Understanding the Role of Livelihoods in the Adoption of Silvopasture in the Tropical Forest Frontier

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Abstract

The land use in the frontier of tropical forests has an important role of buffering the ecosystem and avoiding further degradation. In this frontier, extensive cattle-farming in mountainous pasture-land entails a high risk of soil erosion and biodiversity loss. This is the case in many tropical forests and the extents of the process may expand with the fragmentation of forests that causes that the perimeter of buffer zones multiplies. Silvopastoral systems are a type of agroforestry that is a compromise between cattle-farming and the buffer function of a frontier ecosystem. Despite many projects to encourage its implementation, including payments for ecosystem services, its adoption is slow. Despite being abundantly studied, there is no general consensus on the most relevant predictors for the adoption of agroforestry because, among other reasons, the type of agroforestry practice has an important influence. There are few studies that analyse silvopasture adoption, and very few which model the level of adoption beyond the commonly used binomial variable of adoption and non-adoption. In this paper, we model the participation and the short term adoption of silvopastoral systems in the context of a pilot project for planting fodder trees in the frontier area of a protected forest in Chiapas, Mexico. We gather cross-sectional data from 103 households about demography, income levels and livelihood strategies. We use secondary data about the level of adoption. We use a Heckman selection model to model both the participation and the level of adoption. The variables that influence participation in the program are different from the variables influencing the success in the activities encouraged by the program. Results also show that livelihood strategies are significant to predict participation and level of adoption, although the direction of their effect may be different for each. This has relevant implications for the design and targeting of programs for conservation in the context of development. *Keywords:* adoption, livelihoods, forest degradation, silvopastoral systems Heckman selection model

JEL codes: **D13** Household Production and Intrahousehold Allocation, **Q12** Micro Analysis of Farm Firms, Farm Households, and Farm Input Markets, **Q16** R&D; Agricultural Technology; Agricultural Extension Services, **Q23** Forestry, **Q57** Ecological Economics: Ecosystem Services; Biodiversity Conservation; Bioeconomics; Industrial Ecology

1. Introduction

The land use in the frontier of biodiversity rich tropical forests has an important role in buffering the ecosystem and avoiding further degradation. In this frontier, extensive cattle-farming uses in mountainous pasture-land entail a high risk of soil erosion and biodiversity loss. Deforested soils in steep areas degrade under the strong rainfall in wet season and compact under grazing (Valdivieso-Pérez et al., 2012). This affects the ecosystem functions, including its buffering capability and increases the likelihood of severe perturbations such as floods and landslides (Chomitz and Kumari, 1998; Napier, 1991; Richter, 2000). In the medium term this increases the risk of degradation of the inner forest.

As an alternative, silvopasture is a specific type of agroforestry that is an adequate compromise between conservation objectives and livelihoods in small-scale cattle-farming based social-ecological systems (F. Cubbage et al., 2012; Dagang and P. K. R. Nair, 2003). It consists in planting fodder trees at low to medium density in pasture. It has the double benefit of providing extra protein for cattle also in dry season; and of retaining soil. In contrast, it takes about 2-5 years for trees to grow, in which cows need to be excluded from the plot; and feeding benefits from fodder trees might not be perceived as high as the opportunity cost of pasture. To avoid forest and soil degradation and to rehabilitate landscape in the tropics while allowing sustainable livelihoods, many decentralized projects for the adoption of agroforestry systems are increasingly being implemented. Despite many projects to encourage its implementation, including payments for ecosystem services, its adoption is slower than that expected from the economic and environmental performance assessments of SPS (F. Cubbage et al., 2012; G. E. Frey et al., 2012; Gutiérrez et al., 2008). SPS also have an important potential for carbon sequestration (Holderieath et al., 2012; F Montagnini and P. Nair, 2004).

Several studies model the adoption of agroforestry. There are few studies that analyse silvopasture adoption, and very few which model the level of adoption beyond the commonly used binomial variable of adoption and non-adoption. Few studies investigate the relationship between livelihood strategies of potential adopters and adoption and we argue that these are important.

In this paper, we model the participation and the short term adoption of silvopastoral systems in the context of a pilot project for planting fodder trees in the frontier area of a protected tropical forest in Chiapas, Mexico, where intensive cattle and farming land uses in the buffer area are an increasing threat. We aim to understand: (a) Why some farmers had higher success in the survival percentage of planted trees in comparison to others?, (b) How do livelihood strategies affect participation and the level of adoption?, and (c) What strategies are related to higher levels of involvement?

In 2007, a local research centre implemented a pilot program for farmers to experiment silvopasture. Sixty eight farmers participated, and their level of adoption was measured. Yet fodder tree implementation projects in the area have had varied success in involving participants, and tree restoration results are poor to date (Trujillo-Vásquez 2009). We gather data from 103 households about demography, income levels and livelihood strategies in the ejido of Los Angeles in La Sepultura Biosphere Reserve (REBISE). We model participation and adoption of silvopasture by means of a Heckman selection model, focusing on the share of subsidies and livelihood strategies as predictors.

