coming from quantitative backgrounds. Since Stephenson (1978) described and discussed the *SE* of factor scores, and beyond the standard Q analysis detailed in Brown (1980), no further analytical procedures have been put forward to enhance the reliability and validity of the results to the author's best knowledge. Few other articles discuss the validity of Q methodology or potential technical enhancements to the process (see Section 7.2). Despite providing substantial evidence for discussion, these studies did not lead to enhancements of the standard analytical process.

To address this gap in reporting the level of confidence of results, I propose a novel analytic approach, of bootstrap re-sampling in Q. This approach provides variability measures that are specific for each factor loading and also for each statement scores. The specific error estimates show the relative stability (certainty) of each statement within the factor. The approach also provides increased accuracy of point estimates, and further information to report the reliability for each factor. In addition, bootstrapped (data-based) measures of variability are considered superior to assumption-based measures because bootstrap estimates do not assume normally distributed data (Babamoradi et al., 2013). These measures of variability can help exploring the stability of perspectives without the need to replicate a study.

The key reasons to use the bootstrap in Q method are threefold. It yields improved—more detailed and precise—estimates of values and *SE*s. It provides measures of variability for results that the standard analysis does not (either *SE* or *CI,* for Q-sorts as well as for individual statements). These measures improve the understanding of the data and the level of confidence of the results, they provide further support for key analytical decisions (such as flagging or deciding on the number of factors to extract), and may increase the accuracy of the interpretation.

Finally, it is less strict with violations of parametric assumptions, which may be encountered with Q data, such as non-continuity of responses or non normal distributions.

Differences between the bootstrap results and those from the standard analysis could change the interpretation slightly or significantly. This is because *SE* are instrumental in the selection of distinguishing statements (see Section 6.1), and *SE* specific to each statement provide more precise information about individual interpretative arguments. Besides, in order to assess the overall stability of factors within and across studies, I present an aggregated *factor stability index* as a more comprehensive indicator than the current alternative (the 'composite reliability of factors', see Section 7.1.2).

The bootstrap can be performed with any Q method study. Its results may be reported in cases where these make a significant difference with respect to the standard results, when variability estimates are important in the interpretation, or to report results with higher detail and precision.

Next in this chapter, I identify where in the analytical process of Q the researcher makes important decisions and where sensitivity analyses can be performed (Section 7.2). Focusing on the first of these decisions, the chapter describes a novel implementation of the bootstrap in Q and explains important considerations specific to this particular case of the bootstrap in multivariate analysis (Section 7.3). I develop and detail an algorithm to implement bootstrap in Q studies of any number of Q-sorts, of statements, and any distribution shapes. The chapter offers guidelines for interpreting the bootstrap estimates and formulates a synthesising index that summarises the stability of a factor (Section 7.4). With the details that the chapter provides, other researchers can readily implement bootstrap in Q method. It ends with a brief discussion of the contribution of this additional procedure, and suggests future directions for improvement (Section 7.5).

7.1. The standard analytical approach in Q method

The basic analytical principle is to correlate the entire responses of individuals. The process reduces the data to a few typical responses, based on principal components analysis (PCA) or centroid factor analysis.[46] However, instead of correlating variables (as in regular PCA and FA), in Q the respondents are correlated in order to elucidate relationships between them. The standard data-reduction method is followed by a set of analytical steps specific to Q methodology (explained below). The final results consist of a small number of sets of sorted statements (typically called the *factors*)[47] that are different from each other and summarise the perspectives existing among respondents.

This analysis has been fully programmed in R statistical language for this thesis, and published as an R package (R Core Team, 2015; Zabala, 2014a, 2014b), in order to facilitate the methodological innovation explained in Chapter 7. The analysis uses PCA because its computation is readily available in R (as opposed to centroid FA) and because their results do not differ noticeably. To validate the coding, I contrasted the results of the standard analysis as implemented in R with those obtained with the same options in *PQMethod* (Schmolck, 2012), a software commonly used for Q analysis. Both yield the exact same results to three decimal places.

The key terms to understand the process in Q analysis are: *Q-sorts*, *factors*, *factor loadings*, *z-scores*, and *factor scores*.[48] The distribution of statements by a single respondent—the response—is called a **Q-sort**. When ranking the statements according to their *agreement* or *disagreement*, each statement is assigned a value that corresponds to the column in which the respondent places it. For example, in the distribution in Figure 6.2 (p.161) the statements of most disagreement (numbers 16 and 8) would receive a value of −3. The Q-sort is thus the array of values given to all statements by a respondent.

A **factor** is the weighted average Q-sort of a group of respondents that responded similarly, and it represents an archetypical perspective; how a hypothetical

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46 Centroid FA is a rare form of FA, used exclusively in Q methodology. Its results are not identical to standard FA. Brown (1980) gives full details of the analytical process.

47 In this thesis, the term *factor* is used to refer to both *factors* and *components*, except when talking exclusively about PCA, where *component* is used. The choice of the method for extraction determines whether the extracted objects are factors or components, that are then used for the same purpose of interpreting the final perspectives. However in Q literature the term *factor* is standard.

48 The exact terminology can vary depending on the source.

best-representative of those with similar perspectives would sort the statements. Although no respondent may be a perfect representative of a factor and perspectives have no clear boundaries, typically each respondent is more closely related to a particular factor than to the rest, meaning that his or her Q-sort is most similar to that factor. The interpreted perspectives are rich and holistic, because the data collection method makes explicit the relative preference for every statement with respect to all other statements.

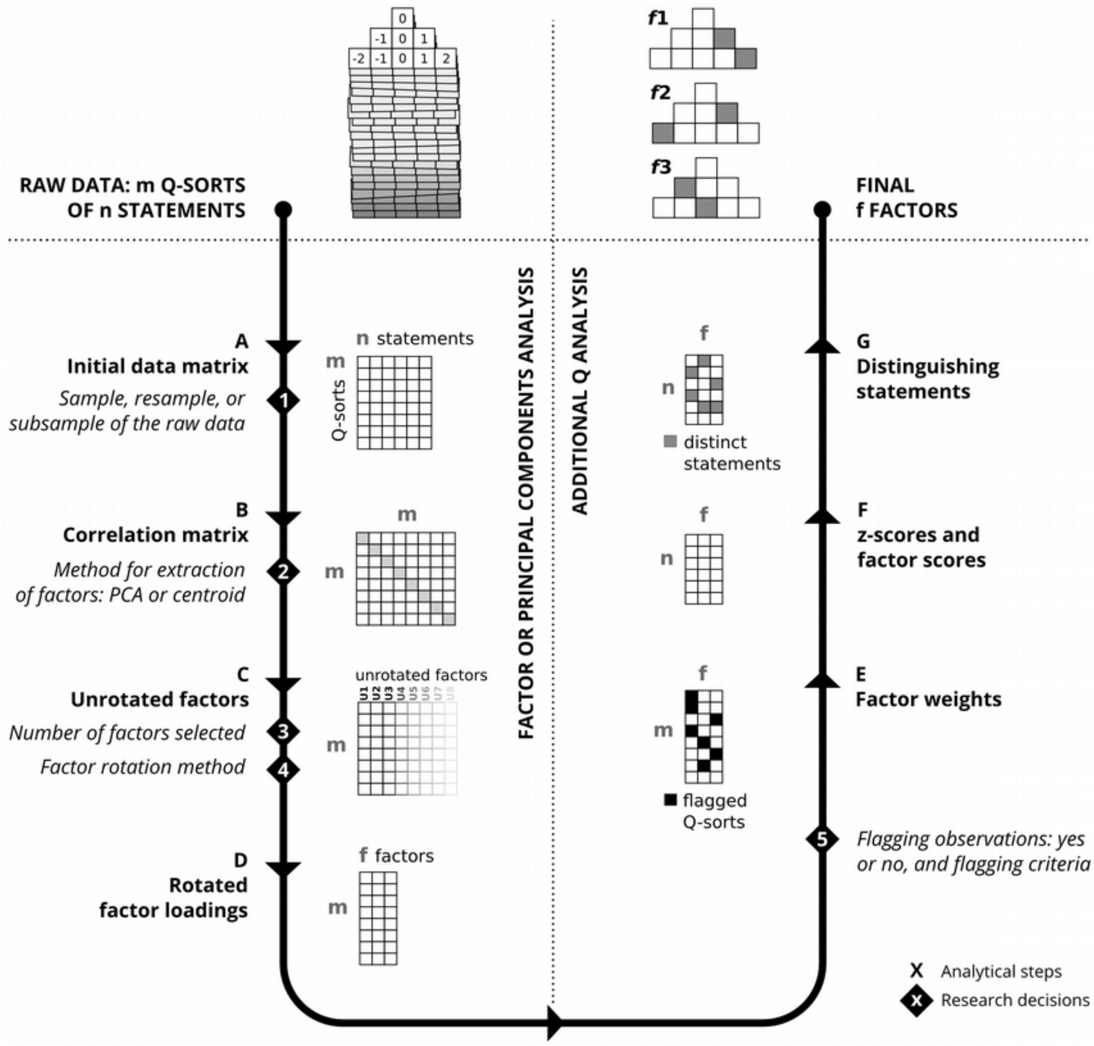
For Q-sorts, the correlation with each factor is given by the **factor loadings**, which range from -1 to $+1$. The respondent is most similar to the factor with which it has the highest loading. Once the Q-sorts with highest correlations are calculated, the analysis proceeds to obtain the z-scores and factor scores for statements.

For statements, the correlation with each factor is given by the scores (**z-scores** and **factor scores**), which indicate the statement's relative position within the factor. The z-score is a weighted average of the values that those Q-sorts most closely related to the factor give to a statement, and it is continuous. The factor scores are integer values based on z-scores, used to reconstruct the Q-sort of a factor, and they ease the interpretation of the perspective.

7.1.1. Factor loadings of respondents

Figure 7.1 illustrates the analytical process for a study of **m** number of Q-sorts and **n** number of statements as it is described in the literature (Brown, 1980). It shows the steps necessary to analyse the raw Q-sorts (top left) in order to finally obtain the factor scores for each statement and factor (top right), which are then interpreted. The process of analysis has two main parts: data reduction (steps A-D) and obtaining statement results (steps E-G).

Figure 7.1: The standard analytical process in Q methodology



The data collected are introduced into a matrix of statements and respondents (Q-sorts; step A). The first part (steps B to D) is the standard procedure of data-reduction in multivariate analysis. From a correlation matrix of Q-sorts (B), unrotated factors are extracted using PCA or centroid FA (C). Among the unrotated factors, the first few factors explain most of the variance of the initial correlation matrix and thus only a number of factors is selected for rotation. Details about the possible criteria to select the number of factors are given in Watts and Stenner (2012) and explained in section 7.2.

Factors are rotated in order to make the data structure clearer (D). Rotation can be manual (judgemental) or mathematically optimal, such as varimax, the former occurring when the researcher has relevant knowledge about a given respondent.

This step results in a matrix **L** of factor loadings (ℓ) that correlate the Q-sorts with the rotated factors.

7.1.2. Statement scores

The second part of the analysis (steps E to G) is specific to Q and reconstructs the archetypical response of each factor, based on the raw data and on the factor loadings. It consists of three steps: flagging the Q-sorts that will define each component (E), calculating the scores of statements for each factor (F; both explained here), and finding the distinguishing and consensus statements (G; explained in the next section).

Only the most representative Q-sorts for each factor are used for subsequent calculations; these Q-sorts are *flagged* (E). The purpose of flagging is to maximise the differences between factors (McKeown and Thomas, 2013). It may be done either automatically or manually. Automatic pre-flagging is based on two criteria (Equation 7.1): that the loading ℓ is significantly high (Brown, 1980), and that the loading is much larger than the loadings of the same Q-sort for other factors—that the square loading for a factor j is higher than the sum of the square loadings for all other factors (Van Exel et al., 2011). Some Q-sorts may be considered confounding because they load highly in more than one factor and thus they are not flagged. Further flags may be added or eliminated after manual examination of the loadings.

Equation 7.1: Criteria for automatic pre-flagging of Q-sorts (Brown, 1980; Van Exel et al., 2011)

$$\boldsymbol{\ell} > \frac{1.96}{\sqrt{N}} \wedge \boldsymbol{\ell}_j^2 > \sum_{i=1}^{f} \boldsymbol{\ell}_i^2 - \boldsymbol{\ell}_j^2$$

The value of 1.96 is for a significance threshold of p-value < .05. N number of statements; f number of factors.

The z-scores are calculated as a weighted average of the statement values given by flagged Q-sorts. The z-scores indicate the relationship between statements and factors; how much each factor *agrees* with a statement. Factor scores are obtained by ordering statements by z-score, and matching them to the array of possible scores in the original distribution. For example in Figure 7.1, the array is (−1, −1, −1, 0, 1, 1, 2). Factor scores are then used to reconstruct the final factor, which is how an archetypical respondent would sort the statements. The sign of the z- and factor scores roughly represents the *agreement* or *disagreement* of the given factor with the statement (in conventional distributions which reference scores are zero in the central column, and negative and positive values for disagreement and agreement respectively). Absolute z- and factor score values indicate the salience of the statements within a factor.

In addition, overall characteristics are calculated for each factor: the number of flagged Q-sorts, the composite reliability (Equation 7.2), the eigenvalues, the percentage of explained variance, and the standard error (*SE*) of z-scores of a factor (Equation 7.3). Two additional matrices indicate the similarity between the z-scores of each pair of factors: a matrix of correlation coefficients and another of standard error of differences (*SED*, based on the *SE*, Equation 7.4). These equations are shown because they are crucial in establishing why the enhancement in Chapter 7 is important.

Equation 7.2: Reliability of a factor (Brown, 1980)

$$r_f = \frac{0.8\,p}{1+(p-1)0.8}$$

Where p number of Q-sorts flagged for the factor. The value 0.8 is the estimated correlation between two responses by the same person (average reliability coefficient).

Equation 7.3: Standard error of factor scores (Brown, 1980)

$$SE_f = s_f \sqrt{1 - r_f}$$

Where s standard deviation of the distribution (of the array of scores in the grid).

Equation 7.4: Standard error of differences between factors (Brown, 1980)

$$SED_{ij} = \sqrt{SE_i^2 + SE_j^2}$$

There is an SED value for each pair of factors i and j.

Both the reliability of a factor and the variability explained are indicators of its strength, although they are rarely used for interpretation. The *SE* and *SED* are important because they determine between consensus and distinguishing statements (see below), and this is very frequently used in the interpretation. However, as seen in the equations, all three indicators are based primarily on the number of defining Q-sorts (p); no other indicator of variability—aside from the array of scores in the grid —is used to calculate them. This calculation, and the fact that work is done with small samples, may raise concerns over the robustness or reliability of the numerical results, particularly for researchers with a quantitative background. To address this concern, I develop the methodological innovation explained below.

7.1.3. Distinguishing and consensus statements

Finally, the statements that distinguish factors and those that are consensus are identified, based on whether the statement z-scores between factors are statistically different (step G). The distinguishing statements are those that a given factor ranks in a position that significantly differs from where the other factors rank it. The threshold for a difference to be considered significant is given by the SED_{ij} for each pair of factors (multiplied by 1.96 for p-value < .05, and 2.58 for p-value < .01, Brown, 1980, p.245). If the difference in z-scores is larger than the threshold, then the statement distinguishes factor *i* from *j*. The distinguishing statements and their position in the distribution are key to the interpretation of the factor.

Those statements which are not distinguishing for any of the factors are considered to be of *consensus*. Consensus may arise for various reasons: they reveal what the common ground is among perspectives, they are ambiguous, or they are taboo and therefore respondents did not want to express engagement.

The interpretation of each perspective is based on the hypothetical response of a factor, reconstructed from the factor scores; on the salience and distinctiveness of statements; and grounded on theory. The key elements to look at are the relative position of statements within the distribution (particularly those at the extremes), the position of a statement in a perspective versus the position of the same statement in other perspectives, and the distinguishing and consensus statements. Each perspective is given a semantic denomination and described in as much detail as necessary, using the qualitative explanations collected after each response.

7.2. Analytical considerations in standard Q

Among the few articles that discuss validity and potential technical enhancements to the analytical process in Q, some have performed ANOVA to test differences in factor loadings of each response across factors (McKeown and Thomas, 2013), or differences in z-scores among factors or between groups of statements within the same factor (Brown, 1999). A few papers are also concerned with the reliability and the external replicability of Q. Arguably, the contributions by Fairweather (2001, 1981) are the most relevant to the discussion of external and construct validity in Q; he investigates the internal replicability of three studies by analysing a few sub-samples and interpreting the results in comparison to the results of the main sample. He finds that the interpretation of factors may change remarkably in solutions of more than two factors or in factors that have few *flagged* responses (see explanation about flagging in Section 7.1.1). Additionally, an extensive test-retest reliability study demonstrated how some views may be more permanent than others (Davies and Hodge, 2012).

The numbered text in Figure 7.1 indicates the key research decisions that a researcher makes throughout the standard analytical process. The sample used in the analysis (decision number 1) may vary if some particular Q-sorts are excluded, or to implement internal replicability methods such as the ones explored by Fairweather (2001) and the bootstrap presented in this chapter. On the method for extraction of factors (2), there is discussion among practitioners of Q about whether to use PCA or the centroid method. Both are widely used and they yield similar results (McKeown and Thomas, 2013; Watts and Stenner, 2012). Regarding the decision on the number of factors to extract (3), the various possible criteria are extensively described in the Q and PCA literatures (a useful summary is given in Davies and Hodge, 2007; more details in Watts and Stenner, 2012). The following is a non-exhaustive list of criteria used to determine the number of factors: the variability explained by factors, at least two Q-sorts loading significantly, eigenvalues higher than a certain threshold, the factor is theoretically relevant, and interpretability and parsimony. The technique for rotation (4) depends on the aim and on the previous knowledge that the researcher has about respondents. It can be manual rotation if the researcher identifies one or a few important Q-sorts around which the rotation is centred. Otherwise, mathematically optimal solutions are used, such as varimax, in order to clarify the structure of the results. The final decision is whether to flag Q-sorts to calculate scores or instead whether to use all the Q-sorts (5). The former predominates because it results in more clearly distinctive factors, and it may be done automatically or manually. Boostrapping is based on the first of these decisions.

7.3. Bootstrapping Q

The underlying idea of the bootstrap is to draw resamples from the original sample multiple times, and to analyse each of the resamples (Efron and Tibshirani, 1993). In resampling, a random set of elements from the sample is extracted, where some elements may be repeated and others may be absent. With each resample, a full analysis is performed. This multiple replication yields an estimated distribution of the result values, from which relevant measures of centrality and of variability (such as mean and *SE*) can be drawn as alternative estimates of the result values.

The bootstrap is used across disciplines to obtain estimates for various results in PCA, such as eigenvalues and eigenvectors (Larsen and Warne, 2010; Yu et al., 1998), factor loadings (Peres-Neto et al., 2003; Zhang et al., 2010) and also to help deciding on the number of components to extract (Chatterjee and Pari, 1990; Markiewicz et al., 2011).

Some authors provide a detailed background about bootstrapping PCA (Babamoradi et al., 2013; Ichikawa and Konishi, 1995; Timmerman et al., 2007) and its performance is compared against other methods to estimate measures of variability, with a growing consensus about the benefits of using bootstrap in PCA (Babamoradi et al., 2013; Peres-Neto et al., 2003). The bootstrap is also considered an adequate approach to calculate standard errors for mathematically complicated processes—such as Q—because it requires no theoretical calculations (Efron and Tibshirani, 1993).

For Q, I suggest a non-parametric bootstrap resampling with replacement of Q-sorts, for three main reasons. First, I consider the bootstrap preferable for Q than other methods of internal replicability, namely cross-validation and the jackknife (Zientek and Thompson, 2007), because it allows more repetitions with smaller samples—which is usually the case in Q studies—and therefore it may provide more accurate estimation of *SE*s.[49] Second, the assumptions of the non-parametric version of the bootstrap are less strict than those of the parametric version (Babamoradi et al., 2013; Timmerman et al., 2007). Third, I reject conducting the bootstrap by resampling statements for two main theoretical reasons specific to Q. A Q-sort is interpreted as a whole and eliminating a statement would imply that the relativity of the score given to each statement is lost. Besides, each step would miss statements from the whole set, thus when obtaining factor scores, matching the full array of scores to an incomplete array of statements would introduce inflated variability.

To run the bootstrap in Q, the original sample is thus resampled multiple times and the full analysis is repeated with each resample. For example, given an initial sample of Q-sorts $\mathbf{m} = (m_1, m_2, m_3, m_4)$, a resample $\mathbf{m'}$ is drawn for each repetition. The resample $\mathbf{m'}$ contains a random array of the elements in $\mathbf{m}$ and, because the random selection is with replacement, a given element of $\mathbf{m}$ might not appear or might appear more than once in the resample, e.g. $\mathbf{m'} = (m_1, m_1, m_1, m_4)$. The resample $\mathbf{m'}$ is analysed. This process of resampling and replication is repeated multiple times. The results from all the resamples constitute an estimation of the distribution of the statistic of interest. Figure 7.2 shows the algorithm to implement the bootstrap, which details are given below.

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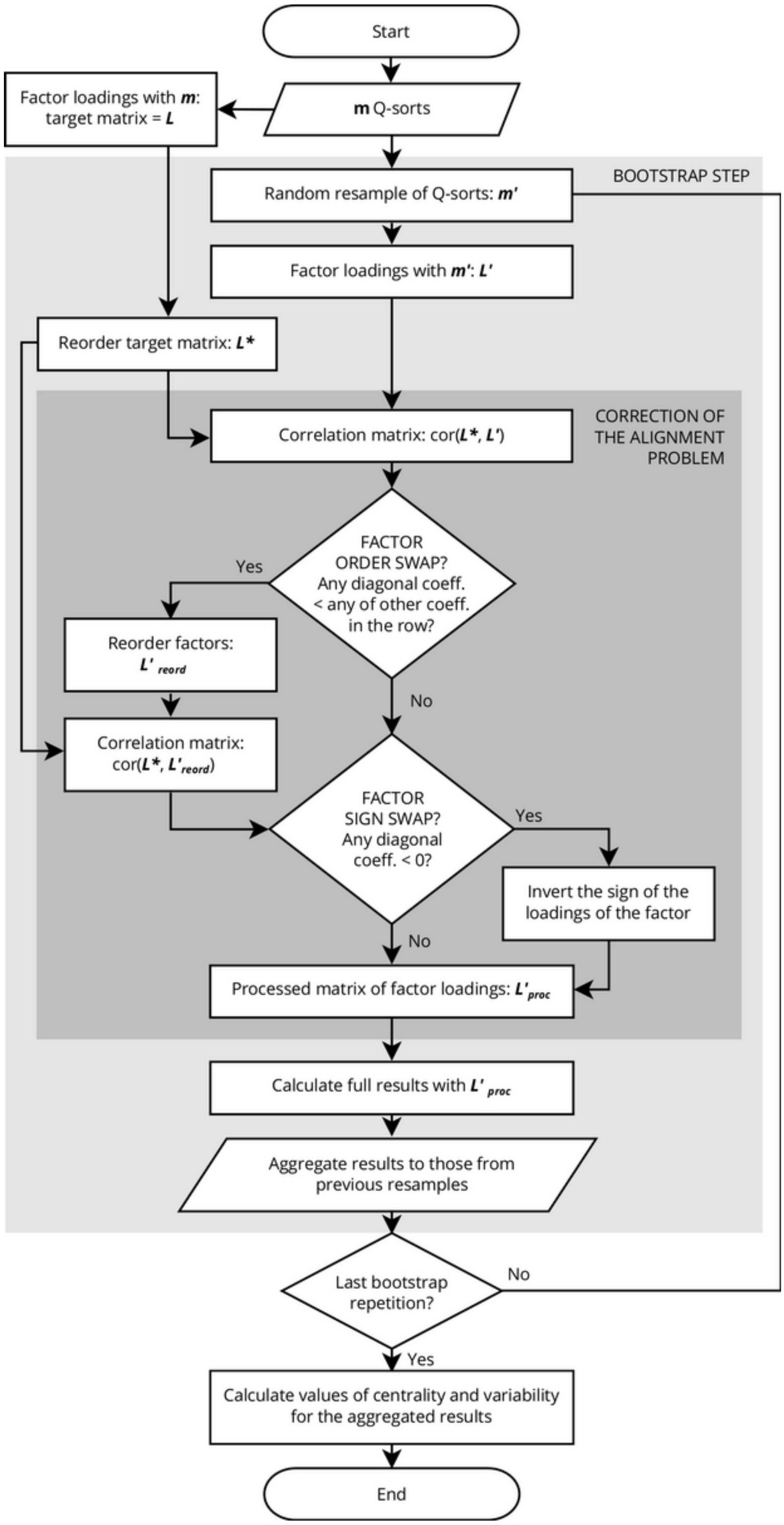
[49] The jackknife may be sufficient if we were concerned only with outlier Q-sorts, yet it would limit the estimation of further values.