The paper continues with a literature review of adoption studies, and a description of the project of study. Section four summarizes the data gathering process, followed by the model analysis. The final section discusses the implications of these results for program design and concludes.

2. Literature review

Decision-making in social-ecological systems is complex and understanding what factors underlie these decisions is key to design effective and efficient conservation policies (Common and Stagl, 2005). When considering whether to adopt sustainable practices, farmers confront a trade-off with various other livelihood activities to which they often give preference when deciding how to administer their effort and land. Prioritising the short term benefit over the long term benefit arguably entails less adoption and continuance of sustainable practices. No perceived benefits and opposing macroeconomic factors interfere with the motivation of farmers to try and adopt practices with high environmental gains in the long term, economic gains in the medium term, but an economic sacrifice in the short term. This is a common pattern hindering environmentally sound practices worldwide.

The literature on adoption of agroforestry practices mostly focuses on explicitly measurable farm, household and personal characteristics amenable to adoption probability analysis (Pattanayak et al., 2003). There is little investigation on the adoption of silvopastoral systems in particular (Jera and Ajayi, 2008; Pagiola et al., 2008, 2007), albeit adoption is identified as a research priority (Dagang and P. K. R. Nair, 2003), and few qualitative articles have analysed the adoption of silvopasture beyond observable characteristics (Calle et al., 2009; G. E. Frey et al., 2012; Hayes, 2012). There is no general consensus on the most relevant predictors because, among other reasons, the type of agroforestry practice is very variable and it has an important influence.

2.1. Mapping independent variables from adoption literature

A survey of 68 published empirical and review papers is done to build an inventory of the main variables used to predict adoption in agroforestry studies. Adoption is generally measured as a dichotomous dependent variable of adoption or non-adoption. A richer measure of rate and levels of adoption, either in the form of continuous numerical or of ordered categorical variables is recommended, but less used in empirical analyses. Whether the adopted activity is continued over time or either unadopted is also another important object of study, although it requires time series data which is very infrequent in studies of this type.

More than sixty independent variables have been identified in agroforestry adoption literature. These are mapped and grouped in eight main clusters (Figure 1), resulting in a comprehensive inventory of variables and theories used to explain adoption of agroforestry practices, and of silvopastoral systems in particular. The clusters are: personal characteristics (objective characteristics, and personality and attitudinal characteristics); household characteristics; farm characteristics; economic considerations and context; knowledge; institutions; social context; and perception of the technology. In a few studies surveyed, the factors were very contextual dependent for them to extrapolate to other studies (f.ex. Perz 2003). These are usually factors related with personal life cycles, such as where the head of household was born, how long he has lived in his current location, etc. Therefore they were excluded from this review.

[Figure 1 Groups of independent variables in adoption literature]

Variables related to the economy are divided into economic context and cost-benefit analysis of the practice. The former include access to credit; access to market; and increases in product demand. The latter include cost; amortization time; opportunity cost from time lags; comparative productive advantage with respect to the activity which will be superseded; and whether there are economic incentives (subsidies or payments). Farm characteristics are divided into biophysical; livelihood strategy; and farm life cycle and experience. Usually considered biophysical variables are mainly related to land and soil quality (hectares under cultivation, land pressure and shortage, quantity of already cleared land, topography, soil quality and extent of erosion intensity); and spatial variables (farm area/ scale of farm, access by road, distance of plot to home). Farm livelihood strategy characteristics include, from broad to specific: level of household pluriactivity (total diversity); dependence on on-farm income (or similar measures such as ratio of dependence of off-farm/ on-farm); crop diversity; main type of farming; major crops; importance of livestock as a source of income; and livestock herd size and livestock land intensity ratio. Psychological, cognitive and motivational variables are excluded from this study for their measure is not unequivocal, since it requires using abstract constructs in psychological tests, or either that the individual itself performs as the measurement instrument by expressing how she thinks she is. Both features of using psychological variables are source of much uncertainty in empirical research implementation.

2.2. The influence of external payments

The interaction effect of other types of external payments and subsidies for different purposes in the effectiveness of direct payments for conservation has been also scarcely investigated. programs with different goals may generate counteracting stimulus and the diversity of recipients' responses may result in highly complex decision contexts, and there are various plausible views on it. Some argue that non-conservation, external payments for off-farm development promote more forested land, because they allow peasants to cover their expenses without needing to work on their lands (Isaac-Márquez et al. 2005). Yet programs for farming intensification may diminish the relevance of conservation payments in household decision-making, in contexts where the farming development budget is much larger than that of conservation. A plurality of external income sources may also be seen as a reason not to act towards the conservation of their land. This may encourage farmers to stop perceiving that they will need to rely on the health of the soil for their future livelihood. The hypothesis is that easy access to external income may be seen as a reason not to act towards the conservation of their land because people might not perceive their close environment as such an essential asset for their livelihood, and therefore they might not adopt conservation practices.

3. Case study: adoption of silvopastoral practices in la Sepultura Biosphere Reserve

The tropical regions in Latin America are a major focus for PES and agroforestry programs and it is previewed that PES and other voluntary programs may be the main form of intervention for conservation in the following decade. Among those regions with endangered forests, Chiapas has suffered some of the highest rates of deforestation and there is little evidence of a forest transition leading to forest recovery (García-Barrios et al., 2009). This is due, among other reasons, to the lack of employment in urban areas that were formerly a migrant destination, to the diversity of external payments that reduce the need for urban migration and to the strong livelihood preference towards cattle-farming.

La Sepultura is a Biosphere Reserve in the Sierra Madre in the Pacific side of Chiapas, Mexico between 40 to 2550m asl (Figure 2). It covers a wide range of ecosystems, including tropical montane cloud forest which provides essential hydrological services, and which is the most threatened ecosystem in Mexico (CONABIO, 2010). In the buffer zone of the reserve, the lower areas and South oriented slopes are highly deforested. The surroundings of the human settlements are highly anthropized and the landscape is degraded due to farming and cattle-farming activities. Farming land faces an increasing risk of soil erosion (Valdivieso et al., 2012). Predominant livelihood activities include the production of maize and beans, cattle-farming, and shade coffee farming.

[Figure 2 Location and zonification of La Sepultura Biosphere Reserve in Chiapas, Mexico (167,310ha). Source: CONANP (2006) and OSM]

Among the various small communities (*ejidos*) in the buffer area, Los Angeles is a representative one with a population of 831 people (Trujillo-Vázquez, 2009) distributed in approximately 200 households. The community broadly follows the agricultural history of Mexico of the last forty years. Since the community settled down in the sixties, the surrounding forest was progressively cleared for maize crop first, and for cattle-farming afterwards (Sanfiorenzo-Barnhard et al., 2009). Maize specialisation came rapidly, being considered the main cause of deforestation at the time. Existing big fauna was shut away to the core of what currently is the protected area. After NAFTA, farming activities began to diversify and with the protection of the area in 1995, farming expansion was limited. Cattle-farming became a preferred livelihood activity, mostly limited by financial capital and land ownership. This is currently seen as a less risky activity than cash-crop agriculture because 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). If households get better off, in such contexts the cattle-farming activity tends to intensify in absolute and in proportional terms, hence intensifying the landscape degradation problem. Land property regime is a hybrid between the traditional *ejido* communal lands, and tacitly acknowledged private land ownership.

Households in Mexico currently have access to a diverse range of external payments for different purposes as well as incentives from various sources in order to engage them into new sustainable activities. These affect directly their livelihood strategies, and hence, the use they make of land. Here we understand the notion of external programs as those designed and implemented by organisations outside of the community. External payments in the form of monetary rewards are increasingly viewed by authorities as a cost-effective approach. In the case study, many such payment schemes exist such as for cattle and agricultural extension, for carbon capture projects and for hydrological ecosystem services. All but carbon capture projects are government-led nationwide programs, and the distribution and conditionality for payments are different in each program. Very different aspects motivate each farmer to seek these external payments, and farmers have a long tradition and experience in administering such diversity of external (and often government-led paternalistic) interventions. Various dissertations partially analyse people's livelihood and conservation policies in this region (Aguilar-Martinez 2007;

García-Barrios, Valdivieso-Pérez, et al. 2009; Escobar-Avalos 2007). Interestingly, it is suggested that due to received payments, people may be leaving aside traditional practices and conservation of local resources, pointing to the lack of instruction on how to use them as an important cause. Also, subsidies are distancing the rural out-migration threshold and reducing the need for farming activities (Sánchez-Hernández 2010). Such external payment matrix affect the effectiveness of programs for the implementation of silvopastoral systems as it alters decisions on investments in human, natural and financial capital at the household level.

Trujillo-Vásquez (2009) describes and documents data for the agroforestry project on which this analysis is based. Since 2007, a regional research institution, ECOSUR, implemented a pilot voluntary and participatory program to encourage cattle-farmers to plant native fodder trees in small pasture plots of their own. They provided incentives in the first year in the form of fencing material and training (Cruz-Morales et al., 2011; Trujillo-Vázquez, 2009). After a first group of 22 volunteers had planted saplings, in 2008 the local office of the National Commission of Protected Areas (CONANP) saw this as an appropriate model to incorporate in its strategy with cattle issues, and provided budget for fencing material for other 22 farmers who joined the group two months later, under joint institutional coordination. In 2009, a total of 68 farmers grouped in 44 plots participated, and CONANP supported these efforts with additional fencing material and payments in cash distributed at the group's own criteria. Farmers were required to plant the trees in order to receive incentives, but there was no real conditionality since the success in establishing fodder-tree plots did not influence the reward received. The actions carried out to cultivate the trees, and the resulting number of trees and their height and quality were monitored for each of the plots (Trujillo-Vázquez and Garcia-Barrios, Unpublished results). His work also analysed how participants took care of land plots and the collective dynamics and individuals preferences when participating in this project. The reasons behind the highly variable degree of involvement are unclear and scarcely related to observable socio-economic variables (Trujillo-Vásquez, 2009).