Figure 7.2: Algorithm for bootstrapping Q methodology data



***m** represents a one-dimensional vector of Q-sorts. **L** is a two-dimensional matrix of factor loadings for Q-sorts and factors.*

The higher the number of repetitions, the better the approximation will be to the true values. The number of repetitions may be limited by computing capability and the literature suggests that at least 50 repetitions are necessary and 200 are satisfactory to calculate *SE*s (Efron and Tibshirani, 1993), and that at least 1,000 are necessary to estimate *CI*s (Davison and Hinkley, 1997). A rule of thumb when bootstrapping PCA is to perform at least 40*m* repetitions (Davison and Hinkley, 1997).

With respect to other decisions in the analysis, the rotation method of choice is to be used consistently in all the bootstrap repetitions. I also suggest automatic flagging or otherwise a fixed flagging for all the repetitions. This is because a manually inspected flagging and manual rotation in each repetition may not be feasible due to computational limits and arguably, to the incomparability of manually manipulated individual repetitions in the bootstrap.

7.3.1. The alignment problem

An essential consideration when bootstrapping PCA is that variability estimates can be arbitrarily inflated due to the *alignment problem* (Timmerman et al., 2007; Zhang et al., 2010). This problem occurs because component extraction and rotation are purely mathematical procedures that overlook the underlying concept behind each component, and it has two main consequences. First, axis reflection (or sign indeterminacy) refers to the fact that component loadings can arbitrarily change sign in subsequent bootstrap repetitions, even though the absolute magnitudes of the loadings remain within the underlying distribution space. A way of assessing whether reflection is a problem is by looking at histograms of bootstrapped factor loadings for a single Q-sort and factor: they may be bimodal—showing peaks at both sides of the zero vertical axis—when the problem occurs (Yu et al., 1998). Second, the components extracted are usually ordered according to the percentage of variance that they explain. When two or more components explain a similar amount of variability, axis reordering or interchange may happen in some of the bootstrap repetitions, hence introducing values which do not belong to the underlying distribution.

In order to solve both sources of variability, it is assumed that the underlying distribution is similar to that of the analysis of the initial sample and thus the results of each bootstrap repetition need to be inspected and corrected when necessary towards matching the initial results. A simple and robust solution for the alignment problem is to reorder and reflect components when necessary (Zhang et al., 2010).[50]

I developed an algorithm to perform the bootstrap (Figure 7.2) which also implements this correction (dark area in the Figure) and I coded it in R statistical language.

The algorithm starts by calculating the factor loadings for the full sample (*target* or *reference*) and for the resample, and then building a correlation matrix between both. The matrix contains as many rows and columns as the number of factors (components) extracted and rotated. If no alignment problem occurred, the coefficients in the diagonal should all be positive and closer to 1 than all other coefficients (e.g. factor one in the standard analysis is most highly correlated with factor one in the resample). Thus for a given component, in order to test for factor order swap, the absolute correlation coefficients outside the diagonal are compared to the absolute coefficient in the diagonal. If the diagonal coefficient is smaller than any of the others, then components need reordering. For a given target component, the bootstrapped component with the highest correlation coefficient is selected.[51]

After reordering, a new correlation matrix is built between the reordered components and the target components to test for reflection (sign swap). High negative correlations in the diagonal indicate reflection and these are corrected by inverting the sign of the loadings in the bootstrapped component.

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[50] Another alternative suggested in the literature to correct the alignment problem in PCA bootstrap is orthogonal Procrustes rotation for optimal reflection of the component loadings, using the loadings of the initial sample as target matrix (Linting et al., 2007; Raykov and Little, 1999; Timmerman et al., 2007) Both reordering-reflection and Procrustes may also be used together (Babamoradi et al., 2013). In the experiments run for this chapter, both approaches give similar results and Procrustes provide only slightly smaller variability measures. I thus suggest the reordering-reflection approach explained above because the correction based on correlation matrices is much more intuitive and transparent.

[51] If one of the bootstrap components is best match for more than one target component, then the bootstrap repetition is discarded, because a solution for this would require a much more complicated algorithm. This may happen more frequently with smaller samples with which the PCA of the resample can differ noticeably from the initial sample. In this case, more bootstrap repetitions may be needed to account for those resamples that are discarded in the process.

7.3.2. Resampling the Q-sorts

As a consequence of resampling Q-sorts, the bootstrap in Q presents its distinctiveness within the literature on the bootstrap in PCA. In order to implement bootstrap in PCA, observations are resampled and variables are correlated. The initial array of observations **o** = (o_1, o_2, o_3, o_4) is resampled into, e.g., **o'** = (o_1, o_1, o_1, o_4), while the variables **v** = (v_1, v_2, v_3, v_4) remain the same. The PCA of the resample **o'** begins by correlating variables and the extraction of factors results in a matrix of component loadings with variables **v** as rows and components as columns. All the variables in **v** are represented and represented only once. The alignment problem is then corrected, using the loadings from the analysis of the initial sample as the target matrix. Each row in the reference matrix corresponds to the same row in the resampled matrix of loadings.

By contrast, in Q analysis the respondents are correlated instead of the variables—some call Q an inverted FA. The initial array of Q-sorts **m** = (m_1, m_2, m_3, m_4) is resampled into, e.g. **m'** = (m_1, m_1, m_1, m_4). The extraction of factors results in a matrix of loadings with the resampled set **m'** Q-sorts as rows and factors as columns. The correction methods for the alignment problem compare the matrix of loadings from the resample and the target matrix row by row and they are sensitive to the order of the rows in each matrix. As a consequence of **m** ≠ **m'**, the resampled matrix of factor loadings is not comparable with the target matrix; by pairing different Q-sorts from **m** and **m'**, the correction methods would give spurious results. The solution that I adopt for bootstrapping Q is to reorder the rows in the target matrix in every bootstrap repetition, resulting in an adapted array of rows, e.g. **m*** = (m_1, m_1, m_1, m_4), so that **m*** = **m'**.

7.3.3. Interpretation of the bootstrap results

The main statistics of interest estimated with the bootstrap are the z-score and the *SE* value for each statement and factor. The former is calculated as the mean of the distribution of z-scores for a single statement and factor and the latter is calculated as the standard deviation (Efron and Tibshirani, 1993). For a given statistic, the *bootstrap estimate of bias* is the absolute difference between the value from the standard results and the bootstrapped estimate. Also, the correlation between the z-scores from the initial results and the bootstrap z-scores indicates how similar the bootstrap factors are to the standard ones. This correlation gives an overall view of the internal robustness of the results.

The bootstrap estimates have two main potential consequences for the interpretation. These consequences depend on the position of unstable statements (with high values of variability) in the distribution and on whether they were considered as distinguishing in the standard analysis: (a) that the description of factors is nuanced after increasing or decreasing the emphasis of certain statements, and (b) in more severe cases, that the description of factors changes importantly due to key statements changing their position remarkably in the distribution, or showing large instability.

The interpretation of bootstrap results for statements is based on the bootstrap estimate of bias of z-scores and their *SE*. Both statistics are useful to understand whether the position of a statement is stable and whether it significantly differs from other statements within the same factor and in comparison to other factors. Also, this statement-specific estimate of *SE* allows performing further inferential tests to determine more accurately than with the standard procedure whether a statement is distinguishing or consensus.

The position of a statement in a factor may be unstable or uncertain if either the z-score *SE* or the bootstrap estimate of bias of factor scores is large. In this situation, the (dis)agreement on this statement is not clear among those representing the factor, thus its reliability may be small and this should be integrated into the interpretation. Likewise, statements that present very stable positions have a very reliable meaning within the factor in which they are stable. When based on factor scores, the interpretation of a stable statement may also be affected if the statements above or below in the factor ranking are unstable and with similar z-score values. Particular attention should be paid if any statements that are distinguishing in the standard results are unstable after the bootstrap. In order to synthesise this information for the interpretation, I suggest a classification of the most relevant statements according to their salience and stability (Table 7.1).

Table 7.1: Theoretical classification of statements in Q according to interpretative power

		<u>Stability</u> (distinctiveness, *SE* of z-score)	
		High	**Low**
<u>Salience</u> (magnitude of z-score)	**High**	Highest interpretative power, very reliable	Meaningful within the factor but its relative position is fuzzy
	Low	Reliable but not particularly meaningful to interpret the factor	Lowest interpretative power, less reliable

Low levels of salience and of stability could also have a conceptual explanation relevant for the interpretation.

Other important values that can be estimated for statements are the *CI* for z-scores using percentiles or either bias-corrected and accelerated *CI* (Efron, 1987, in Timmerman et al., 2009) and the frequency in which each statement is selected as distinctive or as consensus. For Q-sorts, bootstrap can provide alternative estimates of factor loadings, their *SE* and *CI*, and the frequency with which each Q-sort is flagged for a given factor.

Analogous to the interpretation of bootstrap estimates for statements, for Q-sorts the magnitude of the mean and the *SE* of factor loadings indicate respectively how much a respondent defines a factor and how stable it is as a definer. The frequency with which a Q-sort is flagged in the bootstrap is another measure of stability. A Q-sort may be an ambiguous representative of a factor if it is flagged in a moderate proportion of the steps. In sum, the following are possible sources of instabilities (and vice-versa for stabilities) to be detected with the bootstrap:

1. Statements that are unstable because they change position in the factor, or because their *SE* is large.
2. Statements considered as distinguishing not being distinctive any more.

3. Ambiguous Q-sorts that are flagged inconsistently for a given factor. For example, if they are flagged approximately between 20% and 80% of the bootstrap repetitions.
4. Highly influential Q-sorts which exclusion changes the results considerably.

7.4. An aggregate index of factor stability

In order to synthesise the bootstrap information about the stability of a factor I formulate an index that aggregates the estimates of bias of statement scores. This index serves two purposes: to summarise the information from the bootstrap, and to provide an alternative estimate of the stability of a factor, which is based not solely on the number of flagged Q-sorts (see Equation 7.2).

The z-scores give precise results for the interpretation, however the final interpretation of perspectives is mostly based on the position of the statements in the distribution—the factor scores. Thus I base the factor stability index FS_f on the bootstrap estimates of bias for factor scores (Equation 7.5).

Equation 7.5: Factor stability index for Q methodology

$$FS_f = \frac{\sum_{n=1}^{N} |\theta_{nf} - \hat{\theta}_{nf}|}{N}$$

Where f is the factor; n denotes a statement; N total number of statements, θ_{nf} *factor score in the standard analysis;* $\hat{\theta}_{nf}$ *factor score in the bootstrap; thus* $\theta_{nf} - \hat{\theta}_{nf}$ *is the bootstrap estimate of bias of factor scores.*

One factor stability index may be calculated for each factor *f* and this index jointly summarises the number of statements that change position and the magnitude of these changes. The index of factor stability can be applied to both symmetric and asymmetric distributions (see section 6.1.1) and allows the comparison between factors within the same study. It also enables the comparison between studies as long as they have the same distribution and the same number of statements.

Whereas the minimum index of factor stability may always be 0—of highest stability—when no position change takes place, the maximum value is conditional on the shape of the distribution and the number of statements. Thus I suggest a normalised version (Equation 7.6), which bounds the index between 0 and 1 for symmetric distributions.

Equation 7.6: Normalised factor stability index

$$FSN_f = \frac{\sum_{n=1}^{N} |\theta_{nf} - \hat{\theta}_{nf}|}{N \cdot 4t} = \frac{FS_f}{4t}$$

In Equation 7.6, 4*t* represents the maximum that a factor *f* can differ from another factor *f** with the same statements and distribution. We saw that the estimate of bias of factor scores for a statement n_i is the difference in the position of a statement between *f* and *f**, $\theta_{nf} - \theta_{f*}$. Thus the difference between a factor *f* and a factor *f** can be calculated as the sum of the absolute differences in factor scores for all statements. This sum is the numerator in Equation 7.6. The maximum difference (4*t*) between two factors occurs when all the statements change their position in factor *f** with respect to factor *f*.

To calculate the value of *t*, we assume a symmetric distribution where positive scores are assigned to the columns on one side of the central column, and negative scores to columns on the other side.[52] Under this scoring protocol, the value of *t* is the addition of the array of possible factor scores in the positive side of the distribution. For example, for the distribution at the top of Figure 7.1—which ranges [−2, 2]—the value is $t = 1+1+2 = 4$, and the maximum possible difference between two factors (in accumulated differences in factor scores) is $4t = 16$. In a similarly shaped distribution

[52] Using this scoring protocol is essential to calculate the value of *t*, but this is independent of the protocol used in the raw data. The latter can also be with 1 in the leftmost column and with increasing units towards the right columns, for example.

but which ranged [−3, 3], the value would be t = 1+1+1+2+2+3 = 10, and the maximum difference between factors would be $4t = 40$.

The rationale for this calculation of $4t$ is that a factor f differs most from a factor f^* when the statements located on the right half side of the distribution in f are located on the left in f^* and vice-versa simultaneously, as if the distribution of statements rotated around the centre. When this occurs, the cumulative estimates of bias in factor scores of the statements that are on the right hand side in f sum twice the values of the columns on the right half. The same sum applies to the statements that are in the left hand side in f, taking the absolute differences. It follows that when two factors are most different, the sum of absolute differences in factor scores is four times the addition of the positive column values t (Equation 7.7). A numerical simulation was run to confirm this equation, for which code is available.

Equation 7.7: Maximum possible differences between two Q-sorts

$$max\left(\sum_{n=1}^{N} |\theta_n - \hat{\theta}_n|\right) = 4t$$

The resulting normalised factor stability index (Equation 7.6) ranges [0, 1] independently of the number of statements and of the distribution shape, as long as it is symmetric. Thus it allows a broader comparison across studies, irrespective of their number of statements and columns. The lower the index value, the more stable a factor is. An index of 1 may occur if the difference between the bootstrapped factor and the standard factor is the maximum mathematically possible.

By focusing on factor loadings, this index might lose some numerical precision of the z-scores. Yet this index has been selected for its simplicity and it robustly reflects the statement position changes detected with different sensitivity tests performed during the analytical experimentation for this chapter and based on decisions in Figure 7.1. The factor stability index is calculated based on all the statements in the Q-set.

7.5. Methodological discussion

The bootstrap approach provides a more accurate understanding of the data and of the robustness of the perspectives, which may increase the confidence of the researcher in the results. The bootstrap approach quantifies the level of confidence of each individual statement in each factor. This information, together with the factor stability index may help researchers to better understand the uncertainty associated with the results and it may qualify and in some cases change meaningfully the interpretation of perspectives with respect to an interpretation based on the standard results.

Acknowledging ambiguity in statements is particularly relevant if any of the statements selected as distinguishing in the standard analysis shows instability in the bootstrap. On the contrary, other statements that might initially be overlooked could present a very stable and distinguishing position in a given factor, hence becoming reliable definers of it. I also argue that reporting factor stability indices allows for a more accurate comparison of the reliability of the perspectives described, within and across studies.

Bootstrapping Q opens new methodological and empirical avenues for future research. The proposed normalised index of factor stability, which enables wider comparison across studies, is applicable to symmetric distributions because the calculation of the maximum possible position changes (the denominator) may be different in asymmetric distributions. Thus a further methodological development may be to formulate a generalised index for asymmetric distributions and so enable wider cross-comparability of studies. Furthermore, expanding to a systematic sensitivity analysis by varying the number of factors (e.g. Van Exel et al., 2011) may help deciding on the number of factors to extract. This sensitivity analysis can shed light about the existing range of perspectives by showing whether the factors excluded are sub-views of factors actually included or whether they are remarkably different and relevant. Also, this chapter illustrates bootstrap with PCA and varimax rotation, yet the centroid method for the extraction of factors and manual flagging could potentially be implemented. The former involves further solvable computational complexity. The feasibility of the latter can be explored by applying a fixed set of manually flagged Q-sorts throughout the bootstrap. Last but not least, extensive empirical application of the bootstrap and of the suggested factor stability index to several datasets may help establishing acceptability thresholds for index values.

Generally speaking, the process of analysis and interpretation of Q methodology can be enhanced using further quantitative developments. In addition to the bootstrap implemented here, other techniques in statistics have been put forward in recent decades (e.g. new methods to select the number of factors) and computational capacity has increased enormously, yet their application in Q is underexplored. These advances have a large potential to make Q a more solid and reliable method for the identification of the existing viewpoints and decision-making styles to better understand and manage environmental issues involving diverse perspectives.

Applying this bootstrap advancement, the next chapter uncovers the perspectives regarding adoption of silvopasture in order to improve incentive policies to encourage such practice. This approach allows the extraction of more information from the data collected (Section 6.1), and to fully understand the reliability of the results.

Summary of Part III

To understand how livelihoods, perspectives, and subsidy dependence motivate or hinder individual SPS adoption in the case study, Chapter 6 explains the collection and analysis of primary and secondary data. The choices in this design are adapted to the case explained in Part II, and the empirical results and discussion are presented in Chapters 8 and 9.

The collection of data about livelihoods uses an innovative game-like approach to gather information on asset allocation (land, effort, investment) and income portfolio across different livelihood activities. This approach makes explicit the trade-offs between activities, which farmers encounter in real life, in contrast to conventional questionnaires where absolute values are sought independently. It is also more attractive for respondents and reduces bias related to hiding sensitive information. To complement the livelihood data, I gather socio-economic data and multiple-choice opinions about SPS adoption. Data is collected from 104 heads of household, 58 of which were selected because they participated in the tree-planting project, and the rest were selected through stratified random sampling. I introduce the analytical methods employed to understand livelihood strategies (cluster analysis) and to model what predicts adoption (econometric modelling).

I use Q methodology to collect data about subjective (internal) perspectives on key topics derived from Part I and II: SPS adoption, cattle-farming practices, general attitudes towards livelihoods, and conservation views. Q is increasingly used across disciplines and helps uncover heterogeneous perspectives, which are important for the analysis of silvopasture adoption decisions within SES, as explained in Chapter 2. The methodology is systematic and provides quantitative results.

However, the calculation of the measures of spread of these results (the *SE* and subsequent values), used to determine important elements for the interpretation (mainly, the distinguishing and consensus statements), can raise doubts over reliability. Measures of variability are critical for the interpretation in most quantitative methods. Yet the current standard procedure in Q provides rudimentary *SE*s for factors, but not for the individual statements on which the interpretation is based. In order to address this concern, I develop an analytical innovation to improve the accuracy of Q results, based on bootstrapping and explained in Chapter 7. Its purpose is to help researchers better understand their results, and to provide further information to enhance the interpretation and facilitate analytical decisions.

Bootstrap has several advantages—as stated in Chapter 7—and it has been integrated with many other techniques. The main benefit of bootstrapping Q is that it provides measures of variability that are specific to each statement and factor. This information can add or subtract strength to particular arguments in the interpretation of perspectives. While the bootstrap has not been used in Q methodology, several characteristics of the analytical process in Q make this a particular application of the bootstrap in multivariate analysis. Applying bootstrap to Q entails certain theoretical considerations and decisions that I discuss in detail. I provide guidelines for the interpretation of bootstrap results, and develop a factor stability index in order to aid the comparability of factors within a study and, under certain conditions, also across studies.

In Part IV the results are shown and discussed. The bootstrap approach is implemented to obtain the results discussed in Chapter 8. The resulting perspectives are presented in Chapter 8 and they are discussed with respect to their motivations to adopt SPS and potential incentives to trigger these motivations. The livelihoods data are analysed in Chapter 9, which identifies different livelihood strategies, shows the effect of livelihood covariates on participation and adoption in the SPS project, and discusses these effects in the context of the livelihood strategies identified.

PART IV: RESULTS AND DISCUSSION

The next two chapters present the findings about perspectives, livelihoods, and (short-term) adoption of silvopasture in the case study. These results are based upon the empirical approach described in Part III. Chapter 8 uncovers three perspectives on SPS adoption among participants in the fodder tree planting project in the case study, defined principally in terms of beliefs and preferences about cattle-farming and silvopasture, and in terms of attitudes towards conservation, external payments, and innovation. The discussion of these perspectives focuses on their relation with previous typologies in the adoption literature, their likelihood to adopt, and the role of incentives, particularly payments for ecosystem services, in triggering this adoption. Chapter 9 explores the heterogeneity of livelihood strategies existing in the case study, in order to better understand what makes individuals decide upon how they allocate land, investment, and effort into different activities, and therefore to be able to discuss how silvopasture might have a niche in these livelihoods. The chapter presents a model of adoption that considers this action as a process, within which participation in the project and the effort put into adoption are distinct decisions. The model reveals relationships of adoption and participation with livelihood variables, which are later discussed.

These results are utilised in the final chapter of the thesis to discuss future research needed and policy implications for designing more effective external interventions.

Chapter 8. Uncovering social-ecological perspectives towards silvopastoral innovation

This chapter identifies and discusses local farmers' attitudes and perspectives regarding adoption of silvopastoral systems (SPS) in the context of the cattle-farming community in the buffer area of La Sepultura Biosphere Reserve (REBISE; see details of the case study in Chapters 4 and 5). According to the conceptual framework, understanding the distinct perspectives (which reveal their motivations) may be instrumental to explain variability in the adoption of sustainable land uses promoted by incentive-based programmes (as emerged from the theoretical background in Part II). The discussion of perspectives focuses on how each of them might react to policy incentives such as payments for ecosystem services (PES), what types of incentives might be most effective to catalyse their adoption, and how individuals with each perspective might respond to monetary incentives.

Based on the typologies of farmers found, this chapter sheds light onto how incentive policies may be designed to be more cost-effective in a context of gradual adoption of SPS. Results suggests three types of perspective, and their differences in the levels of adoption are not statistically significant. None of the types is particularly prone to adopt SPS, due to reasons that vary across them. Each type has distinct latent motivations and hindrances for uptake, which are discussed in this chapter and for which specific policy implications are suggested in Chapter 10.

The study of perspectives revolves around the topics of innovative practices, external payments, conservation and livelihoods (see research design in Section 6.1.1), which are identified as pivotal through the theoretical background and the description of the case study (Parts I and II). In order to increase the reliability and accuracy of results, the bootstrap is implemented, an analytical enhancement developed in Chapter 7. Data was generated by 32 respondents sorting 26 statements (see sampling in Section 6.1.2).

Perspectives are contrasted to observed data about livelihood strategies and about the performance in the silvopasture adoption programme (which collection is explained in Section 6.2). Results give indication of potential forms of rewards that can effectively incentivise those farmers that are more likely to adopt and continue silvopastoral practices. I argue that this methodological approach can help design policies which are more efficient and capable of boosting a behavioural change.