4. Methodology

In order to understand why farmers did or did not participate, and why some had higher levels of adoption, survey data was gathered from 103 heads of households, which accounted for half of the *ejido*. This included most participants, and non-participants selected through stratified random sampling based on two sources: the community census of all inhabitants and the list of members of the local cattle-farming association. Data collection took place from 29 of April to 22 of June of 2010. Four assistants helped during an intensive period between 8-18 of June. The sample was finally reduced to 91 during data validation due to survey incompleteness.

The data about livelihood strategies is based on the proportion of three assets (land, effort, investment) assigned to each livelihood activity and the returns obtained. The survey was administered in the form of a board based questionnaire with a diagram of the peasant economy (Figure 3). The board-questionnaire is a matrix of 36 activities and five resources: land, effort, money sources, expenditures (including investment) and benefits. Respondents allocated tokens representing their land, effort, investment and benefits within each of the livelihood activities, in order to gather data about the allocation of resource during the previous year in fractional terms. This was based on secondary data, and on consultation with experts and key informants in the community. It was built to understand the decision tree of farmers, what the logics of action are and how family accounts work.

By using a board with tokens, the survey became more attractive for respondents and less compromising so that biases due to the lack of sincerity and attention were minimised. Also, it is suggested that household models that do not separate consumption decisions from production ones better explain dynamics of decision-making in contexts of subsistence agriculture than more simplistic models that assume separability (Douglas 2008). Accordingly, the diagram shows interactions between decisions about how to allocate work and investment, as well as about where money is spent.

This data was complemented with a questionnaire on demographic and economic data, and with qualitative questions about their strategies and in particular, about their attitude and constraints towards planting trees in their plots, based on decision making theories. The secondary data about the level of adoption was collected in the previous year, and included the number of trees found in each plot, their height and a qualitative observation about their health quality (good, medium, and dead). The data collected is summarized as follows:

- Demography: family size; age, level of studies of family members, position in the community (*ejidatario*, full rights; *poblador*, medium rights; *avecindado*, newcomer)
- Economy: wealth proxies (characteristics of the house (categorical); wealth level (ordered categorical); land quantity level (ordered categorical)); years of experience in cattle farming
- Livelihood: number of hectares dedicated to each farming activity (L); percentage of effort and investment (W and I) dedicated to each livelihood activity; share of origin of money in the previous year (O, including from which types of subsidies); share of benefits for each activity (B). All resources but L are fractional data (bounded between 0 and 1, and compositional because the total sum is 1) and compositional (sum up to 1). This data is synthesised in livelihood diversity indices for each resource
- Qualitative questions (categorical, Likert scales): limiting factor for planting fodder trees; level of difficulty found in planting the trees; perceived benefit; perceived time lapse until trees are grown.
- Dependent variables (secondary data): participation/ non-participation (binary); secondary data on involvement (categories of planted/ not-planted; fenced/ not-fenced; weeded/ not-weeded); adoption (numerical construct summing up total length of tree in a plot in single time); adoption level: no participant, participant but no plants, few plants, lots of plants (categories based on quantitative levels of adoption, categories may be less affected by uncontrolled biophysical variables such as slope, humidity and orientation of plot)

Descriptive results from this data include basic statistics of observations and proportional allocation of resources on each livelihood activity; productivity ratios and linear models for each activity in terms of benefit obtained per work, land and money invested; and livelihood diversity indexes. A thorough literature review was done to base the selection of an appropriate diversity indicator among richness, Shannon, Simpson, Herfindahl and Gini. Literature shows that Simpson and Herfindahl are equal, and that Simpson, Shannon and richness are all specifications of a more general Tsallis equation of entropy (Mendes et al., 2008). Finally, an index of richness was selected for analysis, based on its simplicity and theoretical considerations.

5. Results: livelihood strategies, participation and adoption level

The literature review in the previous chapter is used to identify the key variables to include in the quantitative model of participation and adoption. The main livelihood variables are plotted in Figure 4 in order to discern the distinct livelihood strategies existing in the sample. The three main activities of agriculture, cattle-farming and off-farm activities are plotted to identify clusters and general tendencies. Four groups can be identified: households oriented to productive activities of both agriculture and cattle-farming, those dedicated almost entirely to agriculture, households without cattle-farming but with a remarkable off-farm activity, and diversified households.

Table 1 shows the variables considered in the model and their descriptive statistics. It could be expected that a major proportion of subsidies in the total income would encourage less participation in this program because it provided no payments initially, and farmers are arguably used to getting paid in this kind of external programs. People with high livelihood diversity would be expected to participate: these are farmers who tend to try new things. About other variables such as total land, the importance of livestock in livelihood strategy, age and wealth level, literature is contradictory thus the expected direction is unknown. On the number of youth, it can be expected that a larger family has more workforce to dedicate to taking care of the trees and in parallel, that more children may make the head of household to think of conserving the land for their future.

No independent variables are highly correlated with each other (all Pearson correlation coeff. < 0.42). In an initial exploration, we observe a strong relationship between *participation* and *income* level, but not between level of *adoption* and *income* level (Figure 5). In addition, the dependent variable of interest *adoption* is truncated at the zero value because the potential performance of those not participating could not be observed. Therefore a Heckman selection model for censored variables is considered appropriate (Giovanopoulou et al., 2011), where the selection equation for participation includes also the variable of *income* level. The probit selection model for participation is presented in Table 2, followed by the results for the estimated model (Table 3) and the general parameters of the Heckman selection model (Table 4).

6. Discussion and conclusion

This study contributes to knowledge about agroforestry adoption by touching upon silvopastoral systems, a type of agroforestry which adoption causality has been sparsely studied in quantitative studies. It highlights the relevance of including livelihood variables and it analyses the levels of adoption beyond a binary variable, accounting for selection bias in the participation in a pilot program for adoption. The results show that the level of income highly influences participation in the program but not the posterior level of adoption. The effect of livelihood diversity is significant in both participation and adoption but with opposite effect. And the total land owned has a significant effect in the adoption level. Subsidies have no effect according to this model, arguably due to the diverse nature of subsidies. This model aggregates subsidies which are intended to encourage productive activities, for poverty alleviation and development, and for environmental conservation. They may have a clearer effect if considered separately, yet in this study this is limited by the sample size.

This suggests that the variables affecting participation are rather different from those affecting posterior involvement and level of adoption. Indeed, both are different decisions: participation is decided in an initial, single decision, whereas the level of involvement takes place in a second stage of the decision process, where trade-offs with other livelihood activities are actually presented.

These results have relevant implications for program design. They indicate that participation by its own is not sufficient for the program to be effective. The program may need to anticipate how to help participants to handle the hurdles encountered during the process. Results also show that livelihood strategies are significant to predict participation and level of adoption. Understanding that farmers with certain livelihood strategies are more likely to adopt may aid the targeting in program design. Understanding what are the issues encountered by farmers with diverse livelihood strategies - those who are more likely to participate in the first instance, may help avoiding or mitigating these issues and increasing both the effectiveness of the program and the self-efficacy of the participants.

References

Aguilar-Martinez, S., 2007. Efecto de los programas de fomento a la ganadería en la reserva de la biosfera de La Sepultura, Villaflores, Chiapas. El Colegio de la Frontera Sur.

Calle, A., Montagnini, Florencia, Zuluaga, A., 2009. Farmer's perceptions of silvopastoral system promotion in Quindío, Colombia. Bois et forêts des tropiques 79–94.

Chomitz, K.M., Kumari, K., 1998. The domestic benefits of tropical forests: a critical review. The World Bank research observer 13, 13–35.

Common, M., Stagl, S., 2005. Ecological economics: an introduction. Cambridge University Press.

Cruz-Morales, J., Trujillo-Vázquez, R., García-Barrios, L.E., Ruiz-Rodríguez, J.M., Jiménez-Trujillo, J.A., 2011. Buenas Prácticas para la Ganadería Sustentable en la Reserva de la Biosfera La Sepultura (REBISE). Universidad Autónoma Chapingo, El Colegio de la Frontera Sur, Conservación Internacional-México y Comisión de Áreas Naturales Protegidas.

Cubbage, F., Balmelli, G., Bussoni, A., Noellemeyer, E., Pachas, A.N., Fassola, H., Colcombet, L., Rossner, B., Frey, G., Dube, F., Silva, M.L., Stevenson, H., Hamilton, J., Hubbard, W., 2012. Comparing silvopastoral systems and prospects in eight regions of the world. Agroforestry Systems 86, 303–314.

Dagang, A.B.K., Nair, P.K.R., 2003. Silvopastoral research and adoption in Central America: recent findings and recommendations for future directions. Agroforestry Systems 59, 149–155.

Douglas, R.B., 2008. A spatiotemporal model of shifting cultivation and forest cover dynamics. Environment and Development Economics 13, 643–671.