The chapter continues with the explanation and justification of decisions for each analytical step, and presents the results (Section 8.1). This is followed by the interpretation of the typology of perspectives in Section 8.2. Section 8.3 discusses the implications in terms of potential responses to incentives. Section 8.4 sums up and provides final remarks about the importance of a better understanding of the role of heterogeneous motivations for pro-environmental behaviour (PEB).

8.1. Perspectives resulting from Q methodology analysis

The standard Q method analysis reduces responses to a few main types of perspectives and is an extension of multivariate analysis (as explained in Chapter 7).

I select three factors after assessing a number of standard criteria in Q. The first 6 factors have eigenvalues higher than two and would have more than one defining respondent, while the first twelve had eigenvalues higher than one. The scree plot indicated that three or four factors would be adequate. The third factor explains 13% of the variance and the fourth and fifth factors would explain 12% and 10% respectively. A fourth factor would be defined by only three out of the 32 respondents, one of whom defines it in the opposite direction (high negative loading). Most importantly, preliminary interpretation of this fourth factor suggests that the view represented would be very similar to the first factor, with a few traits shared with the second one. I also run a sensitivity analysis of the final results by selecting from two to eight factors, in order to see whether any of the results changed noticeably in the first few factors. Moderate changes were found in the fourth factor, and significant changes in the fifth and subsequent factors.[53] Considering all the above, three factors were finally extracted as a parsimonious compromise, which together explain 54% of the variability in the views of respondents. This percentage of variability is consistent with other Q studies (e.g. Buckley, 2012; Lansing, 2013).

I implement the Q bootstrap approach developed in Chapter 7, in order to enhance the robustness of the results. A bootstrap re-sampling with replacement is run in 3,000 steps, using PCA and varimax rotation. I use PCA for extraction (such as in Buckley, 2012; Fairweather and Klonsky, 2009; Lansing, 2013; Vignola et al., 2010) to allow the bootstrap implementation, and because its results do not differ much from centroid extraction results (see Section 7.1). I use varimax rotation because it is commonly used in Q studies (e.g. Davies and Hodge, 2007; Dryzek and Berejikian, 1993; Kline and Wichelns, 1998; Zografos, 2007), different manual rotations of each repetition may raise concerns of incomparability after the boostrap, and there is no specific respondent around which it would be desirable to make a manual rotation. The full analysis is performed for each of the resamples as per the algorithm in Figure 7.2 (p.199).

Q method yields three important results: the factor characteristics, the respondents' factor loadings, and the statements' factor and z-scores (see Section 7.1). All these results are shown below. Factor characteristics indicate the reliability of the factors and other general parameters (Table 8.1).

53 I also run a sensitivity analysis to identify highly influential respondents. A single highly influential case was found, which was annotated, but the analysis continues with the full sample.

Table 8.1: Q methodology results: factor characteristics

		Self-sufficient[54]	**Environ-mentalist**	**Payment-dependent**
Explained variance		25%	17%	13%
Normalised Factor Stability Index		0.0007	0.0022	0.0011
Number of defining Q-sorts (*p*)		13	8	7
Number of defining Q-sorts by level of adoption	*No plants*	6	3	6
	Some plants	3	4	1
	Many plants	4	1	0

The level of adoption is based on percentiles of the variable of adoption explained in Section 6.3.2.

The overall characteristics indicate that the first factor is most stable and explains a quarter of the variance in the responses. The other two also explain an important amount, and all factors are represented by a considerable number of defining Q-sorts. The Factor Stability Index for the second factor is highest, meaning least stability (see Section 7.4). This suggests that responses closest to this factor might have been less unanimous. This is understandable in comparison with the first factor, but surprising when compared with the third one, which is defined by fewer Q-sorts. This indicates that those who represent the third factor might be more consistent in their views than those representing the second one. The comparison of flagged—defining—Q-sorts with categories of success in planting trees reveals a trend: most of those who had many plants share the first perspective, and those who had some plants are mostly within the first and second perspectives.

Respondents were selected as *defining* following the standard criteria in Q (see Section 7.1.1). Four respondents were not flagged because they had relatively high loadings in two or three factors, implying that they shared features from more than

[54] The denominations of factors are explained later in Section 8.2.

one view simultaneously. Respondents' factor loadings and bootstrapped *SE* are presented in Table A1 in Appendix (p.318).

The statement factor scores are shown in Table 8.2 with an indication of what factors they distinguish or whether they are of consensus (full bootstrap results with z-scores and *SE* are shown in the Appendix, Table A2, p.319). The z-scores are also analysed by topic group. These topics have been selected as most relevant according to the theoretical background and case study description, and are explained in Section 6.1.1. However, no significant differences were found.

Table 8.2: Bootstrap estimates of statement factor scores

ID	Topic	Statement	Self-sufficient	Environ-mentalist	Payment-dependent	Dist. / Cons.
15	**A**	We need more external payments so that my children do not need to go to live elsewhere	–2	2	2	*f1*
21	**A**	If the government does not give me external payments, taking care of the forest does not benefit me	–3	–3	0	*f3*
12	**D**	My land is 'getting tired'	0	2	–3	*All*
17	**E**	If I had more money, I would plant fodder trees instead of increasing my cattle	0	1	–2	*All*
6	**D**	I could increase my benefits in cattle-farming without degrading the land	0	–1	1	*f2*
18	**D**	In dry season there is no alternative other than releasing my cows free into the mountain	–1	–2	0	*All*
20	**E**	It is convenient for me to clean my fodder tree plot from weeds even if I have other tasks, in order to produce more fodder	1	0	–1	*f3*
22	**C**	I try new things in my job	1	0	–1	*f1*
4	**A**	I can maintain my family with my own work, external payments are just an aid	2	0	–1	*f1*
8	**A**	I participate in all external programmes that bring income	–1	–2	0	*f2*
1	**C**	My children and grandchildren will work the same land that I cultivate now	0	0	3	*f3*
11	**C**	I analyse my costs and benefits and thereafter I work on the most beneficial activity	1	1	0	*f3*
2	**E**	I prefer two hectares of pasture than one hectare of fodder trees	1	–1	0	*f1*
13	**D**	What cattle produces is much more than what land loses	–1	0	1	*f1*
26	**E**	In order to dedicate one hectare to fodder trees during two years, I would need more land than what I have	–2	–1	–1	*f1 from f2*
16	**D**	It is more convenient for me to invest money in improving my pastures than in buying cows	0	2	0	*f2 from f3*
23	**A**	I rather live from external payments than from working my lands	–3	3	–3	*f1*
24	**D**	I need to improve my pasture, otherwise cattle-feed will run out in a few years	2	1	3	*f3*
19	**D**	With more training I could improve very much my work in cattle-farming	2	1	1	*f1 from f2*
7	**E**	Cultivating fodder trees involves a lot of effort and little benefit	–1	–1	–2	*Cons.*
9	**C**	It is more convenient for me to cultivate my own food than buying it	3	3	2	*Cons.*
10	**B**	Conserving the forest is responsibility of the landowner	3	3	2	*Cons.*
3	**A**	What is of most interest to me from external programmes is what I learn to earn more money	0	0	1	*Cons.*
5	**E**	With tree planting programmes I receive more money in return for my work	–1	–1	–1	*Cons.*
14	**E**	It takes long for fodder trees to grow	–2	–2	–2	*Cons.*
25	**B**	I can earn more as a cattle-farmer if I let live other wild animals	1	1	1	*Cons.*

Ordered from most disagreement (top) to most agreement, based on z-score differences. Topics (details in Section 6.1.1): 'A', external payments; 'B', conservation and environment; 'C', attitude and personal behaviour; 'D', cattle-farming preferences; 'E', preferences about fodder-tree planting. 'Dist. / Cons.' Distinguishing and consensus statements: 'fi' the statement distinguishes factor i from the rest; 'All', distinguishes all factors; 'Cons.', consensus. Original statements are in Spanish (Table 6.1, p.163).

The Q results are compared with observed livelihood information and with performance in the tree planting programme (see data description in Section 6.2). Factor loadings (Table A1 in Appendix, p.318) are compared with these variables by means of correlation coefficient tests. Table 8.3 shows the correlation test results for key livelihood variables, including specialisation in cattle farming, in other livelihood activities, dependence on external payments, and endowments. In addition, ANOVA test for differences among groups according to the level of income are not significant, suggesting that there are no differences in terms of income among the perspectives.

Table 8.3: Comparison of perspectives and key observed variables

Variable	Self-sufficient	Environ-mentalist	Payment-dependent
*Benefits from **cattle-farming** (%)*	–.33 *	–.38 *	.37 *
*Benefits from **wage labour** (%)*	–.05	.40 *	–.24
*Benefits from **commerce** (%)*	.08	.08	–.34 *
*Benefits from **subsidies** (%)*	.06	–.06	.09
*Livelihood **diversity** (index)*	–.13	.06	.05
*Total **land** owned (Ha)*	–.17	–.39 *	.26
Experience with cattle-farming (years)	–.43 *	–.23	.46 *
Age	–.12	–.16	.21
*Number of **youth** in the household*	.38 *	–.12	–.08
Adoption	.24	.23	–.18

Values correspond to Spearman correlation coefficients between variables and factor loadings for each perspective. Significance: $p < 0.1$, ** $p < 0.05$. Sample N = 32. Bold face is used to facilitate the comparison with results later in Section 9.3.*

The comparison indicates that respondents who define factor three own more land than the rest. Both the first and the second factors had a better performance in the outcomes of tree planting, however this is not significant. More specialisation in cattle-farming distinguishes factor three from the rest. Actual dependence on subsidies does not significantly distinguish perspectives, neither does the diversity in livelihood strategies.

8.2. Interpretation

The interpretation of factors is based on the statements: their salience within each factor and their distinctive position comparing to that on other factors (see Table 8.2). Statements that have significantly different scores across factors are distinguishing statements and they represent an issue of clear disagreement across perspectives. Statements with the lowest differences in scores across factors are of consensus and indicate common ground and shared understandings of the issue, or otherwise taboos (see Section 7.1).

The interpretation below is structured around three themes: the preferences for investments between increasing the cattle herd, improving pasture, or planting fodder trees; the reasons why (and why not) the respondent would adopt silvopastoral practices; and whether the type would continue such practices beyond the experimental period.

There is consensus that food self-sufficiency is desirable, that conserving the forest is the responsibility of the landowner, and that fodder trees do not take much time and effort to grow. There is general disengagement towards statements about the relative importance of the income received through external programmes in comparison to other livelihood activities (statements 3 and 5 in Table 8.2; see external programme details in Section 5.2.4). This might be due to respondents' unease about openly giving their opinion about the economic incentives associated with external programmes.

Major disagreements concern the importance given to external payments, preferences on cattle-farming, and perception about land degradation. Attitudes towards innovation and self-sufficiency distinguish the three main perspectives too. Perspectives one and three are opposite in their view of external payments. Cattle-farming is a topic of remarkable disagreement because only one out of seven statements within this topic is of consensus. The perception about land degradation in particular is saliently opposite between the second and the third perspectives. Each perspective shows distinct preferences towards planting fodder trees: high preference (factor two), disengagement (factor one) and low preference (factor three).

8.2.1. The "self-sufficient pioneer"

The first perspective represents a type of farmer who is pragmatic, self-sufficient, and innovator. He is confident about his capability to maintain his family in an autonomous way and without depending on external financial help. He gives the lowest importance to external payments and he clearly rejects them as being necessary either for him or for his children's future livelihood; PES may not be motivational. He is proactive about learning by experimenting with new practices to improve his livelihood, and he considers that he could improve very much his work in cattle-farming with further training. He has no clear preferences between investing in more cattle or in planting fodder trees, but he would much prefer investing in better pasture. He thinks it is convenient for him to take care of the fodder tree plot even though he has other work to do, and land availability is not a constraint.

The characteristics that would make this person an adopter of fodder trees are his pro-activeness to experiment with innovative practices and his interests in learning to improve his performance and in staying self-sufficient and independent from external payments. In this perspective, the element of self-efficacy[55] may be highly favourable.

This type is identified here also as a *'pioneer'*, referring to the initial adopters, or innovators (in a process explained through diffusion theory see Section 2.4.3). This is based on his distinctive response to statement 22 (Table 8.2), and arguably, to his better performance in the project. Despite not being significantly associated with age, he typically has a young family and fewer years of experience with cattle-farming. This is a sign of youth and of needing to secure an income source in the medium term, which arguably makes him more receptive to innovations.

8.2.2. The "environmentally-conscious follower"

The second main perspective is associated with respondents typically described as being conservationist, other-regarding, concerned about the future, and followers regarding the adoption of livelihood innovations. This type of respondent has the highest degree of environmental awareness, shows concern about soil degradation, and has a higher preference for fodder trees than the rest of his peers. He also

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[55] See internal factors affecting adoption in Section 3.3.4.

acknowledges the importance of investing in better pasture rather than in stocking more cattle. He prefers to invest in fodder trees more than in pasture, and remarkably more than in increasing the cattle herd. In this perspective, the factors of problem and environmental awareness are thus favourable (see these factors in Section 3.3.4).

His perception about the importance of external payments in his livelihood is ambiguous. He shares all of the self-sufficient pioneer's views on payments except for one statement: he expresses a clear need for external payments in order for his descendants to have a livelihood in the community (statement 15). This might be due to pessimism about the future, founded on their perception about degrading land, and presumably about the lack of employment elsewhere.

While this type of farmer is more perceptive to PES, his activity may be strongly motivated by a higher awareness about the need for environmental conservation. Thus I define this type of farmer as *'environmentally-conscious'*. His environmentalist views are supported by stating that the payments provides are not the only reason for participating in external programmes, and that during the dry season there are alternatives to releasing cattle into the forest. Hence, this type of farmer may be genuinely more environmentally concerned than the other two, either intrinsically, subsequent to his own experience, or because he has internalised the externally parachuted discourse of environmental conservation institutions.

The environmentalist is characterised by having more benefits from off-farm activities, less land and lower percentage of benefits from external payments. He is motivated to conserve land but he does not feel as self-sufficient and capable as the pioneer. He is also not so pro-active to trying new livelihood activities. Thus I also interpret this perspective as a *"follower"* regarding the adoption of silvopastoral practices.

8.2.3. The "payment-dependent conservative"

The third perspective is described as being conservative and opportunistic, payment-dependent, rent-seeker, and late adopter or laggard with respect to innovations. He believes that his livelihood is highly dependent on external payments, emphasising most strongly the need for payments in order to live, both for his current livelihood as for his children's future, who would most probably stay in the community. He emphasises that he may not be able to sustain his family without these payments and would also require PES to take care of the forest.

He believes that his descendants will work on the same land, and that probably he will not produce enough animal feed if he keeps to current practices. Yet, he does not perceive that his land is currently degrading, he thinks that he can get more benefits from cattle without damaging the land, and asserts that during the dry season he cannot do other than release his cattle into the forest. He also has the lowest preference toward fodder trees. He is not sure about whether he prefers investing in pasture rather than in fodder trees or in cattle, but he clearly prefers cattle to fodder trees. He considers that it is not convenient for him to weed the fodder tree plot, although he acknowledges that planting fodder trees does not involve much effort.

This type has a significant positive correlation with cattle specialisation, including with more years of experience in cattle-farming, and associates with a lower share of benefits from off-farm activities. Because he is not keen on trying new practices, this individual is likely to be a late adopter of innovative practices. Because he states high dependence on external payments which are a form of immediate, easy income, he can be described as opportunistic, and PES may encourage his participation in conservation programmes. However if the payment stops before the practice yields further benefits, he may possibly abandon it (Pagiola et al., 2007).

8.3. Discussion: incentives to trigger latent motivations for adopting silvopasture

The three main roles uncovered are largely consistent with those predicted in the diffusion of innovation theory according to their general attitude: pioneers, followers, and laggards (Läpple and van Rensburg, 2011; Rogers, 1962). In addition to this time-based distinction of roles, the Q method provides a rich description of perspectives in terms of topics relevant to SPS adoption and interventions, particularly their response to incentives and their attitudes towards conservation.

None of the three types has a clearly favourable predisposition to adopt SPS, and each of them has preferences at odds with adopting or continuing the activity.

This lack of predisposition should not be confused with the characterisation according to diffusion (pioneers, followers, and laggards), which is based upon the general attitudes of each type about innovation, rather than about SPS adoption specifically.

The roles are also relatively consistent with other typologies found in the literature on adoption of sustainable agricultural practices (see Section 3.4.3). Most of the previous studies researching typologies of potential adopters identify at least one perspective of *environmentalists* (Brodt et al., 2006; Valdivia et al., 2012) or *active adopters* moved by environmental awareness (Morris and Potter, 1995). Both types are largely similar with the environmentally-conscious follower identified here. The payment-dependent conservative may be related to previous types in terms of its resistance to adopt (Barnes et al., 2011; Morris and Potter, 1995), somewhat as a *production maximiser* (Brodt et al., 2006), and as a *passive adopter* who is not moved by conservation concerns (Morris and Potter, 1995). The first type identified here (self-sufficient pioneer) is arguably the most novel type in the literature, because he is a likely adopter, but is not moved strictly for environmental reasons, but rather for the potential livelihood benefits that the practice might bring. This type finds its closest counterparts in previous literature in perspectives such as *networking entrepreneurs* (Brodt et al., 2006) and, possibly, *pragmatic organic* (Darnhofer et al., 2005). However, none of the previous sets of perspectives do distinguish in terms of roles within the theory of diffusion of innovations, and neither in terms of their perceived dependence on subsidies.

The three perspectives identified are also compatible with those by a study of adoption of organic farming in Norway (Vartdal 1993 in Padel, 2001) This study broadly identifies innovators strongly committed to their ideas (*Anthroposophists*), those with environmental motives (*Ecosophists*), and the more conventional and pragmatic farmers (*Reformists*). The heterogeneous perspectives identified in this study can also be related back to Weaver's distinction of individuals as *selfish hedonists* driven by prices, *egoistic hedonists* (profits and warm-glow benefits from contributing to public goods), *altruists* (who aggregate profits and public goods), or *imperfect altruists* (who combine profits, own contribution, and public good; Weaver 1996 in Turaga et al., 2010).

Each perspective identified in this study has distinct reasons why they might potentially adopt SPS; these are latent motivations that can be stimulated to increase their involvement, which may be instrumental for policy targeting. The self-sufficient pioneer may adopt if the practice is believed to be novel and if connected with potential broader livelihood benefits, despite its risks. He sees no need for external economic incentives in order to try. The motivation of the environmentally-conscious follower may be associated with normative or moral concerns driven by a long-term perspective on the land. The payment-dependent conservative may adopt in a first phase if there is a clear external monetary support involved, or otherwise at a later stage when realising that the early adopters corroborate the economic benefits of the practice. The fact that the payment-dependent conservative is somewhat related to cattle specialisation is an obstacle for the success of external interventions, because those who have higher responsibility in land use are also those most reluctant to change.

These results provide insights to discuss the role of PES. The main characteristics of the so-called self-sufficient pioneers and payment-dependent conservatives are generally consistent with two types of potential adopters identified by Pagiola et al. (2007), who indicate that PES are not necessary for farmers for whom silvopasture is profitable enough to justify adoption, while for those for whom silvopasture is not profitable at all, adoption happens only while the payment lasts. The self-sufficient pioneers and the environmentally-conscious, who are more receptive to adopt, are less motivated by immediate external economic incentives. Arguably, they may be more responsive to other interventions such as sharing information, purporting the benefits of the practice transparently, or facilitating experimentation. These interventions can raise the self-sufficient pioneers' expectations for benefits, understood in a broad sense and beyond the short term.

Providing PES to all participants, disregarding the views or characteristics that affect farmers' livelihood decisions and underlying willingness to adopt new practices, may affect policy goals unexpectedly. For example, the payment-dependent conservative type may adopt attracted by the expectation of income gains from payments in the short term. After the earlier stages, if the viability and the benefits of the activity are realised, continuing PES may not be necessary for any of the types, as continuation would occur normally. In this case, payments at the early stage would not imply an increase in overall adoption rates but instead a more uniform, accelerated adoption process because the payment-dependent conservative would also participate at the earliest stages of the silvopastoral scheme. If the budget of the external programme is exhausted before the activity is perceived as viable and beneficial, then it is expected that the payment-dependent conservative will discontinue because his only motivation would disappear (Pagiola et al., 2007). In such a situation, the programme may fail to induce a sustained adoption, probably eroding the permanence of the scheme.

Against much of the received wisdom in the literature on PES, voluntary participation in conservation programmes may occur regardless of the uncertain balance between investment and return or of net financial opportunity costs (Kosoy et al., 2007). Payments that cover the opportunity cost of land and/or labour invested in the conservation programme might be more correlated with adoption rates in contexts of commoditised market relationships. In these contexts, farmers' profit-maximising rationale results in their effort being proportional to the economic incentive of the new activity (Heyman and Ariely, 2004).

However, in contexts of wider social exchange and longer term land-use perspectives, additional motivations are behind the voluntary adoption of conservation efforts, meaning that uptake may not be related to payment levels alone (Heyman and Ariely, 2004; Muradian et al., 2010). Thus innovative conservation programmes designed to fit an assumed short-term money-market mindset and self-interested behaviour can generate a misfit at the implementation stage (Bowles, 2008; Brown, 2003) potentially resulting in the erosion of their long term cost-effectiveness and goals (Muradian et al., 2013). Some argue that this misfit is mostly due to decisions and behaviour being context-dependent (Clot et al., 2015). However, environmental psychology indicates that this behaviour has certain non-contextual patterns, but is simply more complex than that modelled by rational assumptions (e.g. Osbaldiston and Schott, 2012), as the results from this chapter suggest.

Motivations that influence decision-making in favour of PEB include maintaining a diverse portfolio of healthy natural stocks or increasing self-sufficiency, in order to optimise livelihood resilience and to keep opportunities open for next generations. These decisions are propelled by the perception of the long-term benefits of adopting innovative conservation actions, and sometimes by other-regarding preferences. More general behavioural motivations include moral or internal motivations and values (Bowles, 2008; Lokhorst et al., 2011; Mzoughi, 2011), such as exploration, looking for innovations, curiosity for experimentation, and personal fulfilment. These are motivational drivers that might go a long way compared to immediate economic returns.

8.4. Conclusion: heterogeneity of perspectives and incentive-based policies

Incentive-based policies in complex social-ecological systems require understanding the motivations of individuals to participate in new conservation activities in order to be flexible and adaptive. This chapter addresses the important research need of uncovering the heterogeneity of preferences among recipients of environmental policies, particularly in relation to sustainable silvopastoral practices in the tropical forest frontier. It provides some empirical evidence of the importance of understanding the attitudinal fabric of a small and otherwise seemingly homogeneous community, which is intrinsically linked to the existence of multiple alternative motivations to engage in innovative silvopastoral programmes.

The results contribute to the debate over PES in social-ecological systems (e.g. Pagiola et al., 2007) and more broadly (e.g. Muradian et al., 2013) by suggesting the potential mismatch caused by selecting forms of rewards that do not catalyse the main behavioural motivations of those individuals most likely to adopt and to continue pro-environmental activities. Arguably, direct payments may spur opportunistic, short-term benefit, or rent-seeking. Individuals who mostly respond to economic rewards may not be the same as those who are more likely to adopt and to continue conservation activities. I argue that uncovering the latent diversity of perspectives for adoption of sustainable practices is key for the cost-effective design and implementation of conservation interventions through reward schemes.