Escobar-Avalos, J.E., 2007. Políticas ambientales y de desarrollo rural en tres ejidos de la Reserva de la Biosfera La Sepultura: variables que inciden en la organización y participación social. El Colegio de La Frontera Sur.

Frey, G.E., Fassola, H.E., Pachas, a. N., Colcombet, L., Lacorte, S.M., Pérez, O., Renkow, M., Warren, S.T., Cubbage, F.W., 2012. Perceptions of silvopasture systems among adopters in northeast Argentina. Agricultural Systems 105, 21–32.

García-Barrios, L.E., Galván-Miyoshi, Y.M., Valdivieso-Pérez, I.A., Masera, O.R., Bocco, G., Vandermeer, J., 2009a. Neotropical Forest Conservation, Agricultural Intensification, and Rural Out-migration: The Mexican Experience. BioScience 59, 863–873.

García-Barrios, L.E., Valdivieso-Pérez, I.A., Plascencia-Vargas, H., 2009b. Cambio de uso de suelo en la zona de amortiguamiento de la REBISE (1975-2005): crisis del maíz, ganaderización y recuperación arbórea marginal, in: Cavalloti Vázques, B.A., Marcof Álvarez, C.F., Ramírez Valverde, B. (Eds.), Ganadería y Seguridad Alimentaria En Tiempo De Crisis. Universidad Autónoma de Chapingo, Chapingo, pp. 350–366.

Giovanopoulou, E., Nastis, S.A., Papanagiotou, E., 2011. Modeling farmer participation in agri-environmental nitrate pollution reducing schemes. Ecological Economics 70, 2175–2180.

Gutiérrez, Z., Viera, G., Fraga, J., 2008. Environmental Impact Assessment of the Establishment of Silvopastoral Systems in San Pedro River Basin, Camagüey, Cuba. Zootecnia Tropical 26, 175–178.

Hayes, T.M., 2012. Payment for ecosystem services, sustained behavioural change, and adaptive management: peasant perspectives in the Colombian Andes. Environmental Conservation 39, 144–153.

Holderieath, J., Valdivia, C., Godsey, L., Barbieri, C., 2012. The potential for carbon offset trading to provide added incentive to adopt silvopasture and alley cropping in Missouri. Agroforestry Systems 86, 345–353.

Isaac-Márquez, R., De Jong, B., Ochoa-Gaona, S., Hernández, S., Kantún, M., 2005. Estrategias productivas campesinas: un análisis de los factores condicionantes del uso del suelo en el oriente de Tabasco, México. Universidad y Ciencia 21, 56–72.

Jera, R., Ajayi, O., 2008. Logistic modelling of smallholder livestock farmers' adoption of tree-based fodder technology in Zimbabwe. Agrekon 47, 379–392.

Mendes, R., Evangelista, L., Thomaz, S., 2008. A unified index to measure ecological diversity and species rarity. Ecography 450–456.

Montagnini, F, Nair, P., 2004. Carbon sequestration: an underexploited environmental benefit of agroforestry systems. Agroforestry Systems 61, 281–295.

Napier, T., 1991. Factors affecting acceptance and continued use of soil conservation practices in developing societies: a diffusion perspective. Agriculture, Ecosystems & Environment 36, 127–140.

Pagiola, S., Ramirez, E., Gobbi, J., Dehaan, C., Ibrahim, M., Murgueitio, E., Ruiz, J., 2007. Paying for the environmental services of silvopastoral practices in Nicaragua. Ecological Economics 64, 374–385.

Pagiola, S., Rios, A.R., Arcenas, A., 2008. Can the poor participate in payments for environmental services? Lessons from the Silvopastoral Project in Nicaragua. Environment and Development Economics 13, 299–325.

Pattanayak, S., Mercer, D.E., Sills, E., Yang, J., 2003. Taking stock of agroforestry adoption studies. Agroforestry Systems 57, 173–186.

Perz, S.G., 2003. Social determinants and land use correlates of agricultural technology adoption in a forest frontier: a case study in the Brazilian Amazon. Human Ecology 31, 133–165.

Richter, M., 2000. The ecological crisis in Chiapas: a case study from Central America. Mountain Research and Development 20, 332–339.

Sánchez-Hernández, M.G., 2010. Análisis del sistema agropecuario en el municipio en el municipio de Santiago el Pinar, Chiapas, Mexico. El Colegio de la Frontera Sur.

Sanfiorenzo-Barnhard, C., García-Barrios, L.E., Meléndez-Ackerman, E., Trujillo-Vázquez, R., 2009. Woody Cover and Local Farmers' Perceptions of Active Pasturelands in La Sepultura Biosphere Reserve Buffer Zone, Mexico. Mountain Research and Development 29, 320–327.

Trujillo-Vázquez, R., 2009. Viabilidad Ecológica y Social del establecimiento de módulos silvopastoriles en el Ejido Los Ángeles, Zona de Amortiguamiento de la Reserva de la Biósfera La Sepultura, Chiapas, México. Universidad Internacional de Andalucia.

Valdivieso-Pérez, I.A., García-Barrios, L.E., Álvarez-Solís, J.D., Nahed-Toral, J., 2012. From Cornfields to Grasslands: Change in the Quality of Soil. Terra Latinoamericana 30.

Tables

Table 1: Variable definitions and summary statistics

Variable	Description	n	Mean	SD	Median	Participants Mean	Participants SD	Non-participants Mean	Non-participants SD
participation	Participated in fodder tree project	91							
adoption	Total length of trees found in each plot (m^2, proxy for biomass)	91	4.59	10.46	0.00	8.04	12.84	NA	NA
subsidies	Dependence on subsidies: proportion of total income from subsidies	91	0.21	0.16	0.22	0.22	0.14	0.21	0.18
diversity	Livelihood diversity measured in the number of activities divided by total possible activities	91	0.51	0.21	0.53	0.57	0.21	0.44	0.18
land	Total land owned (ha)	91	29.40	31.74	22.00	31.36	33.86	26.78	28.90
cattle-farming	Importance of livestock as a source of income (share of income from cattle-farming)	88	0.23	0.19	0.22	0.26	0.18	0.20	0.20
age	Age of farmer	91	43.88	14.61	39.00	46.19	13.77	40.80	15.30
youth	Number of household members aged <=15	91	1.34	1.22	1.00	1.23	1.08	1.49	1.39
income	Level of income: very low = 2; low = 33; medium = 38; high = 17	90							

Table 2: Probit selection equation results: participation in fodder tree planting project. The baseline for income is 'Low', the level with highest participation

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	-0.46	0.72	-0.64	0.53	
subsidies	-0.45	1.12	-0.40	0.69	
diversity	2.00	0.85	2.34	0.02	*
land	0.00	0.01	0.83	0.41	
cattle-farming	0.44	0.89	0.50	0.62	
income - Very low	-0.05	0.99	-0.05	0.96	
income - Medium	-0.65	0.37	-1.74	0.09	.
income - High	-1.56	0.48	-3.25	0.00	**
age	0.01	0.01	0.46	0.64	
youth	-0.15	0.14	-1.11	0.27	

Table 3: Results of the equation: level of adoption, 87 observations (38 censored and 49 observed)

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	25.61	11.95	2.14	0.04	*
subsidies	22.73	14.24	1.60	0.12	
diversity	-29.97	11.21	-2.67	0.01	**
land	0.15	0.06	2.65	0.01	**
cattle-farming	-11.93	10.96	-1.09	0.28	
age	-0.07	0.14	-0.49	0.63	
youth	2.89	1.72	1.68	0.10	.

Multiple R-Squared: 0.37
Adjusted R-Squared: 0.27

Table 4: Heckman selection equation parameters

Error terms	Estimate	Std. Error	t value	Pr(>|t|)	
invMillsRatio	-11.96	6.23	-1.92	0.06	.
sigma	13.26	NA	NA	NA	
rho	-0.90	NA	NA	NA	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1