The use of Q methodology facilitates the analysis of this diversity of subjective viewpoints. Ascertaining such different social-ecological motivations about adoption of conservation practices helps identifying the potential pioneers in a diffusion process, and their complex perspectives. These individuals can play a key role even if they are few in number.

As with other stated preference methods, in a context where individuals can have expectations of further external interventions being brought to the community to support their livelihoods, there is a risk inherent to investigating subjectivity. Some responses may not represent the genuine view of the respondent, but to show an attitude that the respondent thinks is in accordance with the discourse brought from external agents, in order to attract further programmes. This might have affected particularly the second perspective in this study.

The implications of acknowledging the heterogeneity of perspectives for conservation policy are twofold. First, higher cost-effectiveness and a more permanent behavioural change toward adoption of the environmental innovation (and its associated social sustainability) can be achieved by designing conservation programmes in a way that they deactivate or minimise opportunistic strategies, which are the ones most likely to discontinue the activity once the budget supporting the programme ceases. Second, a stronger emphasis on engaging self-sufficient pioneers from the outset may also enhance effectiveness. Such programmes may be designed in a way that they attract and self-select individuals genuinely interested in the conservation activity (e.g. self-sufficient pioneer and environmentally-conscious follower). These individuals are most likely to perform and may have a boosting effect on getting the rest to adopt at a later stage, when the demonstration of the private benefits from the activity is sufficient to motivate others. This may be done by catalysing the self-sufficient pioneers' latent motivations to adopt the pro-environmental practice. For them, external payments may not be the most appropriate incentive, and financial stimuli can be insufficient (Läpple and Kelley, 2013) or even counterproductive (due to crowding-out intrinsic motivations, Bowles, 2008) to encourage adoption in the longer term. These policy implications are detailed further in the final chapter.

Chapter 9. Understanding the relationship between livelihoods and silvopasture adoption

This chapter questions which livelihood characteristics drive and hinder the adoption of silvopastoral systems (SPS) in the case study. It uncovers the relation of livelihoods and subsidy dependence, two rarely explored external variables (see Chapter 3) with adoption, in order to better inform targeting of actions to foster SPS. The chapter demonstrates that understanding what livelihood strategies exist and why these strategies are the way they are, can be instrumental to elucidate why particular characteristics of livelihoods appear to have an effect upon participation and adoption.

To do so, I disentangle what are the key characteristics that define livelihood strategies and what types of strategies exist in the case study (using the data collected as per Section 6.2). Then I model the relationship of livelihood characteristics with participation and short-term adoption, based upon the hypotheses explained below. Results leads us to explore the likely barriers for adoption of a given strategy. This knowledge is used in Chapter 10 to discuss the policy implications regarding the way SPS adoption may be best encouraged by heeding the needs specific to each livelihood strategy.

The degree of livelihood diversity (versus specialisation) is a key definitional concept for livelihoods in developing countries (Ellis, 2000b). However, as found in the review in Chapter 3, little attention has been paid to this topic in the literature of adoption. The literature on sustainable livelihoods and diversification, substantiated by the work by Ellis (2000a, 2000b, 1998), pivots around the role of diversification to alleviate poverty and reduce vulnerability (e.g. Fabusoro et al., 2010; Perz, 2005), and the study of diversity quantifies it predominantly as the portfolio of income sources (Perz, 2005; Vedeld et al., 2007). However, no discussion exists about the broader implications that diversity may have in influencing adoption of sustainable practices, or about the distinct decision-making context that more diverse livelihoods might imply. This chapter attempts to fill this gap, and explores the relation between decision making and diversity by conceptualising the latter in terms of the effort dedicated to different activities (see operationalisation of diversity in Section 6.3.1).

Each analytical section in the chapter is guided by one of the following questions: a) what characterises the livelihood strategies present in the case study? b) why are strategies as they are? c) how do strategies affect participation and adoption in the fodder-tree planting project? and d) why do strategies affect adoption as they do? The last question is essential to the goal of this thesis, as it provides the necessary knowledge to explore how to influence SPS adoption through policy, by means of understanding the filter that livelihood strategies create. Questions a) and b) are fundamental to discuss the potential causalities and implications of the model elaborated to respond question c).

Some definitions are due. *Participation* is defined as the formal involvement of individuals in the fodder-tree planting project (see Section 5.4). *Adoption* of SPS in this study is estimated as the short-term success in growing fodder trees, measured in standardised length of trees per plot as a proxy for biomass (explained in Section 6.3.2). The term *adoption* refers to adoption of SPS throughout (to the measure explained in Section 6.3.2), unless specified otherwise. Tree growth was monitored a year after planting, thus at an early stage of piloting the practice (as narrated in Section 5.4). This short-term success is reflective of activities such as planting and protecting saplings during the initial growth against weeds, desiccation, and cattle. The variables of adoption and of livelihood diversity are indices derived from observed variables, and their computation is based on a review of the literature on indicators of reforestation and on (livelihood) diversity respectively (see details in

Section 6.3). For simplicity, in this chapter the terms *strategy* and *diversity* refer solely to livelihood strategy and livelihood diversity respectively.

A number of hypotheses are formulated based on the review in Chapters 2 and 3 (on decision making theories and on agroforestry adoption respectively). The first one refers to the general approach for explaining adoption. I argue that it is more appropriate to model overall adoption as a sequential process (Morris et al., 2000)—as described in Section 2.4 and in contrast to most empirical studies on adoption (Section 3.4). The hypothesis is that this process is composed of distinct steps (such as participation and adoption) and the set of predictors and the magnitude and sign of their effect can differ.

The other two hypotheses refer to two specific independent variables: diversity and external payments (the share of subsidies). These variables are central to the conceptual framework in Chapter 2, but have received little attention in the quantitative literature (Chapter 3). The two hypotheses shed light on what drives individuals to adopt, hence tying directly to the main question of the thesis.

In terms of diversity, the hypothesis is that higher livelihood diversity is conducive to higher participation and short-term adoption, because diversity can be an indicator of an agent's tendency towards experimentation (as emerged from Section 2.3.2). Individuals with higher diversity may be more prone to adopt SPS, since diversity may reflect the innovative attitude of the individual.

In terms of subsidy dependence (approximated by the share of subsidies in benefits), it may have a negative influence over participation in a programme that does not provide payments for ecosystem services (PES). This is hypothesised because subsidy dependence may have shifted an individual's genuine interest on innovative practices, and monetary incentives may be their major motivation to participate (Heyman and Ariely, 2004). Arguably, this dependence can also make individuals less intrinsically interested in conserving their local natural resources (see Section 2.3.1). Higher reliance on subsidies can also indicate the existence of lack of self-sufficiency and/or of rent-seeking strategies. While this dependence reduces vulnerability to market and climatic variations, it also makes livelihoods less autonomous and more vulnerable to variations in external policies.

The remainder of this chapter is organised in three analyses that correspond to the analysis of each of the questions posed above. To disentangle what are the livelihood strategies, in Section 9.1 I explore bivariate associations between observed livelihood variables and formalise a typology of strategies by using cluster analysis (CA). To understand what drives these strategies, in Section 9.2 I analyse the profitability and perceived uncertainty of livelihood activities. To investigate how livelihood variables affect adoption, in Section 9.3 I infer differences between participants and non participants for all the livelihood variables, and I test the three hypotheses above through a selection model of participation and adoption. In Section 9.4, I use the knowledge obtained from the first two sections to explain the results of modelling participation and adoption in the SPS project, presented in Section 9.3.

9.1. Livelihood strategies in the case study

In this small community, where most families began with similar land endowments and have access to the same services and external programmes, livelihood strategies are highly heterogeneous as a result of the driving forces explained in Chapter 4, such as changing international markets or the ups and downs of subsidies, differing household trajectories, and arguably to the heterogeneity of perspectives identified in Chapter 8, such as self-sufficient or subsidy-dependent ones. The distinctiveness of these strategies is demonstrated below and shows that also in a social-ecological microcosm there is complexity about livelihood strategies.

9.1.1. Bivariate associations among livelihood, demographic, and wealth variables

This section explores bivariate associations among livelihood, demographic, and wealth variables (described in Section 6.2), in order to uncover livelihood patterns in the case study, according to what heads of household reported about themselves. This inference helps understanding in detail the context in which livelihood decisions are made.

Livelihood *assets* are defined here as the inputs—land, effort, and (monetary) investment—necessary for an economic activity,[56] and their discussion in the following is combined with that of the output (benefits). Asset allocation is measured as a share (fraction) of the total asset that a head of household had available to allocate across livelihood activities in the previous year (the measurement of asset allocations on livelihood activities, collected through board and tokens, is detailed in Section 6.2 and summarised on Table 6.2, p.170, row *'Livelihoods'*). For example, one of such share would be the portion of land dedicated to maize cultivation, as a percentage of the total land. Investment and consumption expenses were measured using the same pool of tokens (representing the financial capital available). However, when referring to investment in the following analyses, this excludes expenses in consumption. Benefits (income) correspond to the return derived from each activity during the present year *t* and as a result of the allocation of the assets available from the previous year (*t - 1*). In the rest of the chapter, when alluding to land, effort, investment, and benefits, it is implicit that I refer to the *shares* of each of them.

Bivariate associations among all livelihood, demographic, and wealth variables are explored using appropriate tests (correlations, t-test, Kruskall-Wallis, or Fisher's exact, depending of each pair of variables).[57] After inspection, I select the variables that are most theoretically relevant (based on the case study and the conceptual framework) and representative (many variables are conceptually highly related, thus illustrative variables are selected only, in order to avoid unnecessary redundant complexity). These variables are shown in Figure 9.1. It is to note that these association values do not necessarily imply causation.[58]

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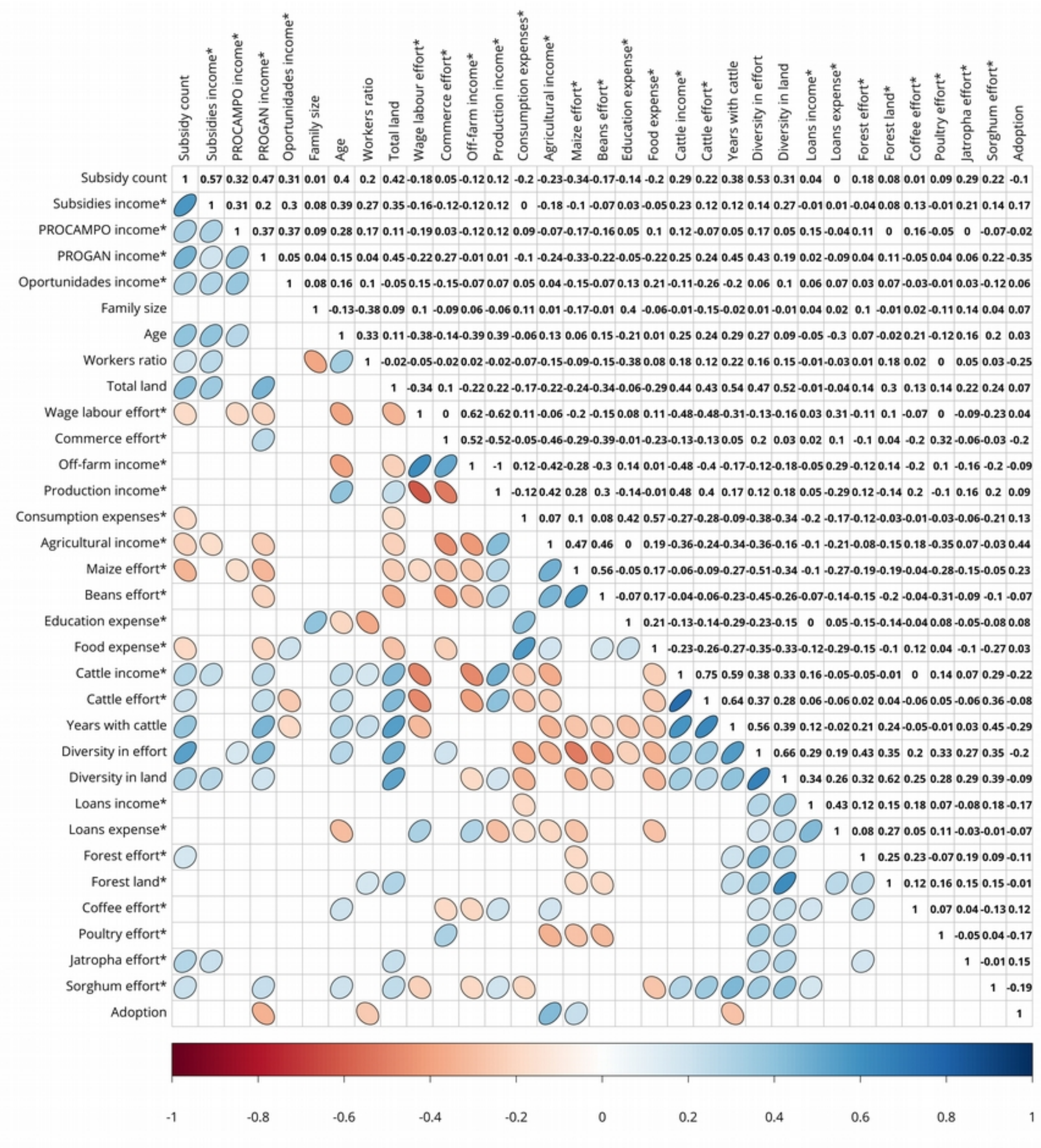
[56] Traditionally in economics, land and financial assets are distinguished from labour. However in this chapter and for simplicity, effort is implicitly included in the term *asset*.

[57] A number of additional analytical procedures were probed but finally discarded on simplicity grounds and because these did not yield theoretically relevant insights beyond those found with the procedure shown here. These procedures included transformations of non-normally distributed variables (logarithmic and arcsine), recoding shares of assets into percentiles, and reducing data by using principal components analysis.

[58] Additionally, appropriate statistical tests to explore bivariate associations were performed among all the variables in the dataset (including the ones in Figure 9.1) and variables that are theoretically key according to the conceptual framework: diversity, subsidies, and adoption (not shown).

Figure 9.1: Correlations among the main livelihood, demographic, and wealth variables, and adoption



Top: Spearman correlation coefficients. Bottom: magnitude and direction of the correlation, illustrated only for coefficients that are statistically significant at a p-value < .1. Colour code for correlation coefficients: from −1 (red) to 1 (blue).
** variable measured as share of an asset or of benefits. Built using package 'corrplot' (Wei, 2013).*

On average, approximately half of the benefits are from (on-farm) production, more from agriculture than from cattle, and one fifth from subsidies. The rest is obtained from off-farm activities, savings, or loans. The principal source of subsidies is PROCAMPO (9% of the benefits in the previous year, with a high variability), followed by *Oportunidades* and PROGAN (subsidies are explained in Section 4.2). Larger benefits from subsidies for agriculture does not contradict the current trend of cattle-farming expansion, but just indicates that either subsidies are lower for cattle-farming, that the conditions for their distribution are more lax for agriculture, or that agriculture has been so paramount in the recent social-environmental history that cattle-farming has not yet taken over.

Those who have proportionally more cattle tend to have a somewhat more diverse strategy, dedicate less to subsistence agriculture (beans and maize), and to wage labour. This may be explained because cattle require moderate to high levels of wealth and land, thus those who can specialise in cattle-farming do not need to work for others. Trade-offs between off-farm and (on-farm) production show the following specific contrasts: commerce versus agriculture, and wage labour versus cattle-farming. Commerce and cattle-farming are activities linked to wealthier families, as opposed to agriculture and wage labour. All these relations between activities refer to the effort or benefits, as indicated in Figure 9.1, yet these linkages are also observed when exploring other assets (not shown). Coffee, poultry, and shares from subsidies do not clearly relate to any other variables.

Two main messages derive from the bivariate statistics: land appears to be a critical asset to escape poverty (simplistically defined as having access to take on more profitable activities), and there is a strong preference for cattle-farming. Both cattle-farming practices and land use are what silvopasture seeks to make more sustainable. Therefore these messages are important to understanding how SPS might find a niche within livelihood strategies.

Data suggest that owning land is a very valuable asset that facilitates both diversification and access to subsidies (Figure 9.1). Small increases in the amount of land owned are related to larger increases in diversity. Also, many subsidies are for agricultural development or conservation, hence inherently related to land endowment. Therefore privately owning land (a characteristic strongly related to the condition of *ejidatario*, as defined in Section 4.1.2) appears to be an important precondition to access subsidies, either directly (as in the case of PROCAMPO) or indirectly (as in the case of PROGAN or of forestry programmes).

According to the data, it can be expected that agriculture is replaced by cattle-farming if resources allow. Trade-offs are observed between variables related to cattle-farming (e.g. experience in cattle-farming) and agriculture. The share of land in cattle is inversely correlated with land share in maize, and this relation is not linear, but rather exponential; a small increase in cattle entails a large decrease in maize (land may be allocated to other activities, as shown in Figure 6.3, p.167).

9.1.2. Typifying livelihood strategies

The above description of bivariate associations between livelihood variables hints at what types of strategies may be found in the case study. This distinction is formalised using CA to uncover additional features that characterise strategies that are diverse, or that are specialised in cattle-farming, for example. Looking at strategies as an integral combination of several livelihood variables (rather than defined by individual variables such as specialisation in agriculture) is useful to identify what may be the hindrances for adoption of SPS, and how policy can help overcome these obstacles, as discussed in Section 9.4.

Section 6.4 reviews empirical applications of CA and other quantitative typifications of livelihood strategies, which provide the foundation for the following analysis to uncover types of strategies. Strategies are first explored by using visual classification and ternary plots. Then, a quantitative CA reveals five clearly distinctive strategies (the analytical details are given in Section 6.4.3). The relation of strategies with SPS adoption is tested in Section 9.3, and their relevance for the results of the econometric model is discussed in Section 9.4.

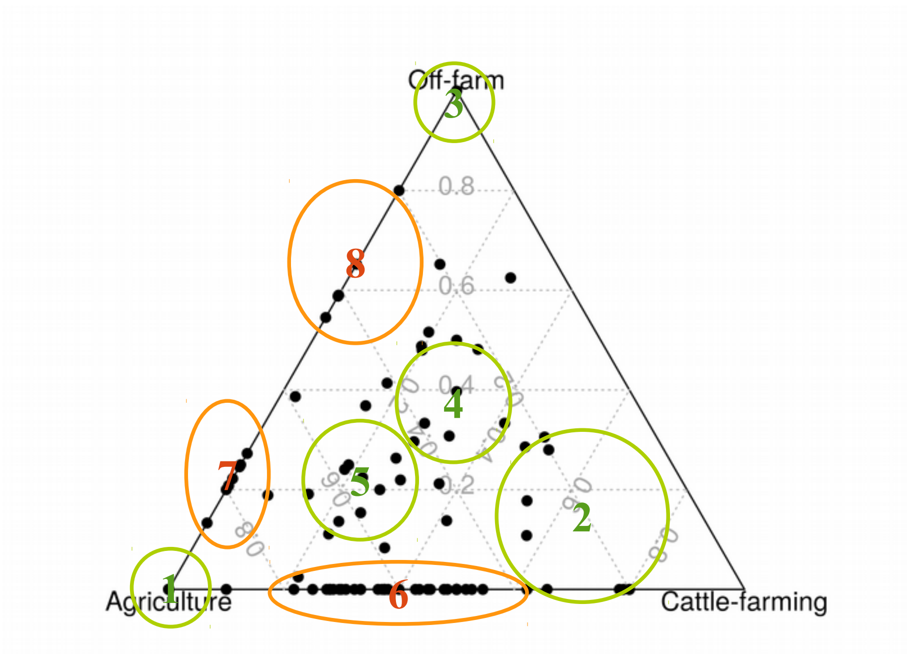
a. Visual exploration

Each respondent's shares of assets and benefits across livelihood activities was displayed in barplots and printed in individual cards. Cards were organised by visual similarity, according to the dominance of activities. Two features are identified as the vectors that differentiate strategies. One is the gradient from high specialisation in any given activity to a high number of activities with balanced dedication (high diversity). The other is the relative predominance of one of the main sectors: agriculture, cattle-farming, forestry, and off-farm (which merges commerce and wage labour).

The combination of these two vectors results in a grid of possible livelihood strategies. Not all the combinations are present in the case study. For example, there is no individual highly specialised in forestry. Instead, 28% of the individuals in the sample are focused on agriculture, of which half are highly specialised. Thirty-six percent is focused on cattle farming (11% highly specialised). Ten percent specialise in off-farm activities. Eleven percent have a noticeably higher share of forestry than the rest and some wage labour or commerce. On the other end, 14% have a diversified strategy: 2% are outstandingly diverse, 4% combine a diverse mix of agriculture and cattle-farming, and 8% incorporate more off-farm activities.

Based on the main areas distinguished in the visual exploration, a stylised *livelihood space* is represented in the ternary plot in Figure 9.2. This plot shows the shares of benefits for each of the three major livelihood activities and diversity/specialisation simultaneously. Each dot is an individual and its position represents their strategy, where diversified livelihoods locate at the centre and highly specialised strategies are in the edges of the triangle.[59]

Figure 9.2: The stylised space of livelihood strategies



[59] Forestry is excluded from ternary plots, because data on assets for this activity is less predominant.

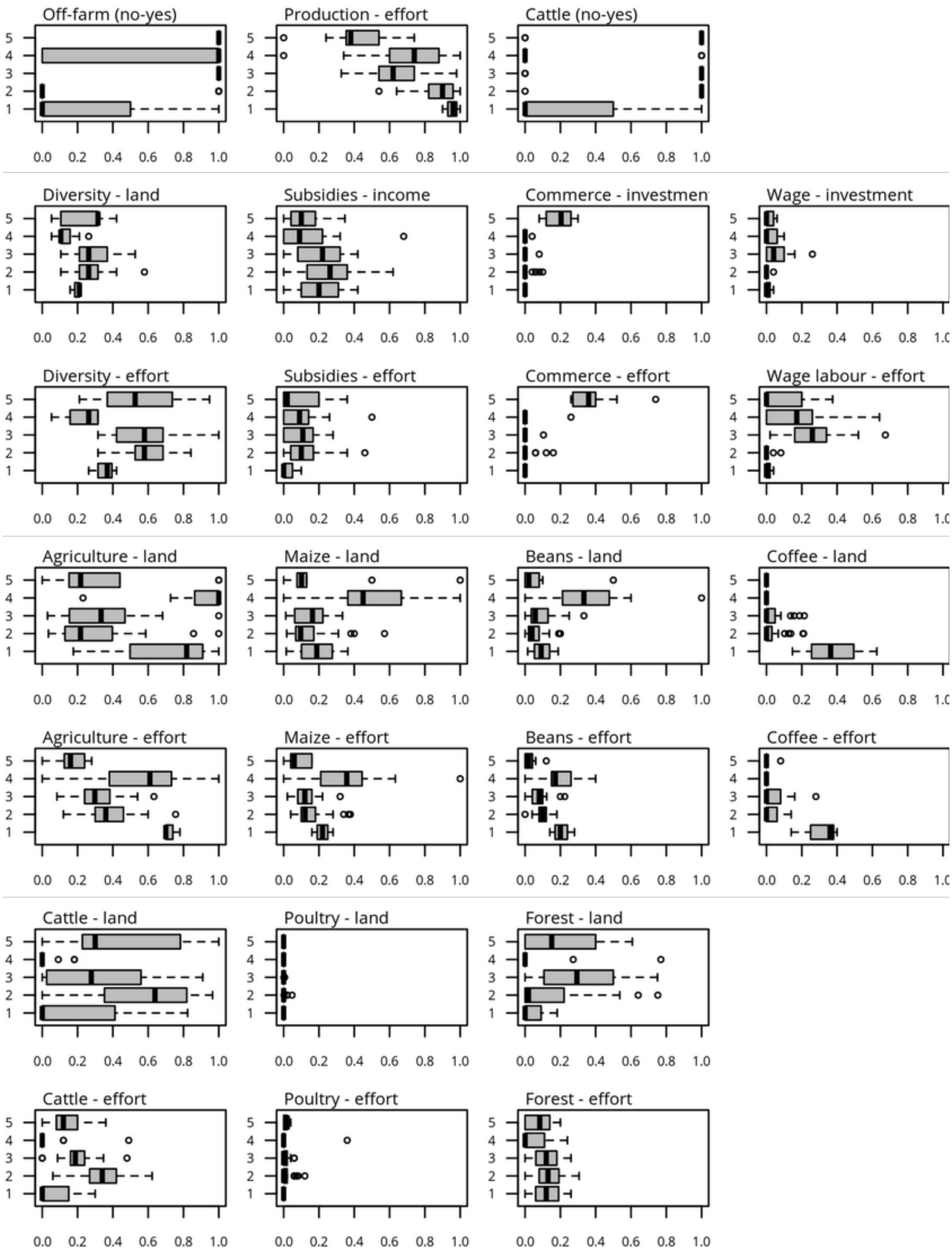
This abstract space illustrates the heterogeneity of livelihoods. It suggests strategies similar to the ones of the visual exploration: highly specialised, either entirely in agriculture (group 1), mostly in cattle-farming (2), or entirely in off-farm (3); and diversified households—very diverse (4; in the centre), and slightly diverse, with mostly agriculture (5), but also with some cattle and of off-farm activities. Three further groups are identified, not for what they have, but rather for what they lack. These are livelihoods with no off-farm benefits (group 6); without cattle and little off-farm benefits (7); and without cattle and more off-farm benefits than agriculture (8), presumably wage labour.

b. Cluster analysis

The cluster analytical process is described in Section 6.4, including clustering methods and a brief review of empirical studies that use CA to define livelihood strategies. The section also explains and justifies the CA design in this research: the selection of variables, clustering method, and number of clusters. Accordingly, CA is performed with 25 variables (chosen upon literature review, the case study description, and sensitivity analyses, as explained in Section 6.4.3), using k-means clustering with centroids obtained through hierarchical method, obtaining five cluster. This formal clustering helps understand with precision what characterises strategies, in order to discern hindrances and opportunities for adoption.

Once identified, the five clusters are described by comparing values for each of the variables used for clustering (see median and quartiles per cluster in Figure 9.3). Kruskal-Wallis tests for differences between groups indicate that clusters are distinguished by all variables (p-value < .05), except for the two variables of poultry, of subsidies, and the variable of effort allocated to forest. Post-hoc Tukey tests for pairwise differences between clusters support this description.

Figure 9.3: Description of livelihood clusters: boxplots of defining variables



Boxplots represent the distribution of a given variable for each of the five clusters. Within each variable, boxes which stand out from the rest may be interpreted as defining the given cluster. For example, cluster five has more effort in 'Commerce – effort' than all other clusters.

Based on what variables are most distinctive for each cluster, the five clusters obtained can be defined as agricultural (coffee) specialist (1st cluster with 3 observations), cattle-farmer (2nd, 40), diverse (3rd, 25), agriculture with wage labour (4th, 16), and with high dedication to commerce (5th, 9).

Cluster one represents an agricultural specialist, and more land and effort employed in coffee distinguishes it from all others. Cluster two groups mostly cattle farmers dedicated to no off-farm activities, who also have a quite diverse strategy and receive somewhat more subsidies than the rest. Cluster three represents individuals with the most diverse strategy, with some dedication to cattle-farming, wage labour, and forestry, but little dedication to agriculture. Every observation in this cluster does some wage labour. The strategy in cluster four is similar to cluster one in its agricultural specialisation, but mostly committed to maize and beans. The strategy associated with cluster five stands out for its high dedication to commerce, even though it has high diversity too. It is the least dedicated to agriculture. Most people in this cluster also have cattle and dedicate a moderate amount of land to this activity.

These livelihood strategies can be contextualised through the social-environmental history narrated in Chapter 4. The agricultural specialist was the first of these strategies to emerge, arising from the traditional Mexican combination of maize and bean cultivation, and further encouraged by subsidy schemes and the green revolution in the central decades of the past century. This strategy is seen across Mexico. The coffee farmer and the cattle-farmer might have been a minority in the early stages of the community, and did not belong to traditional subsistence livelihoods. Rather, these activities are driven by external demand, hence were born in direct connection to national and international markets. Similarly to the case study, coffee-farming is a relatively prosperous activity across Central America, but only feasible under certain biophysical conditions. Biophysical conditions are less limiting for cattle-farming, which spread in the region mostly after the 1990s. Fewer individuals have capital necessary to engage in commerce, and this is illustrated by the lower numbers found in the sample. These individuals also have cattle, but might have acknowledged that diversifying into commerce is desirable to secure wealth. Finally, diverse livelihoods are likely to have been present throughout, likely driven by entrepreneur or experimenting attitudes, and by seeking more livelihood security.

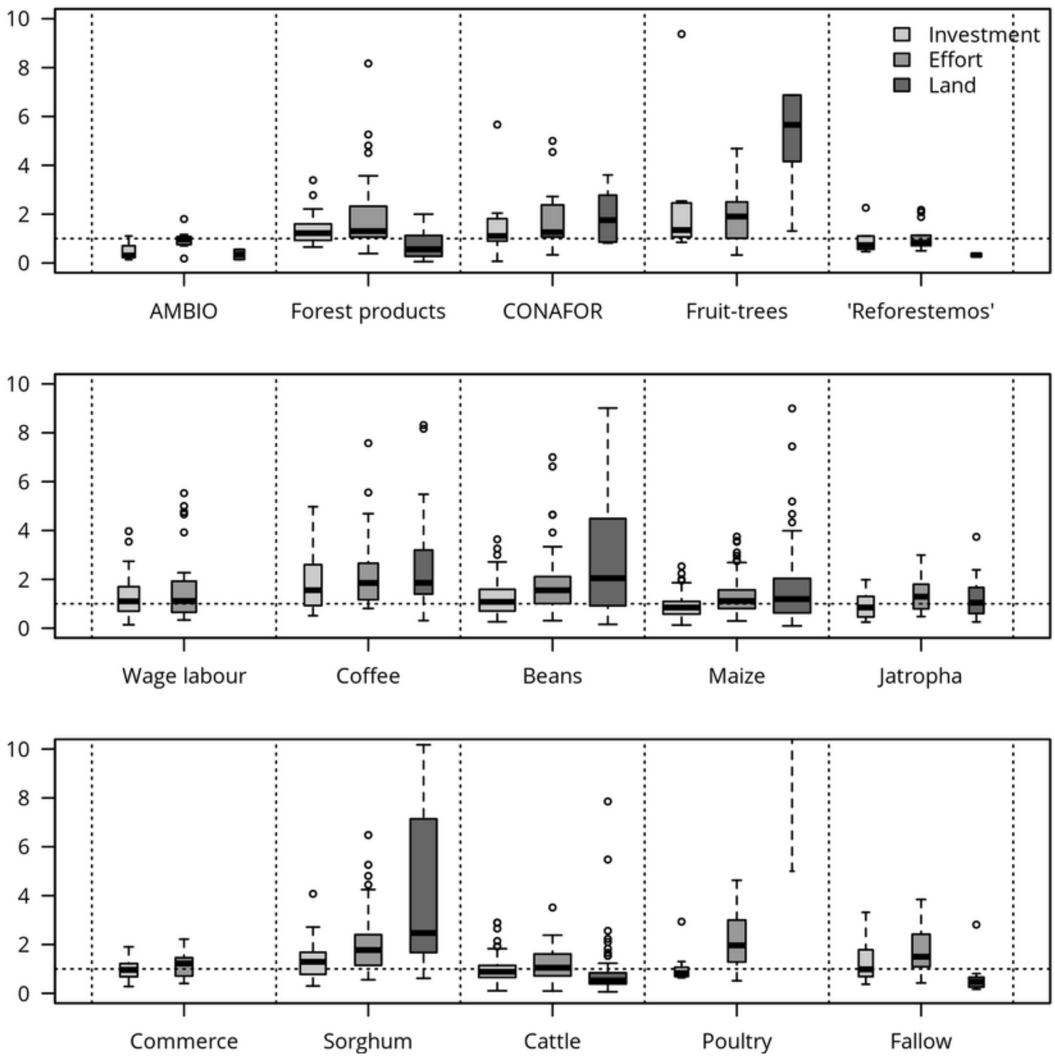
According to the social-environmental history of the region, is highly plausible that all these same strategies may be found in other parts of southern Mexico surrounding tropical forests. Their chronology is also consistent with Mexican livelihoods elsewhere identified under a panarchy framework (Gunderson and Holling, 2002) by Huber-Sannwald and colleagues (2012).

9.2. Reasons for livelihood preferences: perceived profitability and uncertainty

Why is the current preference for cattle farming so strong? What is the impact of livelihood choices on land use and income? Chapter 4 explained the recent evolution of livelihood strategies, suggesting that, if households become better off, cattle is likely to expand. The description of livelihoods above further suggests this point. This section disentangles what makes each livelihood activity attractive, to uncover trade-offs confronted in livelihood decisions which may affect the adoption of SPS. In order to explain the likely reasons for the existing strategies I analyse the perceived profitability and perceived uncertainty that characterise the most relevant activities (the activities highlighted in grey in Figure 6.3, p.167).

Perceived profitability and uncertainty of activities may importantly drive the choice of strategies. Profitability is approximated by calculating the ratio between benefits and each asset. A value of the ratio is obtained for each respondent, and the aggregation of the values of all respondents for a given activity constitutes a distribution of the activity's perceived profitability. These distributions are represented in Figure 9.4.

Figure 9.4: Activity profitability, measured as the ratio of benefits with land, effort, and investment



Box widths are proportional to the square root of the number of observations (e.g. few respondents had 'Ambio', whereas most respondents had beans and maize). 'Ambio', CONAFOR, and 'Reforestemos' correspond to forest-related programmes.

The centrality of these distributions represents relative profitability, and the spread may be related to perceptions about the uncertainty of returns, as explained below. The most relatively profitable activities are those which have higher ratios between benefits and assets, for example: investment in coffee or land in fruit trees.

It is not the aim of this analysis to obtain the profitability of a given activity in absolute terms to be compared with another activity in another context. Rather, the focus is on the perceived relative profitability of a given activity in comparison to others in the actual decision context.

High variability in ratios (larger whiskers, such as land in beans or in sorghum) may have two explanations: either the evaluation or perception of the activity differs importantly across individuals (there is lack of consensus about the profitability of an activity), or returns are perceived as highly uncertain. Conversely, low spread can indicate higher consensus and certainty about returns, which can be due to a more standardised process, to activities related to a well-established market or a clearly-set conservation programme (e.g. *'Ambio'*, in which the process and prices are rather homogeneous for everyone), or to less dependence on weather or on other uncontrollable conditions. Therefore activities with small spread may be more reliable, and their returns might be perceived as relatively less uncertain.

The results of a few activities are remarkable. Commerce has low variability, its profitability is close to the unity, and the ratios are normally distributed, with no outliers. This reveals low level of relative uncertainty. Coffee and fruit-trees have highest returns on investment, although they are more variable than commerce. Fruit-trees and poultry have the highest returns to land. However, the small number of respondents who declared both activities limits the generalisability of this result.

The spread of the ratio of land in cattle-farming is among the lowest but also has very low spread; much land is needed to raise cattle and there is consensus over it. This certainty, together with low spread in effort and investment profitability, suggests why cattle-farming is indeed a preferred activity, as identified in Chapter 4.

9.3. The influence of livelihoods on participation and adoption

This section investigates how livelihoods affect participation and adoption in the programme. It seeks response to the following: a) which livelihood characteristics predict higher adoption? b) do predictors affect participation and adoption equally? and specifically (following the hypotheses posed at the beginning of this chapter) c) what is the effect of subsidy dependence and livelihood diversity on participation and adoption?

These questions are addressed by using a selection model (explained in Section 6.5) for participation and adoption. The selection of independent variables for this model is based on the literature review in Chapter 3, on the key livelihood variables identified in the previous two sections, and on the comparison between participants and non participants developed below.[60] The relationship of clusters with adoption and participation is also shown, and the variables that most distinguish these clusters are included in the model.

The section continues with a synthesis of the differences between participants and non-participants, and of how livelihood variables relate to adoption. This helps specify the model in Section 9.3.2, results from which are discussed in Section 9.4, in combination with the knowledge acquired in previous sections.

9.3.1. Bivariate relations of livelihoods with participation and adoption

The main messages about the relation of livelihood-related variables with participation and adoption in the SPS project derive from correlations with adoption (shown in Figure 9.1) and tests of differences for participants. Descriptive and inferential statistics comparing participants and non-participants for all the variables in the dataset are run (demographic, wealth-level, livelihood and opinion questions; see description of the dataset in Table 6.2, p.170), and those for the most important variables are shown in Table 9.1.

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[60] Using the clustered strategies as independent variables is discarded for two reasons: sample size limitations and the fact that, by including clusters based upon a previous analysis, this model would become too specific and its results would not be so suitable for inclusion in further meta-analysis, hence limiting the usefulness of the approach and of the results in other contexts (a shortcoming identified about some of the studies reviewed in Chapter 3).

Table 9.1: Descriptive statistics and differences between participants and non participants

Variable	N	Description		m/c (*SD*)	Partic. m/c (*SD*)	Non-part. m/c (*SD*)	s
□ ***Participation***	97	Partake in fodder tree planting project			**56**	**41**	
□ ***Adoption***	56	Performance in growing fodder trees; standardised length of trees in plot			**8.28**(12.3)	-	
Ejido title	82	Position in the ejido	*Avecindado*	**9**	**2**	**7**	'
			Poblador	**29**	**16**	**13**	
			Ejidatario	**44**	**28**	**16**	
■ ***Age***	97	Age of adult male respondent (yrs)		**44**(15)	**46**(14)	**42**(17)	
■ ***Youth***	97	Number of youth in the family (< 16 yrs)		**1.4**(1.2)	**1.3**(1.1)	**1.4**(1.4)	
■ ***Income***	92	Level of income (1,000 MXN/ year)	*Low (< 5)*	**36**	**26**	**10**	*
			Moderate (5-15)	**39**	**23**	**16**	
			High (> 15)	**17**	**5**	**12**	
Land category	92	Total land owned	*None*	**17**	**5**	**12**	*
			< 20 Ha	**48**	**34**	**14**	
			20-50 Ha	**17**	**11**	**6**	
			> 50 Ha	**10**	**4**	**6**	
■ ***Land*** *total*	97	Total land owned (Ha)		**29**(31)	**32**(33)	**26**(29)	
✱ ***Diversity***	97	Diversity index for effort: number of activities divided by the total possible activities		**.52**(.21)	**.59**(.21)	**.44**(.18)	***
Land portfolio	97	Diversity index for land		**.25**(.11)	**.27**(.11)	**.22**(.11)	*
Commerce effort	97	Effort in commerce (share)		**.05**(.13)	**.06**(.14)	**.03**(.10)	
Wage labour effort	97	Effort in wage labour (share)		**.11**(.16)	**.10**(.15)	**.13**(.18)	
Beans effort	97	Effort in beans (share)		**.10**(.08)	**.09**(.06)	**.13**(.09)	*
Maize effort	97	Effort in maize (share)		**.17**(.14)	**.18**(.16)	**.17**(.12)	
Jatropha effort	97	Effort in *Jatropha (share)*		**.03**(.05)	**.04**(.06)	**.01**(.04)	*
Subsidy count	97	Number of subsidy programmes received		**2**(1.4)	**2**(1.4)	**2**(1.3)	
✱ ***Subsidies*** *income*	97	Benefits from all subsidies (share)		**.21**(.16)	**.21**(.14)	**.20**(.18)	
PROGAN	90	Benefits from PROGAN (share)		**.04**(.06)	**.04**(.05)	**.04**(.06)	
PROCAMPO	90	Benefits from PROCAMPO (share)		**.09**(.11)	**.09**(.10)	**.08**(.12)	
Commerce income	97	Benefits from commerce (share)		**.05**(.13)	**.06**(.15)	**.03**(.08)	
Wage labour income	97	Benefits from wage labourer (share)		**.12**(.19)	**.09**(.16)	**.16**(.22)	
Agricultural income	95	Benefits from agriculture (share)		**.47**(.22)	**.46**(.19)	**.48**(.25)	
■ ***Cattle*** *income*	94	Benefits from cattle-farming (share)		**.23**(.19)	**.26**(.17)	**.20**(.20)	'
Forestry income	95	Benefits from forestry (share)		**.12**(.11)	**.11**(.10)	**.12**(.12)	
On-farm income	97	Benefits from all production (share)		**.83**(.23)	**.84**(.21)	**.81**(.26)	
Benefit tokens	97	Number of tokens chosen as benefits		**34**(20)	**38**(22)	**29**(17)	*
Willingness	94	Willingness to plant more fodder trees	*I am not interested*	**16**	**5**	**11**	'
			Indifferent	**1**	**1**	**0**	
			Other type of trees	**51**	**29**	**22**	
			I am interested	**26**	**18**	**8**	
Limitation	91	Limiting factor to plant fodder trees	*Land*	**25**	**7**	**18**	*
			Money	**22**	**15**	**7**	
			Information	**3**	**2**	**1**	
			Material	**9**	**5**	**4**	
			Working hours	**17**	**13**	**4**	
			Others	**15**	**9**	**6**	
Time lapse	84	Years for fodder trees to provide benefits		**3**(2.4)	**3**(1.1)	**3**(3.5)	

*'m/c': Mean value (for continuous variables) or count (for categorical variables). 's': Significance codes for bivariate tests for differences between participants and non-participants (two-sample Wilcoxon tests for continuous variables, Fisher's exact test for categorical variables): 0 *** 0.001 ** 0.01 * 0.05 '. Variables included in the*

econometric model below: '□' *dependent variables.* '✱' *independent variables in the hypotheses,* '■' *control variables.*

Two main messages are drawn from the bivariate associations of observed variables with participation and adoption (shown in Figure 9.1 and Table 9.1). First, participants have lower levels of income and are more diverse. Second, diversity is related to lower adoption.

Participation and diversity are positively related (Table 9.1). However, adoption as a continuous variable is negatively correlated (although not significantly) with diversity (Figure 9.1). Adoption does not covariate with income levels (Kruskall-Wallis test p-value > .1), land endowment, nor age. It is however negatively related to the share of benefits originated from cattle farming, with benefits from PROGAN, and with the ratio of workers.

There are no significant differences between participants and non-participants in the share of benefits from subsidies, in the number of subsidies in which they participate, in demographics in general (such as the number of youth), or in either of the two off-farm activities. However, participants differ significantly in terms of age, ejido title, income and land categories. Participants are more frequently in the poorer categories of income. With regards to cattle farming, participants have on average more benefits from this activity. It could be argued that individuals enter the programme because they have cattle and then those that have cattle are inherently more diverse.[61]

Among responses to specific questions about the project, the perception of technology is reflected in the reported limitations and willingness to plant trees (Table 9.1). The stated limitations to plant trees differ between participants and non-participants. The former perceive investment (money) and effort as the main limitations, while the latter focus on land and investment. Most respondents show some interest in planting trees, mostly other types of trees (such as fruit trees), but there is a significantly higher proportion of non-participants who are not interested.

[61] Remarkably six participants declared no cattle. This may be explained because they participated in plots shared with other participants who did have cattle.

The influence of the strategies identified through CA on participation and adoption is also explored by means of pairwise tests, similar to the ones described in Section 9.1.1. The comparison of clusters yields differences in the level of adoption (Table 9.2), although these are not significant.

Table 9.2: Comparison of clusters with participation and adoption

Cluster	No partic.	Partic.	No plants	Some plants	Many plants	Adoption (average & *SD*)	Adoption median
1. Coffee	2	1	1	0	0	0 (–)	0.0
2. Cattle	18	22	10	6	6	9.8 (15.8)	0.9
3. Diverse	9	16	6	4	6	10.7 (11.9)	5.1
4. Agriculture	10	6	1	3	2	8.6 (8.7)	6.1
5. Commerce	2	7	4	2	1	2.6 (5.7)	0.0

Those in the cluster *diverse* and specialised in *agriculture* had somewhat higher adoption, whereas those in cluster *commerce* performed worst. Clusters also differ in the following, although none of them are significant: participation, interest in planting fodder trees (those in cluster three are most interested, and clusters four and one are least), and those in cluster one also perceive that trees take longest to provide benefits.

These relations help select appropriate independent variables for the model below, and to discuss its findings.

9.3.2. Selection model of adoption of silvopasture

Participation and adoption are modelled on a set of predictors using a Heckman selection model, which is adequate to explain adoption as a multiple-decision process (the model is detailed in Section 6.5). The variables used to model participation and adoption (indicated in Table 9.1) are selected based on the literature review from Chapter 3 and on the explorations above.

The expected directions are as follows. A higher proportion of subsidies in total benefits may encourage less participation. The SPS project under study provided no PES initially and individuals with higher subsidy dependence might be used to getting paid when participating in external programmes, following a rent-seeking strategy. This covariate is not found in previous literature and so the expectation is reasoned upon the discussion in Section 2.3.1. Individuals with high livelihood diversity are expected to participate because they arguably have a tendency to experiment (as discussed in Section 2.3.2). This contrasts with the two studies that include some form of livelihood diversity (Bosselmann, 2012; Mukadasi et al., 2007), which found a negative effect, although they found no significance.

About control variables such as total land, the importance of livestock in livelihood strategy, age, number of youth, and wealth level, there is no clear consensus in the literature. Land or farm size is used in most of the regression studies included in the meta-analysis (Section 3.4.2). Overall, land size is observed to have a positive effect, though significant in less than half the studies that include it. Few studies find a negative effect, and from those which find this negative effect to be significant (Amsalu and Degraaff, 2007; Cranford and Mourato, 2011; Mercer and Pattanayak, 2003) either the effect is small, or the studies report two models corresponding to two aspects of the adoption, in which the effect is positive and negative respectively. Thus the land owned is expected to have a positive effect, but unlikely to be significant.

Few studies include some form of measure about the importance of cattle, and from those, most find it to have a significant effect, either positive (Läpple and van Rensburg, 2011; Marenya and Barrett, 2007), or negative (Amsalu and Degraaff, 2007). Thus the expectation is unknown.

Age is used in all but three of the regression studies in the meta-analysis, and found significant in nearly half of them. The significant effect was positive in over 70% of the times in which it was found significant (e.g. Läpple and van Rensburg, 2011; Mercer and Pattanayak, 2003; Sanginga et al., 2006), and three studies found the effect to be significant and negative (Faße and Grote, 2013; McGinty et al., 2008; Mukadasi et al., 2007). Thus the effect is expected to be positive.

Results about demography are rather contradictory. The family size is found to have a negative effect in about 60% of the reviewed regression studies that include it, but, from the only two that find it significant, in one the effect is positive (Läpple and van Rensburg, 2011) and in the other it is negative (Arslan, 2011) (though the adoption reported by the latter is not an innovation). Other similar measures are also inconclusive, such as children-to-adult ratio (Bosselmann, 2012) or adults in the house (Bosselmann, 2012; Marenya and Barrett, 2007). Based on the review beyond regression studies, it can be expected that a larger family may encourage participation and success: it has more workforce to take care of the trees, and more children increase the influence of the *successor factor* (Wilson, 1997) (by which the head of the household is encouraged to conserve the land for the future of the progeny; see Section 3.3).

With respect to the selection equation, the exploration above indicates a strong relation between participation and income, but not between adoption and income (as explained on page 248). Such a covariate that explains the selection substantially but not the outcome, provides an appropriate exclusion restriction required for the Heckman selection model, so that the model is well identified (Toomet and Henningsen, 2008). Thus in the model, the selection equation for participation includes the variable of income level.

Literature on the effect of income is not unanimous. It is found to be significant in about 40% of the reviewed studies that include it. But again, the effect differs. Some studies find higher income or wealth to have a significant negative effect (e.g. McGinty et al., 2008), and others a positive effect (e.g. Faße and Grote, 2013). The pattern of (farm) income having a significant effect in the decision to participate, but not in the continuation in a programme has also been found (Hynes and Garvey, 2009), though with a positive effect of income in participation.

The selection model results are presented in Table 9.3. One observes that the parameters for diversity are significant in both equations, but with opposite effects. The parameters for levels of income are significant for participation (selection equation), lower income being related to higher participation. The parameters for land and the number of youth are positive and significant for adoption (outcome equation).

Table 9.3: Heckman selection model results (two-step): participation and adoption in the fodder tree planting project

	Probit selection: ***participation***					**Outcome equation:** ***adoption***				
	Estimate	***SE***	**t-val.**	**Pr.**		**Estimate**	***SE***	**t-val.**	**Pr.**	
(Intercept)	–0.52	0.70	–0.75	0.46		23.73	11.90	2.00	0.05	*
Subsidies	–0.49	1.11	–0.44	0.66		20.11	13.76	1.46	0.15	
Diversity	2.14	0.83	2.60	0.01	*	–27.96	11.00	–2.54	0.01	*
Land	0.00	0.01	0.81	0.42		0.15	0.06	2.66	0.01	**
Cattle-farming	0.42	0.88	0.48	0.64		–10.97	10.84	–1.01	0.31	
Income – medium	–0.64	0.36	–1.75	0.08	.					
Income – high	–1.56	0.48	–3.29	0.00	**					
Age	0.01	0.01	0.49	0.63		–0.05	0.14	–0.37	0.72	
Youth	–0.15	0.14	–1.07	0.29		3.50	1.65	2.12	0.04	*
N	89					51				
Log-likelihood (df=9)	–48.51					–190.99				
AIC	115.03					399.97				
χ^2	24.44				**	20.27				**
% correctly predicted	75%									
Nagelkerke / Cragg & Uhler's pseudo-R^2	0.32									
R^2						0.36				
Adjusted R^2						0.25				
F-statistic						6.90 [8, 43]				***

Tobit-2 (sample selection) model estimated by the two-step method. Base level for income is 'Low', the level with highest participation. The Inverse Mills Ratio parameter is significant in the outcome equation (p-value = 0.048). ρ = *–0.93. 'Pr.' probability of the t statistic. Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1.*

A Ramsey's retest test for specification (Wooldridge, 2006; Zeileis and Hothorn, 2002) is run for both the selection and the outcome equations, suggesting no changes are needed in the specification (p-values = 0.39 and 0.72 respectively). The ratio of observations in the sample per independent variable is satisfactory (> 6) (Field et al., 2012). Multicollinearity is discarded in the outcome equation (highest

Spearman correlation coefficient = 0.47, and highest Variance Inflation Factor = 1.36) (Greene, 2008). As a test of robustness, I run the outcome equation (adoption) of the Heckman selection model with the same specification of independent variables, but for an ordered categorical variable as the dependent variable, thus using an ordered probit model (Table 9.4).

Table 9.4: Robustness test: selection model with ordered probit

	Estimate	***SE***	**z-value**	**Pr.**
Subsidies	2.66	1.45	1.84	0.07 .
Diversity	–2.06	1.10	–1.87	0.06 .
Land	0.01	0.01	2.11	0.03 *
Cattle-farming	–2.25	1.13	–1.99	0.05 *
Age	0.01	0.01	0.37	0.71
Youth	0.36	0.17	2.10	0.04 *
Intercepts:				
0 No participant|1 No plants	–5.97	0.05	–127.23	0.00 ***
1 No plants|2 Some plants	–0.94	1.27	–0.74	0.46
2 Some plants|3 Many plants	0.13	1.26	0.10	0.92
N	51			
Log-likelihood (df=10)	–46.21			
Residual Deviance	92.42			
AIC	112			

*'Pr.' probability of the z statistic. Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1.*

The directions and relative magnitudes of the coefficients are similar. In this model, also the coefficients of subsidies and cattle-farming are significant. However the Inverse Mills Ratio (IMR) is not significant, suggesting that the selection model would not be necessary in this case. As a further test, the outcome equation with the specification above—ordered multinomial probit—is run without the IMR (as a single-step model). This alternative model has much less explanatory power (AIC = 243, and none of the coefficients are significant).

The IMR of the model in Table 9.3 is significant at a p-value < .05 and thus suggests that the estimates of the outcome equation would have been biased had the model not controlled for selection bias, and that adoption and participation are distinctly explained by covariates. Indeed, the effect of some variables differs for participation and for posterior involvement and tree outcome. These differences show that the two are different decisions: participation is decided in an initial, single decision, whereas involvement and actual performance occur in a second stage of the process, when the trade-offs with other livelihood activities are actually encountered.

A more detailed discussion of the results from this model is provided below, after bringing together the main findings from the previous two sections that have explained livelihood strategies in the case study. Understanding why livelihoods are they way they are, helps explaining the coefficients found in the model.

9.4. Discussion: why do livelihoods affect participation and adoption?

The first goal of the chapter was to profile the characteristics of livelihood strategies in the case study. The exploration of which strategies exist (Section 9.1) reveals a number of useful classificatory dimensions. The dichotomy between specialisation (in either cattle-farming, agriculture, or off-farm) versus diversification is the first dimension, observed in the ternary plots in Figure 9.2. In addition, despite the strong preference for cattle-farming, other niches for livelihood activities are also found, which have great potential for economic stability and for conservation: (shade) coffee, palm, and forest programmes. These activities however, are practised by a minority.

The second dimension is that of available capitals in terms of land and wealth. A fifth of the benefits on average are from subsidies, although this is highly variable and tied to those who own larger areas of land. Land is indeed a major definitional characteristic; it is related to access to subsidies and to diversification, hence arguably a keystone to reduce vulnerability and to escape poverty. The *elite* of the community can be described as individuals who are *ejidatarios*, have more land, more cattle, higher levels of income, and belong to the cattle-farming association.

Their higher diversity may be due to either having tried many activities along their longer lives and having kept practising some of them, or to having had more access to land in the first instance. At the other extreme, poor individuals can be considered those who specialise in the basic crops of maize and beans, and have higher expenditures on basic consumption. These are related to less diversity. Clearly, their adoption of innovative or more prosperous activities may be limited by physical and financial capital, and they rely on what is left: the cultivation of maize and beans, in a tradition inherited from the early stages of the community, as seen in Chapter 4. Indeed, a large group of people have no cattle at all, and may need to work as paid labourers to compensate their lack of assets.

The formal analysis of strategies reveals five clearly distinctive groups: specialised in coffee; in cattle-farming with no off-farm and receiving many subsidies; those with a most diverse livelihood; agricultural specialists doing a lot of work as paid labourers (seemingly the poorest and youngest); and those who dedicate remarkaby to commerce, with a somewhat diverse strategy and who own moderate amounts of cattle (arguably the most prosperous). Each of these types has distinct contexts for their decision-making. The agricultural specialist may be limited in any decisions by the lack of land and income, while the diverse and the commerce specialist may be limited by the lack of time (due to being dedicated to a large number of activities) and might give priority in his decisions to the productivity of his working time.

Why do livelihoods take the shape described above? In response to the second question of this chapter, the perceived profitability and uncertainty of activities demonstrates why there is such a high preference for cattle. It might not be the most productive activity (coffee and fruit-trees appear to give higher returns), but it is a much more secure activity; farmers know that they will get some returns at the end of the season. In contrast, agriculture in general is perceived as more uncertain as it depends much on the weather, it requires more investment in chemical products, and it might have more variable market prices. Instead, cattle-farming requires less dedication and, arguably, also solves the problem of fallow land. Fallow land may be a problem for individuals because it can be quickly taken over by natural vegetation. Maintaining it demands effort, especially under protection rules which limit the use of fire (the traditional form of controlling fallow) and the cutting of trees. As it is practised in this context, cattle are left to freely browse and thus they also maintain fallow land relatively free of bush—with the additional impact of reducing sapling recruitment, which hinders the natural generational replacement of trees.

The third main question of this chapter interrogates how do livelihoods affect participation and adoption in the SPS programme. As seen in Section 9.3, participants in the project distinguish from non participants in that the former are more diverse and from lower levels of income. However, once they participate, those who have a more diverse livelihood performed worse (had lower adoption). Clearly, participation and adoption relate differently to many livelihood characteristics.

The selection model reveals further nuances about how livelihood characteristics may affect participation and adoption. From the two hypotheses on independent variables posed at the beginning of the chapter, one is confirmed to a large extent (on diversity) and the other remains unclear (on subsidies). The hypotheses state that higher livelihood diversity leads to higher participation and short-term adoption, and that subsidy dependence influences participation negatively.

The effect of diversity is significant in both participation and adoption but with opposite effect. This is a key finding. Higher levels of livelihood diversity in the case study seem to encourage participation in the tree planting programme, whereas it is negatively related with adoption. One possible explanation is that higher levels of wealth—more cattle—are also related to higher livelihood diversity and, going back to the conclusions in Chapter 8, those with more cattle are also more conservative and attracted by subsidies; they participate to see whether there is any PES to gain, and then they do not take care of the trees. However, the total land owned has a significant positive (albeit small) effect in adoption. An alternative explanation is that more diverse individuals already have a range of activities to which they dedicate their effort and, even if they are keen to participate, they may not have much time left to devote later on, which causes lower levels of adoption.

Aggregate benefits from subsidies had no effect according to the model and the null hypothesis cannot be rejected.[62] This result is plausibly because the model pools

[62] Variations of this model specification were tested, in which each subsidy was considered as an entirely separate independent variable, or aggregated into subsidies for productive activities, for conservation, and for development. However in none of the models subsidies had any significant effect neither improved goodness of fit.

subsidies which are of very distinct nature, intended to either encourage productive activities, to alleviate poverty and development, or to conserve forest and hydrological services. Thus this requires further research.

Demography was expected to influence positively on participation and adoption. However the model suggests that the number of youth affects participation negatively (although its coefficient is non significant) but affects adoption positively (and with a significant coefficient). This is consistent with the expected impact of the successor factor.

In sum, the coefficients found in the model of both participation and adoption have plausible explanations, which are better understood by looking at the broader characteristics and drivers of livelihood strategies.

9.5. Conclusion: heterogeneous livelihood strategies and silvopasture adoption

This chapter has the following contributions, related to the three main questions posed in the introduction. It reveals the different livelihood strategies found in the case study, which is representative of the region in Chiapas, and suggests trade-offs and synergies between variables, to profile five main types that help derive further conclusions on the hypotheses of the chapter about what influences SPS adoption. It explains what shapes current livelihoods and points at the reduction of uncertainty as a key driver of preferences. This is a key lesson to consider when trying to encourage the incorporation of SPS in the strategies. It models participation and adoption in the SPS project, it uncovers how covariates are related with each of these two steps in the adoption process, and finds that covariates can have a surprisingly distinct effect in each of the two decisions. The understanding of livelihood strategies, trade-offs, and livelihood preferences is instrumental in explaining the model, and is useful to gauge how SPS can have a role in these livelihoods.

Connections and covariation are detailed between livelihood, demographic, and wealth variables. I find the presence of poorer, younger families who concentrate on maize and beans, and of wealthier, older families—normally *ejidatarios*—with more land, who dedicate to cattle farming, have more subsidies, and are quite diverse. This diversity is perhaps not due to intrinsic curiosity, but rather to age and accumulation of activities, as well as to having more land in the first instance; land is key to both access to subsidies and to diversify. The approach taken can serve to explain the heterogeneity of livelihood strategies in other contexts.

The model of adoption demonstrates empirically the relevance of considering livelihood variables in studying the uptake of sustainable practices. It analyses the outcomes beyond a binary variable of adoption, using a continuous variable of the level of adoption. It also accounts for selection bias in the participation, hence including valuable information about non-participants, and at the same time explaining adoption as a process where participation is the first of a series of decisions. Both characteristics of the model are recommended (Feder and Umali, 1993; Pattanayak et al., 2003), but unseen together in SPS adoption models in developing countries, and rarely found in the adoption literature (Chapter 3). Adopting this sequential approach reveals that indeed, the heterogeneity in the measurement of dependent variables (see Section 3.5), can be the reason for inconsistency in the coefficients of independent variables across studies.

Results show that variables related to livelihood strategies are significant to predict participation and outcomes. Understanding that individuals with certain livelihood strategies are more likely to adopt may aid targeting and predicting whether those adopting will be the same who have a more negative impact on the ecosystem. Understanding the issues encountered by individuals with diverse livelihood strategies—those who are more likely to participate in the first instance—may help avoiding or mitigating low levels of adoption and increasing both effectiveness of the programme (in terms of continuance) and self-efficacy and satisfaction of participants, which may further contribute to ensuring continuance. As seen later in Section 10.2, PES may not be the most effective instrument to reduce these barriers.

Chapter 4 about the social-environmental history has suggested that current livelihood diversification is a result of pathway-dependent trajectories driven by local and global factors (Huber-Sannwald et al., 2012). These drivers include transitions from slash-and-burn to specialisation in modern cultivation of maize, changing international commodity markets, the introduction of subsidies for agricultural and cattle-farming expansion, and changing local land-use regulations due to the protection of the area. These drivers are characterised by uncertainty in the medium term, which contribute to increase vulnerability of farmers with low financial resources and limited opportunities, both emphasised by deficient health and education systems (Ellis, 2000a). Naturally, activities that are perceived to have a higher level of certainty will be pursued (such as cattle-farming), despite providing lower productivity than others. This livelihood context of vulnerability and uncertainty is common elsewhere in Mexico and in other countries worldwide that combine high levels of biodiversity and natural resources and low-income and vulnerable livelihoods.

In these contexts, both livelihood diversification and an increase in income from external programmes seem viable strategies to cope with vulnerability and uncertainty, and these strategies heavily influence decisions about land-use practices. Diversification and subsidy dependence are distinct strategies to seek security in livelihoods; individuals whose livelihoods are dominated by either of the two may have different vested interests in innovation and conservation. These livelihood characteristics can also be objectively identified, which makes them useful for targeting. Thus programmes to impact on environment and development ought to heed the heterogeneity of livelihoods to identify challenges and opportunities for effectiveness.

Summary of Part IV

Acknowledging the heterogeneity of preferences, goals and motivations of recipients is critical to improve the effectiveness of conservation interventions (as stated in Chapter 2). The last two empirical chapters present and discuss the results of analysing subjective perspectives and livelihood strategies, and of modelling participation and adoption of SPS in the case described in Part II.

Chapter 8 uses Q methodology to uncover the diversity of motivations to adopt silvopastoral practices. The research design is described in Section 6.1, and the analytical innovation developed in Chapter 7 is implemented to improve the accuracy of results. The chapter also explores the links of the resulting perspectives with key livelihood characteristics and success in the fodder tree planting project.

The analysis uncovers three distinct types of farmers with regard to their social-ecological perceptions: self-sufficient pioneer, environmentally-conscious followers and payment-dependent conservative. Most individuals in the highest category of adoption are self-sufficient pioneers, and in the second category of adoption self-sufficient pioneers and environmentally-conscious followers predominate. The payment-dependent conservatives are more specialised in cattle-farming, but not higher observed subsidy dependence, thus this dependence is a perception. The three types are discussed based on their potential to adopt silvopastoral practices, their views about external payments for their livelihood strategies, and the theory of diffusion of innovation.

Results have key implications for voluntary, incentive based conservation interventions such as payments for ecosystem services. They suggest that beyond short-term monetary incentives—often associated with the design of direct payments—other complex motivations held by farmers may play a more important role in voluntary conservation programmes. For an incentive programme to be successful, it may have to catalyse the different latent motivations for SPS adoption of each type of perspective, by using adapted policies and rewards. Also, focusing on incentivising the self-sufficient pioneers may be most effective and efficient, because if they demonstrate that the practice is successful, this will be instrumental in enticing the rest to adopt. This is further discussed in the final chapter.

In Chapter 9, decisions about livelihoods are understood in depth by looking at distinct decision contexts posed by different livelihood strategies, and at preferences among livelihood activities, based on perceived profitability and uncertainty for each activity. A cluster analysis reveals five livelihood strategies: specialists in agriculture, coffee, cattle, commerce, and diversified. Each strategy may arguably have distinct limitations and potentials to incorporate SPS to their activities. Strategies differ between participants and non participants, but not in terms of adoption levels.

Finally, participation and the level of adoption are modelled using the Heckman selection approach to understand what predicts higher adoption. To aid the selection of independent variables, a set of key observed variables is described and compared between participants and non-participants in the SPS project. The decision to participate in the programme is different from the decision about the intensity of the performance (adoption), and the effect of covariates on each of these decisions can differ. The level of income, for example, affects participation, but is unrelated to adoption. Remarkably, diversity is found significant in both, but with opposite effect. A plausible explanation is that people with diverse strategies partake more, searching new innovations or seeking rent. Once they are in the project, they find either that other activities do not leave sufficient time to dedicate to fodder trees, or that the lack of payments or of conditionality disincentivises them to perform better. Results thus show that variables related to livelihood strategies are significant to predict participation and the level of adoption, and that the direction of the effect of some can be different for each. This has relevant implications for the design and targeting of programmes for conservation in the context of development.

The policy implications, limitations, and future directions of these empirical results are exposed in the next chapter.

Chapter 10. Conclusions: improving the design of programmes to encourage sustainable land-use practices in the tropical forest frontier

This chapter underlines how this thesis contributes to understanding the motivations to adopt silvopastoral practices, in low-income rural areas surrounding tropical forests. The thesis has investigated smallholder livelihood decisions in order to inform the elaboration of incentive-based programmes that effectively encourage the uptake of sustainable land-use practices.

Tropical forests comprise most biodiversity hotspots, and diffuse, small-scale forest degradation due to farming pressure is a major, and arguably underestimated, immediate threat to their preservation (Geist and Lambin, 2001). The frequent trade-off between livelihoods and conservation can be mitigated by implementing innovative sustainable land-use practices, such as silvopasture (Broom, 2013). However, diffusion of silvopastoral systems (SPS) is low, and there is a clear research gap in understanding why this is the case (Dagang and Nair, 2003) and how SPS adoption may be encouraged.

A conceptual framework has been developed to understand the context in which decisions of whether to adopt SPS are taken (illustrated in Figure 2.1, p.48). This framework places livelihood decision-making within social-ecological systems that integrate the ecosystem, livelihoods, cognitive processes, and institutional aspects. Based upon this framework, decisions are influenced by external (observable) factors, mediated by internal (subjective) ones (Chapter 2). The impact of incentive-based interventions, such as payments for ecosystem services (PES), on land use and ecosystems materialise through these livelihood decisions. Therefore, to understand how incentives can fit motivations for SPS adoption in such contexts, this research has been directed to better understand livelihood decisions.

To understand decisions to adopt SPS, Chapter 3 makes a systematic quantitative review of the literature about adoption of silvopasture, and about sustainable agricultural innovation in general. This review results in a comprehensive inventory of factors influencing adoption, among which internal variables (such as perspectives) and holistic livelihood strategies have been rarely studied, despite their high potential to explain decisions.

To fill this gap, an already-implemented pilot project is empirically analysed. The project sought to encourage silvopasture adoption in the buffer area of a biosphere reserve in Chiapas, Mexico. Specifically, this research investigates the reasons for the high variability in the outcomes of this project, which coached smallholders to grow fodder trees in privately-owned plots. The focus of this explanation is therefore on perspectives and livelihood strategies.

The thesis explains the historical and macroeconomic drivers that shape current livelihood decisions and land-use transformations in this representative case study (Chapters 4 and 5). The social-environmental history of the case reveals two main land and livelihood transitions in recent decades, strongly driven by external forces: from primary forest to maize, and from maize to cattle-farming. As currently practised, cattle-farming is highly unsustainable and could lead to the loss, not just of forest cover, but also of soil in some areas in just a few decades, as observed in other similar places in Chiapas and Central America. Following a complex systems approach, current decisions may be pathway-dependent, and therefore livelihoods can continue swaying, influenced by external interventions. This explanation is instrumental to develop the methodological approach (Chapter 6), and to understand livelihood trajectories that may be shaping current preferences.

Partially, the reason why internal variables are rarely incorporated to this type of empirical study is the difficulty of operationalising them. Therefore Chapter 7 develops a novel approach to improve the reliability of Q, an increasingly used instrument to understand perspectives.

The research continues with the results from the in-depth analysis of individuals' motivations for adopting (or not) SPS, related to perspectives and to observable livelihood variables (Chapters 8 and 9). This analysis reveals a heterogeneity of actors, which provides important insights to understand why PES may not be the most appropriate tool to encourage behaviour in some individuals, and what alternative policy instruments can be used under certain circumstances.

The next section revisits how the key research questions have been tackled, what has been found, and what the findings signify for these questions (Section 10.1). After, the practical policy implications are discussed (Section 10.2), followed by a recapitulation of the main contributions of the thesis (Section 10.3). The chapter ends with an exposition of limitations and caveats of this research, and policy-relevant future research directions (Section 10.4).

10.1. Key findings of the thesis

In the following text, I revisit what has been found that sheds light on each of the three main questions. The findings refer to the following:

- Factors influencing the success of programmes to encourage adoption of sustainable land-use practices in the tropics
- Motivations and hindrances for smallholders to adopt or discard silvopasture
- Adaptation of incentives, with attention to PES, to fit motivations, help overcome obstacles, and catalyse adoption

10.1.1. Factors influencing the success of programmes to encourage adoption of sustainable land-use practices in the tropics

In uncovering the factors influencing uptake, the thesis offers a new, clarifying synthesis of what the literature on adoption of SPS, and broadly on sustainable agricultural innovation, suggest that may influence behaviour (Chapter 3).

In terms of independent variables, I find six main groups of factors that influence adoption (synthesised in Figure 3.2, p.80): farm and household characteristics (including livelihoods), social environment and institutions (including external policy interventions), knowledge and information, technical feasibility, economically rational motives (including costs and benefits), and individual factors (including objective or external, and subjective or internal). The coverage of these factors in empirical studies is highly variable. Some factors are almost always incorporated (e.g. individual objective characteristics), while others are hardly included at all (e.g. individual subjective characteristics), and this level of coverage does not necessarily correspond to the level of importance in explaining adoption. There are also differences in what each body of literature (reviews, regression studies, and other methodologies) emphasise as influencing adoption. These differences are partially due to difficulties in operationalising certain concepts, which also span multiple disciplines.

The synthesis also shows that regression studies which consider adoption as a sequential process are scarce. I argue that this predominance of the 'static' view is another major cause for the lack of consensus about what predicts uptake, because it implies that cross-sectional studies might have been measured at different stages of adoption. Studies on adoption report high variability and contradictory directions of the effect of some predictors (e.g. available labour). Reasons for this variability include the diversity of practices studied and of geographical contexts, and these arguments are widely acknowledged. However, depending on the stage of the process at which the dependent variable is measured, the covariates may be different or have distinct effects (Morris et al., 2000). This theoretical explanation is empirically demonstrated in Chapter 9, where some predictors have clearly distinctive effects in each of the two decisions (participation and adoption). If a sequential process of adoption is assumed, acknowledging this additional heterogeneity in dependent variables is critical to explain why many of the predictors in the literature seem to have inconsistent effects. In sum, how and when the dependent variable is measured may be a major source of variability across studies, and this argument has not been put forward in the literature to the author's best knowledge.

10.1.2. Motivations and hindrances for smallholders to adopt or discard silvopasture

This study focuses on aspects of decisions about adoption that have received little attention thus far (perspectives, the subsidy context, and livelihood diversity). Theoretical literature beyond adoption studies suggests that both the perspectives and livelihood diversity can explain an important amount of this variability, and the results of this study demonstrate so.

The study of individual internal factors reveals three perspectives: self-sufficient pioneers, environmentally-conscious followers, and payment-dependent conservatives. These perspectives are identified in terms of attitudes towards SPS adoption, conservation, and livelihoods. The understanding of perspectives has been improved through the bootstrap-based analytical innovation, which provides more precise and detailed results.

No perspective is significantly more likely to adopt SPS, but distinct motivations can be identified that could be catalysed in order to encourage adoption. The self-sufficient pioneer is mostly interested in activities that can provide a secure livelihood in the future. Individuals presenting this perspective are also the ones who adopted most. The environmentally-conscious follower is aware of soil erosion problems and is also driven by normative concerns. These individuals also adopted at a high level. The payment-dependent individuals directly state needing subsidies for their future and PES to conserve the forest. These adopted least.

The thesis explores, for the first time, the role of livelihood diversity on the adoption of SPS, and shows a significant link between both. Individuals have heterogeneous livelihoods and understanding the distinct contexts of decision inherent to each livelihood strategy can be instrumental to discuss how to adapt incentives to encourage changes in land uses. This exploration is also unique among studies of adoption of sustainable agricultural innovation more broadly.

Following a sequential approach, a two-step selection model of participation and adoption reveals that these two are indeed distinct decisions, and that covariates can have different effects on them. Participants in the project have lower levels of income and more diverse livelihood strategies, although income and strategies are not necessarily related in the case study. In contrast, livelihood diversity is inversely correlated with levels of adoption. A positive effect of livelihood diversity was expected for participation, but a negative one was not expected for adoption. Potential explanations for this unexpected finding stem from the conceptual framework (Section 2.3.2). Individuals with more diverse strategies might also be those who seek rent from external programmes, thus once they see that the project does not provide PES, they might underperform. Alternatively, the same individuals might be genuinely interested in trying a new activity, but once they take the easier decision (participate) they find that they actually do not have time to dedicate to it. In terms of other important effects found in the model, the successor factor (Wilson, 1997) can explain why the number of youths in the household has a positive and significant effect on adoption.

Decisions on whether or not to adopt SPS can also be explained in terms of current livelihood preferences more broadly. Currently in the case study, cattle-farming is a relatively secure activity. It is less demanding and uncertain than agriculture, and thus there is high preference towards it. As seen in the empirical analysis, this preference may be shaped by the higher certainty of returns, and lower dependence on external inputs and on weather, even though it might not be perceived as the most profitable activity (coffee and fruit-trees appear to be more profitable). Therefore in order to make SPS attractive, it is important to ensure that it is perceived not just as a beneficial activity, but also as an activity that will reliably produce these benefits, hence contribute to reduce vulnerability.

10.1.3. Adaptation of incentives, particularly payments for ecosystem services, to fit motivations

The third question, about how incentives can be adapted, has direct practical policy implications (further discussed below). The underlying query is why and in which circumstances might PES have little effect upon behaviour, and what alternatives can be employed in such cases. The response to this query derives directly from the findings after the second question, which has interrogated the heterogeneity of motivations influencing uptake—including factors beyond purely rational behaviour, on which PES are theoretically based (Engel et al., 2008).

A look into broader theories of decision-making suggests that the processes underlying behaviour are strongly influenced by internal forces. Accordingly, profit maximising considerations can be diluted by perceptions, attitudes, beliefs, and norms. This may explain why a positive effect of PES on conservation may not be always significant.

Policy instruments (Osbaldiston and Schott, 2012) that can encourage voluntary pro-environmental behaviour (PEB) include (in order of increasing engagement): easing the practice, prompts, information, performance feedback, rewards, and social-psychological models. It is suggested that the level of effort and persistence required for a specific PEB determines what instruments may be more appropriate (more effort requiring instruments with higher level of engagement) and that each type of PEB might respond most effectively to a specific instrument (Osbaldiston and Schott, 2012). Among these instruments, payments are but one more. By making recommendations for matching instruments to heterogeneous individuals, this study gives further nuance to the choice of tools for specific PEBs and levels of engagement.

The heterogeneous perspectives give an indication of what incentives may be appropriate for each view. These instruments can be: reliable and trusted information or social recognition for the self-sufficient pioneers, emphasising environmental motives for the environmentally-conscious followers, and PES for the payment-dependent conservatives. However I argue that the first perspective, and maybe the second one, are more likely to continue the activity after the intervention than the third one. The third perspective would probably stop if the incentive stops, unless widespread adoption has already occurred. Continuation from any of the three perspectives would probably occur as long as the activity is beneficial, in that it emphasises gain, hedonic, and normative goals (Steg et al., 2014). Indeed, it could be plausible that each of the perspectives is more driven by one of these three goals: the self-sufficient pioneers by hedonic goals, the environmentally-conscious follower by normative ones, and the payment-dependent conservative by gain ones (see definition of these goals on footnote 9, p.55).

Further insights are found in considering the relationship between strategies and adoption. Results suggest that those who are more likely to participate in the first instance (those whose livelihood is more diverse), may encounter more obstacles once they are in the programme. These obstacles could be related to the lack of labour available for the activity, or to the lack of immediate benefit. Conversely, among those who did not participate, the lack of land seems to be a major obstacle.

These two hindrances clearly require distinct incentive strategies. For the former group (those who are more likely to participate but fail to adopt later on), the incentive should seek to ease the most labour-intensive sub-tasks or enable more efficient team-working. For the latter group, forms of easing access to land can be effective to encourage them, such as offering securely-tenured communal silvopastoral plots. Such instruments can help increase participation among those who do not own land, whereas a likely small PES would not induce them to participate nor to acquire land. Strategies that are effective for the former group are unlikely to be effective for the latter group, and vice-versa. However, a combination of these strategies can increase participation and adoption in a community with heterogeneous livelihoods.

The next section explains how the effectiveness of policy interventions can be enhanced according to the findings of this study, especially in terms of reducing obstacles and catalysing opportunities and motivations.

10.2. Implications for policy design and implementation

The findings suggest that policy instruments other than PES, such as informational strategies, social modelling, or reducing risk, can be effective and more targeted to specific needs and motivations. Results also lead to policy recommendations that integrate various forms of instruments (as explained below), including payments or cash transfers depending on the case, in order to achieve both environmental and social goals, as has been suggested (Rodríguez et al., 2011). Steg and Vlek (2009), when discussing their classification of instruments, argue that the most effective policy strategy may be the one that best fits with the specific barrier of the PEB in question. In terms of matching intervention with behaviour, Osbaldiston and Schott (2012, p.280) suggest that “low-engagement treatments are appropriate for low-effort behaviors” and vice-versa. In this case, SPS is a rather long-term commitment which implies a moderate to large amount of effort, thus high-engagement interventions, such as commitment and goal setting appear to be appropriate (see Section 2.2).

Paying for conservation is not necessarily the most effective way of using resources for environmental policy making, as responses to incentives may depend upon an individual's goals. This is because in decision-making (especially with reference to PEB) there are other factors that have a strong influence, beyond the cost-benefit balance that a payment can affect. Acknowledging this diversity of factors implies that the effect of PES may be small and it would explain why empirical findings often do not find conclusive effects.

The findings of this research have policy implications for the pre-assessment of a context where an intervention may take place, and for the design of the intervention. The broader lessons from these results are relevant for sustainable activities beyond SPS, thus some of the implications discussed below can be extrapolated to broader decision-making on PEB in other contexts and practices.

10.2.1. Policy pre-assessment

Acknowledging the heterogeneous nature of perspectives and livelihoods can help identify those who are more likely to adopt according to intrinsic interests—likely to be catalysed by non-monetary rewards or by other instruments pointed by Osbalditson (2012)—and those who may need monetary incentives to participate. Determining the conditions under which PES may be replaced with other forms of incentives or instruments may require an identification of heterogeneity. Identifying both characteristics (perspectives and livelihood patterns) is feasible in the context of low-resource policymaking in order to help targeting (using the methods explained in Chapters 6 and 7). This identification could be done in at least three ways.

One way may be to pre-assess the specific contexts where the intervention is to be made—arguably a task which demands skilled or abundant human capital. Q methodology and the game-like procedure to collect data on livelihoods presented here proved to be valuable and effective approaches to understand heterogeneity. Results indicate that to understand livelihoods, the distribution of effort and, to a lesser extent, of land, are as good as or better indicators than the sources of income (which are more frequently used in past research). This implies that an effective assessment can be done by collecting effort allocation information, rather than the more sensitive information on income, and a token approach gives all the necessary information to characterise diversified and specialised strategies, while avoiding some drawbacks from conventional surveys. Knowing these strategies, a practitioner can envision who is more likely to try as a pioneer—whose hindrance may be the lack of time—and who cannot try because of a lack of assets, but might have more time to dedicate to it—such as in the case study, those specialised in maize and bean cultivation. Of interest for SPS adoption specifically, one can also find who are specialised in cattle, the ultimate target of such projects. Parallel approaches may be implemented in other contexts by adapting the livelihood map illustrated in Figure 6.3 (p.167), and pre-identifying which activities associate with certain asset endowments, etc.

Another way to adapt policy to heterogeneity can be to assume a set of expected typologies of individuals, which need not be too complex. Instead of assuming a single type of individual who follows predominantly rational behaviour, the programme developer can expect just two or three types of individuals, each of whom, is mostly moved by gain, hedonic, or normative goals (Steg et al., 2014) (see Figure 2.2, p.60). Under this assumption, instead of providing a single type of reward (e.g. PES), the programme also may employ instruments to emphasise hedonic motivations (e.g. long-term security, self-sufficiency, self-efficacy), and normative ones (e.g. increasing problem awareness). Alternatively, the policymaker can expect a typology based on diffusion (pioneers, followers, and laggards) and adopt incentives to their specific motivations. These instruments may be used simultaneously or separately, depending on the specific PEB, and on what the programme developer knows about the context where the intervention is to be made. A single instrument, the one expected to be most effective, may also be chosen if the programme budget is too limited.

A third way may be to direct pre-assessment efforts to identify hindrances for adoption, which might also be specific to distinct livelihood strategies. These hindrances may be identified from among the potentially limiting factors inventoried in Chapter 3 (Figure 3.2, p.80): those related to livelihood activities (land access and security, availability of labour, financial capital), knowledge and information, social networks, internal variables (such as self-efficacy or lack of awareness), etc. To be effective—also in the long term—an environmental policy instrument shall assess and ensure that none of these factors becomes a significant barrier within a given context. To put this approach in practice, the inventory of factors can be used as a check-list for a case-by-case rapid assessment of the preconditions for adoption (based, for example, on expert assessment or key informant interviews), and to address potential barriers before doing so becomes impracticable. Adoption is a continuous process, and close attention must be paid to the obstacles found by participants during this process in order to avoid discontinuance. Again, depending on perspectives and livelihoods, these obstacles may be different (such as available labour for those who have a diverse livelihood, or lack of immediate monetary benefits for the subsidy-dependent), and a policy ought to be ready to aid these circumstances when they arise.

10.2.2. Policy design adapted to heterogeneity: targeting pioneers and programme at stages

A cost-effective environmental policy to encourage voluntary PEB may pursue one or more of these three main goals: to eliminate possible barriers to be encountered among the manifold predictors, to catalyse an individual's favourable preconditions, and to spur those factors that are more likely to encourage long-term adoption. The policy can try helping those who are more likely to partake to overcome the limitations that affect posterior uptake. It also can aim to find ways to involve those who are more likely to adopt and continue. Acknowledging the relation of perspectives and livelihood diversity with adoption can aid the identification of appropriate incentives (as discussed above) and the development of smarter strategies. For example, according to the distinction of participation and adoption as different decisions, a policy to encourage adoption could emphasise different aspects at each stage of the programme.

Although low in number, innovators—or pioneers—can play a key role and reach the minimum threshold beyond which an activity is adopted by the majority. Indeed, a study has found that 58% of participants that entered a programme in a second phase, were influenced by observing the success of the participants in the first phase (Hayes, 2012). Regardless of whose impact on land use is highest, results suggest that it might be more effective to target pioneers because they are more likely to be motivated to try the innovative practice, and they can become an example to spread it through communication and social influence. This conclusion logically emerges when framing the adoption analysis under a paradigm of a process.

Therefore a plausible policy strategy could be to target rewards to so-called pioneers. This group is intrinsically motivated towards experimentation and innovation processes, and for them an immediate payment is a secondary interest, according to the results in Chapter 8. Providing rewards for pioneers may be done in exchange for them to share such experimental knowledge with other farmers (also presenting them as social role models). However, targeting pioneers may be challenging, not just as a consequence of the challenge of identifying these individuals, but mostly for equity and fairness concerns, because a selective distribution of rewards could be perceived as unfair by others (Pascual et al., 2014). The role of differentiated targeting based on behavioural diversity may impact equity in the distribution of payments and this needs be dealt with due caution. Both hurdles could be overcome by designing the programme with characteristics that attract mostly the so-called pioneers, and with conditions that are unattractive for the payment-dependent, so that pioneers self-select. Also, inviting tenders as if it were a selection for a position, such as in a job call, might reduce unfairness perceptions (Knight et al., 2010).

It follows that the type of external incentives to initially catalyse the pioneers' motivations might not necessarily be cost-based, but might be those that deliver a transparent and convincing informational strategy (Calatrava and Franco, 2011; Egmond et al., 2006). This would require providing adequate, clear, and complete information about the advantages and disadvantages of the practice, and highlighting the innovative aspect and the potential of the new technique to benefit smallholders in social, economic, and ecological ways. Information may be disseminated through multiple authoritative and trusted sources, in order to reduce the uncertainty involved, up to an inflexion point where farmers decide to adopt (Garbach et al., 2012). This can be complemented by facilitating networks with other groups of innovators.

The pioneers may arguably be further motivated if their leading action is socially rewarded (Heyman and Ariely, 2004). For instance, rewards can take the form of acknowledging their service to the community while voluntarily taking risks, or promoting them as educators through a process of constructive communication and demonstration between pioneers and other potential adopters (Atwell and Schulte, 2009; Egmond et al., 2006). An adapted combination of these measures may need careful attention to the complexity of targeting, equity concerns, and associated transaction costs. Yet this approach for enhancing precision in targeting could make a programme more cost-effective than direct PES without targeting based on heterogeneous perspectives.

A further approach may be to design a dynamic and adaptive programme in stages. For example, in a first phase of the programme no information would be provided about prospective PES or other similar incentives, but rather would focus on proven benefits of the practice, so that mostly pioneers would volunteer to participate in the programme. In a second phase, payments might be introduced for participants who entered in the first experimental phase. In a third phase, and if necessary to accelerate the participation of late adopters, payments may be introduced for all. This dynamic approach, which adapts a programme in stages to the roles based on diffusion, complements the recognised need for PES to be adaptive to evolving biophysical and socio-economic conditions, as well as flexible towards changing markets (Pascual et al., 2014). For example, a differential payment throughout time has been found to be the most cost-effective method for reducing sedimentation by combining SPS in cattle-farming (in an optimisation model simulated with data from Colombia) (Roldán Vásquez, 2008). It has also been suggested that a first phase to create an appropriate "context conducive to conservation" followed by a second phase with payments, may avoid destabilising social norms, therefore increasing success (Cranford and Mourato, 2011, p.89).

The results from the model of adoption have additional relevant implications for programme design. They remind us that participation on its own is insufficient for effectiveness, and that distinguishing participation from adoption can reveal what hinders people with diversified livelihoods from adoption. For some, it might be the lack of time, for others, the lack of genuine interest. These individuals could become the pioneers who attract others, and policy can be targeted towards them, inclusive of measures to help them address hindrances specific to their diversified livelihood. A programme needs to anticipate important hurdles to be encountered and help participants in handling them. If these obstacles can hardly be reduced, then the emphasis might turn to increase the participation of individuals who are less likely to participate, but who would perform better if they entered the programme.

10.3. Research contributions of the thesis

The dissertation contributes to fill an important gap in the evaluation of programmes to coax active reforestation by focusing on two aspects—livelihoods and perspectives—which have received little attention in the evaluation literature, but are strongly emphasised in the development and psychology literatures respectively. It also concentrates on an often underestimated type of forest dynamic: diffuse, small-scale degradation and deforestation. Agents responsible for this deforestation are argued to be less driven by purely rational motives (Geist and Lambin, 2001). Thus this research takes an approach to uncover heterogeneity of motivations for participating and performing in programmes for active reforestation in these contexts.

Silvopasture is presented as a promising agroecological system to conciliate livelihoods and conservation in areas of high preference for cattle-farming, but the understanding of its adoption processes is scant (Dagang and Nair, 2003). This research empirically and quantitatively analyses the outcomes of a pilot project to encourage silvopasture among smallholders. Thus, this thesis contributes to the scarce pool of studies doing so (e.g. Calle et al., 2013; Jera and Ajayi, 2008), and improves these studies by considering adoption as a process composed of a number of steps, by including internal (subjective) variables in the analysis, and by fully integrating livelihoods in its modelling. These contributions are also novel in the broader (and much more abundant) literature on factors influencing agroforestry adoption (Pattanayak et al., 2003). The study is also innovative in fully embracing the theoretical literature of inducers of PEB (e.g. Osbaldiston and Schott, 2012; Steg et al., 2014), mostly derived from psychology, and applying it to the study of adoption of sustainable land-use practices. Last but not least, by questioning the forms of incentives, the thesis contributes to the ongoing discussion about the suitability and effectiveness of PES, which are the type of incentives receiving most attention in recent years (Swallow et al., 2009) in environmental policy.

Overall, this thesis has four main original contributions to knowledge, of empirical, theoretical, and methodological natures. These are highlighted in order of importance.

First, the empirical analysis of perspectives about incentives and adoption of SPS yields new insights into what motivates farmers to adopt sustainable and innovative practices. The role and distinctive motivations of pioneers in the adoption process is emphasised and discussed in detail, and this has direct implications for policy design in terms of targeting and adaptation of incentives. By incorporating such heterogeneous motivations, the theory of diffusion, typically assumed to require that the innovation is more profitable, can also be applied to PEB, in which the importance given to economic profitability might not be superior and may be accompanied by other motives. The approach in this research is novel in using diffusion of innovations to find that focusing on pioneers can be a cost-effective way for policies to encourage PEB. The key messages may be applied to PEB more broadly, and therefore they are of interest for researchers in other topics within sustainability studies, such as agroecological practices in developed countries, or energy-efficient behaviour.

Second, the analysis of both participation and adoption—focused on livelihood strategies—reveals how the two decisions are clearly separate and influenced by predictors differently. This empirical regression model is the first to fully integrate livelihoods and livelihood diversity into decisions for adoption, and one of the few that explains adoption as a process. Results suggest the need to preview hurdles that individuals who are more likely to participate—with diverse livelihood—encounter once they are experimenting. The case also indicates that those who are less likely to participate may encounter fewer obstacles for implementation. Hence the emphasis could be on getting them to try in the first instance. This contribution is complemented with an original and time-efficient approach to collect data, based on board and tokens and inspired by natural resource management research employing role-playing games.

Third, the meta-analysis of literature on adoption of silvopasture and agroforestry is the first one focused on SPS. It is unprecedented among reviews of agroforestry and sustainable agricultural innovation because it integrates regression studies, qualitative and other quantitative studies, and reviews in a systematic manner, by quantifying the frequency of predictors in all three types of publications. Former reviews focus either on quantitative studies only, or review the literature in a purely qualitative manner. It is also unique because it balances the focus between internal and external variables, whereas in former reviews the external aspect was largely predominant. The synthesis (the factors in Figure 3.2, p.80) can be readily transposed into a practical check-list for practitioners to assess *ex-ante* whether the preconditions in a given context are favourable, and to quickly identify what factors are likely to become barriers.

Fourth, the methodological innovation for Q analysis is the first one proposed to improve Q results since the current standard analysis was described in the early 1980s. The integration of internal variables in quantitative studies is less frequent, plausibly due to difficulties in their operationalisation. Q methodology emerges as a suitable approach for such integration. Despite its increasing use, it is still a marginal, perhaps considered too subjective, methodology. In order to facilitate a more robust inclusion of internal variables in PEB research, I develop an analytical innovation that provides more detailed results, which contribute to enhance their interpretation and defence. The improvement brings recent advances of statistics into the Q analytical process, in order to increase the understanding and reliability of results. To implement bootstrapping in Q, I make an additional contribution to research by coding and publishing an open source package to perform Q analysis in R statistical software (R Core Team, 2015), and developing additional useful features unprecedented in previous software (Zabala, 2014a). This new scientific software has a number of contributions (Zabala, 2014b)—remarkably, making the analysis more transparent, flexible, and cross-platform—and has already attracted collaborators and interest among Q practitioners.

In addition, the cluster analysis of livelihood strategies proves useful for developing programmes aimed at encouraging sustainable livelihoods. I argue that livelihoods can be studied in a generalisable manner by structuring the analysis in terms of degrees of specialisation and diversification, of the balance between land-based and off-farm activities, and visualising them through ternary plots. This approach could be used to compare strategies across sites and countries, throughout historical trajectories (as exposed in Chapter 4), or to forecast policy scenarios.

10.4. Limitations, caveats, and future research

Finally, an outline of limitations of these findings and of the research forward is due. These limitations refer to each of the four main contributions indicated above.

The limitations of the empirical results relate to typical limitations of field economic and psychological data. Great effort was put in the sampling approaches and in minimising biases in the responses, but a residual error may still remain. Also, the sample of the livelihood data is sufficient for the conclusions drawn, but a larger sample would provide clearer results about the influence of predictors that may have a smaller effect, such as each type of subsidy. The typology identified through Q method, its relation to innovation, and predisposition towards payments may be further studied and confirmed by extending the sample to other populations and environmental topics, and by refining the set of statements to focus on finding more precise information about these topics. The Q-sorting may also be extended to non-participants, in order to better understand what hinders adoption.

The literature review of SPS adoption is based on 72 studies, which includes all studies on SPS adoption and a purposive sample of oher agroforestry and sustainable agricultural innovation studies, as explained in Chapter 3. The selection criteria do not allow us to draw statistically significant conclusions about the 'population' of predictors discussed in the literature. These criteria are deeply conditioned by the characteristics of this body of studies, which is highly heterogeneous in terms of inclusion and measurement of outcomes and predictors, therefore hindering the possibility of more rigorous statistical meta-analysis. Notwithstanding, this review maps out a synthetic and uniquely inclusive overview of predictors, which can help practitioners to understand the key aspects to consider when designing and implementing policies aimed at encouraging PEB.

The bootstrap in Q methodology is a sophisticated—although mathematically simple—way to improve the information reported in the results. In many cases, it may not actually provide notably different results, but just more precise ones. Its implementation draws on literature from Q and from broader social, statistical, and natural sciences in which PCA bootstrapping has been implemented on occasion. In order for the full details to be understood, this exercise is theoretically demanding; it requires sufficient knowledge of the analytical process in Q, of PCA, of bootstrap, and of bootstrapping PCA. Relatively few scientists may be found with this background. This means that the concept of bootstrapping Q can be challenging for many Q practitioners, and that the considerations discussed in Section 7.3 may be only slowly debated in the near future. The essence of bootstrapping is rather simple; repeating the analysis recursively with slightly different samples each time, and calculating centrality and spread values out of the cumulative results from all repetitions. This simplicity, and the tools I provide—the R package (Zabala, 2014a)—should make bootstrapping Q accessible for any interested researcher.

Additional studies may be needed to fully understand the impact of livelihood strategies—specialisation and diversity—on adoption of innovative sustainable land-use practices. The same asset-allocation survey approach can be used in other contexts, and contrasted to data on participation and adoption of such practices after external interventions. Remarkably, analysing the impact of subsidies on adoption did not yield significant results, and this is possibly due to the distinct nature of the subsidies studied. Further sampling may therefore be needed to understand the effect and interaction of such a variety of subsidies. The hypothesis to test would be that the success or failure of PES is strongly conditioned by the set of other, non-environmental subsidies to which recipients have access.

Further lines of enquiry are identified, each with their own merits. The first two are directly tied to alternative methodologies. The last ones refer to specific niches that can shed instrumental knowledge about what motivates adoption.

First, simulation and modelling can aid the understanding of the aggregate effects of heterogeneity on land use. The combined information about farmers presented here may form a solid basis to define agents in a multi-agent based model such as that proposed by Valbuena et al. (2008), who consider five agents according to their attitudes and farm characteristics. Such a simulation could provide insights on the rates and impact of diffusion of SPS on land use, over different initial distributions of types of incentives.

Second, on value and motivational heterogeneity, quantifying how each internal motivation influences decisions can help to discern to what extent cost benefit considerations are important, or how this importance varies across individuals. A point of departure are the goals identified by Steg and her team (2014) (see Figure 2.2, p.60). Quantifying the relative weight of these goals upon different PEB and across individuals can help more precise selection of the form of incentive. This quantification may be done appropriately by choosing from the wide range of experimental methods available.

Very closely related to the above quantification, a third line of enquiry that derives directly from the literature review and the case study refers to the potential mismatch between types of external incentives and motivations, and to the distinctive impact of rewards and PES on adoption and, particularly, on long-term adoption of sustainable practices. The hypothesis is that the form of reward affects the effectiveness and continuation of a programme in encouraging sustainable practices. A mismatch between incentives and motivations this might explain potential counterproductive effects such as crowding-out intrinsic motivations for conservation (Bowles, 2008). There is little quantitative evidence to this regard, on which experimental and field-experimental studies can shed valuable light. For instance, by testing whether PES crowd-out intrinsic motivations for conservation and if so, under what conditions, or alternatively, whether non-monetary rewards reinforce these motivations.

Fourth, as identified in Part I, the flow of knowledge and social networks can be important factors influencing adoption (Lokhorst et al., 2011; van der Horst, 2011). These aspects are left out of this study for they demand a rather different empirical approach in terms of methods and data requirements, in contrast to the focus on an individual's decision processes. However, their understanding may shed fruitful insight, particularly under the umbrella of diffusion theory and to understand adoption processes at larger scales. New lines of enquiry are needed to better understand the distinctive mechanisms of diffusion of PEB and the ways to enhance the role of networks in this diffusion (Frey et al., 2012; Rico García-Amado et al., 2012).

Fifth, if the aim is to encourage long-term continuance, analysing what drove previous adopters to discontinue can give key insights about adoption hindrances. Only one such study is found in the literature reviewed (Mekoya et al., 2007). Notwithstanding the difficulties of researching disadopters, they can provide information that may be highly valuable for improvement. Perhaps one main idea derived from this study of motivations, and particularly from the clustering of livelihood strategies, is that what really matters might be what barriers are found at each stage of the process of adoption. Indeed, as suggested by Kollmus and Agyeman (2002), there are a large number of factors that motivate decisions for PEB, but their influence has to overcome numerous filters posed by barriers. A person may have a moderate degree of motivation, of attitude, of knowledge, and of moral drive (and I would argue that the large majority of people do have these to different degrees), but when putting thoughts into actions, the barriers are decisive. In such situations, additional incentives are key. Therefore, finding what considerations led disadopters to stop the activity seems logically necessary to be able to identify how to encourage long-term adoption. In turn, knowing what these obstacles are may be critical to envision whether the incentives considered (in this case, PES) will hit the bullseye.

Finally, one may heed other patterns of deforestation (Geist and Lambin, 2001; Hansen et al., 2013). Investigating the specific drivers behind each pattern, what are the agent's motivations across patterns, and the policy instruments that could trigger transitions to sustainable social-ecological systems for each type of pattern, presents a field of enquiry that can help researchers support the effective implementation of solutions that lead to the conservation of the world's remaining biodiversity.

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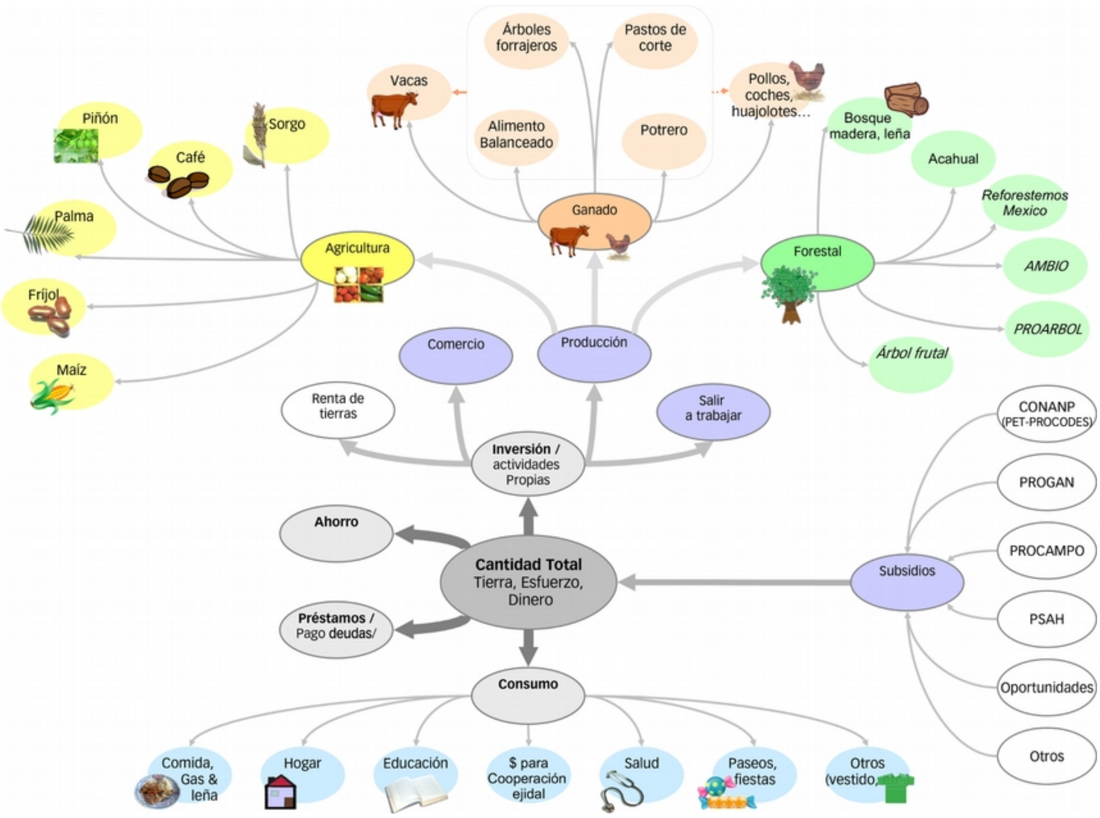
Appendix

Figure A1: Diagram of the peasant economy as represented in the data collection board, and example of responded board..314
Figure A2: Livelihood questionnaire protocol..315
Figure A3: Livelihood questionnaire...316
Table A1: Bootstrapped factor loadings and flagged Q-sorts..................................318
Table A2: Full Q methodology bootstrap results for statements..............................319

Figure A1: Diagram of the peasant economy as represented in the data collection board, and example of responded board



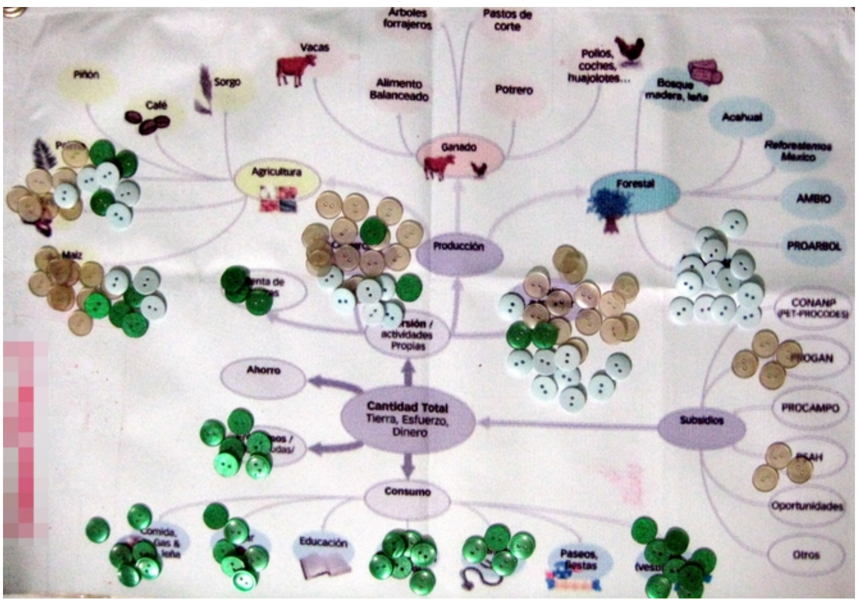


Figure A2: Livelihood questionnaire protocol

Encuesta

Presentación

- Soy (...), compañera de la gente de ECOSUR
- Estamos haciendo un estudio de cuáles son las estrategias de vida de la gente en el ejido: cómo deciden distribuir sus acervos y qué alternativas existen, para que los futuros programas de conservación que se elaboren desde las distintas instituciones se adapten mejor a sus necesidades y a su modo de vida
- No le voy a preguntar cuánto gana, o cuántas vacas tiene, solamente quiero saber cómo distribuye sus acervos y se lo preguntaré mediante una especie de juego
- Toda la información recogida será confidencial y no será reportada a terceras entidades sin su permiso previo
- Puede parar en cualquier momento si se aburre o no quiere seguir

Parte II: Distribución Acervos

1. Descripción resumida del juego

- Hemos intentado representar la economía de la gente de Los Ángeles: qué actividades se llevan a cabo para sacar el sustento
- Este diagrama muestra, desde el centro hacia las esquinas, cómo distribuye usted su dinero, tierras, esfuerzo
- Usted tendrá cincuenta botones que representan, por ejemplo, el dinero que gastó en el último año *[mostrar montón]*
- El juego consiste en que vaya distribuyendo, paso por paso, los botones *[mostrar distribución]*. Poco a poco y según le vaya explicando, distribuye los botones colocados en cada actividad entre las actividades que la componen, de modo que lo que está en el paso anterior, quede completamente distribuido entre las actividades del paso siguiente
- Haremos así con botones que corresponden a esfuerzo, tierras, dinero invertido y ganado y tierras
- Responda sobre lo que usted considere que ocurrió, refiriéndose al último año, de Mayo 2009 a Mayo 2010

2. Procedimiento

1. **Esfuerzo**
   1. Producción propia (<u>subdividir</u>)
   2. Subsidios (<u>subdividir</u>)

Q6. ¿Quiénes deciden qué se hace con la tierra?

2. **Tierras** (¿hectáreas o botones?)
   1. Rentar tierras
   2. Agricultura (<u>subdividir</u>)
   3. Ganadería (<u>subdividir</u>)
   4. Forestal (<u>subdividir</u>)
3. **Origen** del dinero
   1. Subsidios (<u>subdividir</u>)
   2. Ahorro
   3. Préstamos
   4. Inversión (<u>subdividir</u>)

(SACAR FOTOGRAFÍA)

4. **Gastos**
   1. Consumo (<u>subdividir</u>)
   2. Ahorro
   3. Deudas
   4. Inversión (<u>subdividir</u>)
5. **Beneficios** de las Actividades Propias
   1. Comercio
   2. Producción (cada una de las actividades)
   3. Jornal

(SACAR FOTOGRAFÍA)

Parte III: Cuestiones Cualitativas sobre el tablero

Parte IV y V: Datos Demográficos y Económicos

- Por último, quisiera preguntarle unos detalles sobre su hogar
- Gracias por participar. Una vez hayamos analizado, le comunicaremos los resultados

Figure A3: Livelihood questionnaire

Parte I: Información general

Hora ....a........... Fecha....../....../2010

1

Código..Núm. foto..................... Entrevistadora..................
Casa / calle.. 1.[ ] aislada; 2.[ ] 2º piso;
Responde..Género F / M........... Edad..............................

Parte II: Distribución Acervos

Parte IV: Datos demográficos

Q1. ¿Cuánta gente pertenece a su hogar?

Indiv.	**Total** *(edades)*		**Trabajando** **Q2. ¿Qué empleo?** *(escribir)* **Q3. ¿Vive fuera?** *(cód. Q3)*		**Estudiando** *(tick ✓)*		Nivel de **Estudios** *(código Q4)*		**Cabeza** de familia *(tick ✓)*	
	Fem	Masc	Fem	Masc	Fem	Masc	Fem	Masc	Fem	Masc
A										
B										
C										
D										

Códigos:

Q3. Migrantes **M** – municipal ; **E** – estatal ; **N** – nacional ; **I** - internacional

Q4. Nivel de estudios **0** – Ninguno ; **1** – Primaria ; **2** – Secundaria ; **3** – Estudios Superiores ; **4** – Otros

(3) Estudios superiores..

(4) Cursos de capacitación..

Q5. ¿Cuál es su posición en el ejido?
1. ( ) Ejidatario básico / pleno derecho
2. ( ) Ejidatario poblador
3. ( ) Avecindado
4. ( ) Otro ………………

Q6. ¿Quiénes deciden qué se hace con la tierra?
1. ( ) Cabeza de familia
2. ( ) Cabeza de familia e hijos
3. ( ) Cabeza de familia y cónyuge
4. ( ) Otro ………………

Q7. ¿Cuántos años lleva con el ganado?.................

Parte V: Datos económicos

Q8. Características de la casa; ( )En propiedad; ( )Rentada; ( )Prestada

Muros	**Tejado**	**Suelo**	**Ventanas**	**Energía**
1. madera	1. teja	1. madera	1. cristal	1. madera
2. ladrillo	2. metal / lámina galvanizada	2. loseta	2. plástico	2. gas
3. tabicón	3. losa / concreto	3. tierra	3. nada	3. electricidad
4. adobe	4. otros.................	4. cemento	4. otros................	4. otros...............
5. otros..............		5. otros..............		

Q9. Nivel de ingresos económicos anuales
1. ( ) < $5000
2. ( ) $5000 - 15000
3. ( ) $15000 - 30000
4. ( ) > $30000

Q10. ¿Cuántas hectáreas posee?
1. ( ) Ninguna
2. ( ) <20 ha
3. ( ) 20-50 ha
4. ( ) >50 ha

Parte III: Cuestionario cualitativo

Q11. Viendo sus recursos distribuidos en el tablero ¿Podría describirme su estrategia?

Q12. ¿Porqué decidió distribuirlo así?

Q13. ¿Cómo cambiaría la distribución para mejorar? *¿En qué podría apostarle?*

Q14. Si tuviera 10 botones más de ingresos, ¿Dónde los colocaría? (FOTO O ANOTAR)

Q15. ¿Qué actividades implican más riesgo? ¿Qué riesgo(s)?

Q16. ¿Cómo le fue el trabajo plantando árboles forrajeros?

1( ) Muy mal	2( ) Mal	3( ) Regular	4( ) Bien	5( ) Muy bien

Q17. Viendo el tablero ¿Cómo lo explicaría?

Q18. ¿Le gustaría plantar más árboles forrajeros en sus terrenos?

1( ) No me interesa	2( ) Indiferente	3( ) Me interesa	4( ) Me interesa mucho

Q19. ¿Le requiere mucho esfuerzo? ¿Cómo de difícil es para usted?

1( ) Muy difícil	2( ) Difícil	3( ) Regular	4( ) Fácil	5( ) Muy fácil

Q20. ¿Qué es lo que le limita?

1. ( ) Terreno
2. ( ) Dinero
3. ( ) Información
4. ( ) Material
5. ( ) Horas de trabajo
6. ( ) Otros............

Q21. Al plantar árboles forrajeros ¿Cuánto tiempo tardarían en darle beneficio?

Q22. ¿Cómo de probable es que den beneficios?

1( ) Muy improbable	2( ) Improbable	3( ) No lo sé	4( ) Probable	5( ) Muy probable

Q23. ¿Cuánto beneficio le dará? (Coloque botones en el tablero) (SACAR FOTO)

Q24. ¿Añadiría alguna otra tarea que falte en el tablero?

Q25. ¿Qué otras alternativas de sustento podría llevar a cabo?

Table A1: Bootstrapped factor loadings and flagged Q-sorts

Respondent	Self-sufficient		Environmentalist		Payment-dependent	
S01	–.16 (.23)		–.12 (.21)		.45 (.23)	*
S02	–.11 (.16)		.32 (.19)		.39 (.25)	*
S03	.10 (.14)		.08 (.16)		.58 (.21)	*
S04	.23 (.18)		.54 (.20)	*	.36 (.28)	
S05	.64 (.17)	*	.20 (.19)		.18 (.24)	
S06	.12 (.18)		.02 (.20)		.70 (.19)	*
S07	.50 (.28)	*	–.04 (.21)		.35 (.23)	
S08	.66 (.20)	*	.19 (.19)		.35 (.25)	
S09	.22 (.17)		.52 (.21)	*	.35 (.26)	
S10	.41 (.19)		.30 (.21)		.36 (.29)	
S11	.70 (.18)	*	.28 (.21)		.34 (.25)	
S12	.29 (.17)		.29 (.18)		.42 (.25)	*
S13	.32 (.21)		.14 (.19)		.63 (.21)	*
S14	.69 (.17)	*	.08 (.18)		–.02 (.23)	
S15	.60 (.18)	*	.20 (.20)		–.02 (.21)	
S16	.54 (.18)	*	.25 (.18)		.11 (.24)	
S17	.08 (.18)		.24 (.22)		.47 (.27)	*
S18	.29 (.16)		.60 (.22)	*	–.03 (.16)	
S19	.52 (.19)		.47 (.21)		.24 (.21)	
S20	.15 (.16)		.62 (.20)	*	.13 (.15)	
S21	.43 (.17)		.50 (.20)	*	.25 (.22)	
S22	.30 (.20)		.57 (.21)	*	.07 (.22)	
S23	.59 (.20)	*	.22 (.20)		.06 (.19)	
S25	.35 (.18)		.37 (.21)		.37 (.24)	
S26	.49 (.24)	*	.25 (.25)		–.06 (.26)	
S27	.61 (.16)	*	.44 (.17)		.00 (.24)	
S28	.43 (.19)		.45 (.21)		.21 (.18)	
S29	.73 (.17)	*	.23 (.21)		.08 (.22)	
S30	.38 (.16)		.67 (.20)	*	.04 (.18)	
S31	.39 (.26)	*	.14 (.29)		.05 (.31)	
S32	.00 (.12)		.60 (.22)	*	.01 (.17)	
S33	.42 (.16)	*	.34 (.18)		.20 (.22)	

*Values in parenthesis are the SE of factor loadings. * defining (flagged) respondents.*

Table A2: Full Q methodology bootstrap results for statements

Statement	Bootstrap z-scores (*SD*)			Standard z-scores			Bootstrap factor scores			Standard factor scores		
	F1	F2	F3	F1	F2	F3	F1	F2	F3	F1	F2	F3
15	-1.56 (0.44)	0.74 (0.81)	0.82 (0.74)	-1.83	1.04	1.01	-2	2	2	-2	2	2
21	-1.60 (0.61)	-1.81 (0.57)	-0.12 (1.12)	-1.90	-2.23	-0.13	-3	-3	0	-3	-3	0
12	0.01 (0.48)	0.73 (0.57)	-1.06 (0.66)	-0.20	0.99	-1.71	0	2	-3	0	2	-3
17	0.15 (0.65)	0.72 (0.51)	-0.75 (0.59)	-0.04	1.03	-1.10	0	1	-2	0	**2**	-2
6	0.27 (0.46)	-0.68 (0.74)	0.53 (0.73)	0.24	-1.06	0.92	0	-1	1	0	**-2**	1
18	-0.51 (0.64)	-0.98 (0.80)	0.14 (0.53)	-0.66	-1.10	0.38	-1	-2	0	-1	-2	**1**
20	0.52 (0.31)	0.22 (0.35)	-0.54 (0.37)	0.58	0.18	-0.87	1	0	-1	1	0	-1
22	0.53 (0.47)	-0.03 (0.43)	-0.47 (0.47)	0.54	-0.04	-0.68	1	0	-1	1	0	-1
4	0.65 (0.42)	0.08 (0.59)	-0.34 (0.57)	0.91	0.05	-0.80	2	0	-1	**1**	0	-1
8	-0.27 (0.45)	-1.09 (0.61)	-0.20 (0.66)	-0.41	-1.65	0.14	-1	-2	0	-1	**-3**	0
1	0.15 (0.60)	0.35 (0.80)	1.07 (0.68)	0.31	0.59	1.73	0	0	3	0	**1**	3
11	0.59 (0.64)	0.73 (0.56)	-0.09 (0.55)	0.69	0.95	-0.22	1	1	0	1	1	0
2	0.57 (0.72)	-0.27 (0.36)	0.07 (0.55)	0.94	-0.45	-0.04	1	-1	0	**2**	-1	0
13	-0.46 (0.37)	0.20 (0.51)	0.17 (0.61)	-0.41	0.41	0.15	-1	0	1	-1	0	0
26	-0.95 (0.43)	-0.26 (0.88)	-0.69 (0.70)	-1.17	-0.25	-0.70	-2	-1	-1	-2	-1	-1
16	0.34 (0.53)	0.76 (0.78)	0.08 (0.90)	0.40	0.87	0.23	0	2	0	**1**	**1**	0
23	-1.65 (0.53)	-1.17 (0.62)	-1.01 (0.80)	-1.93	-1.50	-1.42	-3	-3	-3	-3	**-2**	**-2**
24	0.78 (0.47)	0.73 (0.61)	1.32 (0.86)	0.96	0.88	1.91	2	1	3	2	1	3
19	1.11 (0.59)	0.46 (0.49)	0.76 (0.81)	1.21	0.22	0.85	2	1	1	2	**0**	1
7	-0.56 (0.38)	-0.64 (0.53)	-1.01 (0.64)	-0.64	-0.90	-1.45	-1	-1	-2	-1	-1	**-3**
9	1.46 (0.61)	1.29 (0.91)	1.01 (0.82)	1.69	1.69	1.27	3	3	2	3	3	2
10	1.19 (0.62)	0.79 (0.71)	0.90 (0.70)	1.53	1.10	1.34	3	3	2	3	3	2
3	0.06 (0.71)	-0.15 (0.69)	0.19 (0.78)	0.16	0.01	0.29	0	0	1	0	0	1
5	-0.56 (0.38)	-0.37 (0.60)	-0.49 (0.65)	-0.61	-0.46	-0.61	-1	-1	-1	-1	-1	-1
14	-0.68 (0.43)	-0.77 (0.42)	-0.72 (0.68)	-0.71	-0.94	-0.93	-2	-2	-2	-2	**-1**	-2
25	0.42 (0.55)	0.43 (0.46)	0.42 (0.64)	0.35	0.55	0.44	1	1	1	**0**	1	1

In the standard factor scores, numbers in bold indicate differences with respect to the bootstrap results.