Figures

Figure 1: Groups of independent variables in adoption literature

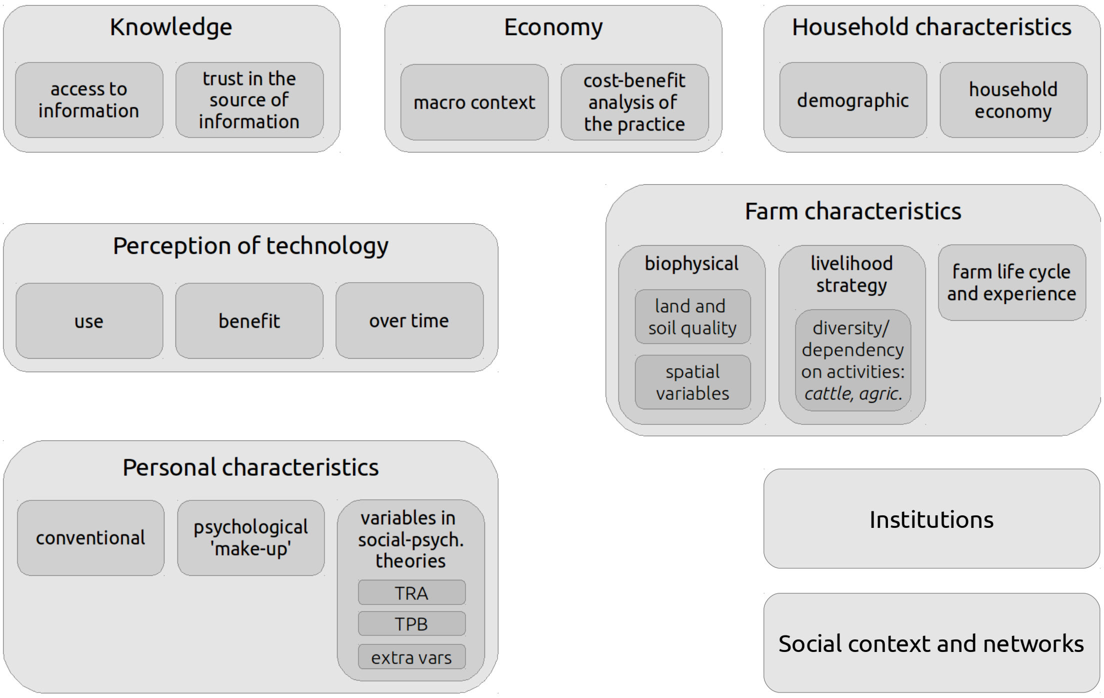

Figure 2: Location and zonification of La Sepultura Biosphere Reserve in Chiapas, Mexico (167,310ha). Source: CONANP (2006) and OSM

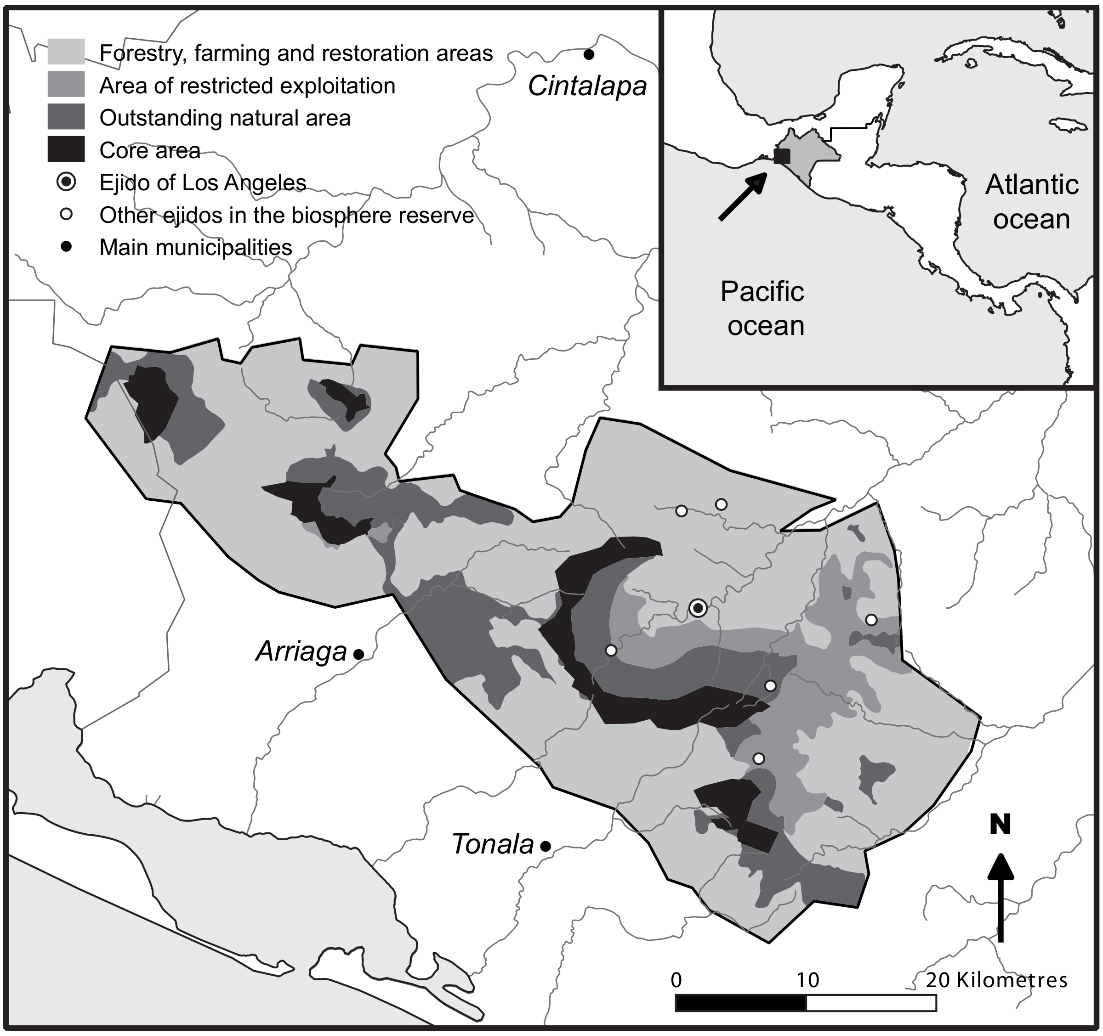

Figure 3: Diagram of the peasant economy

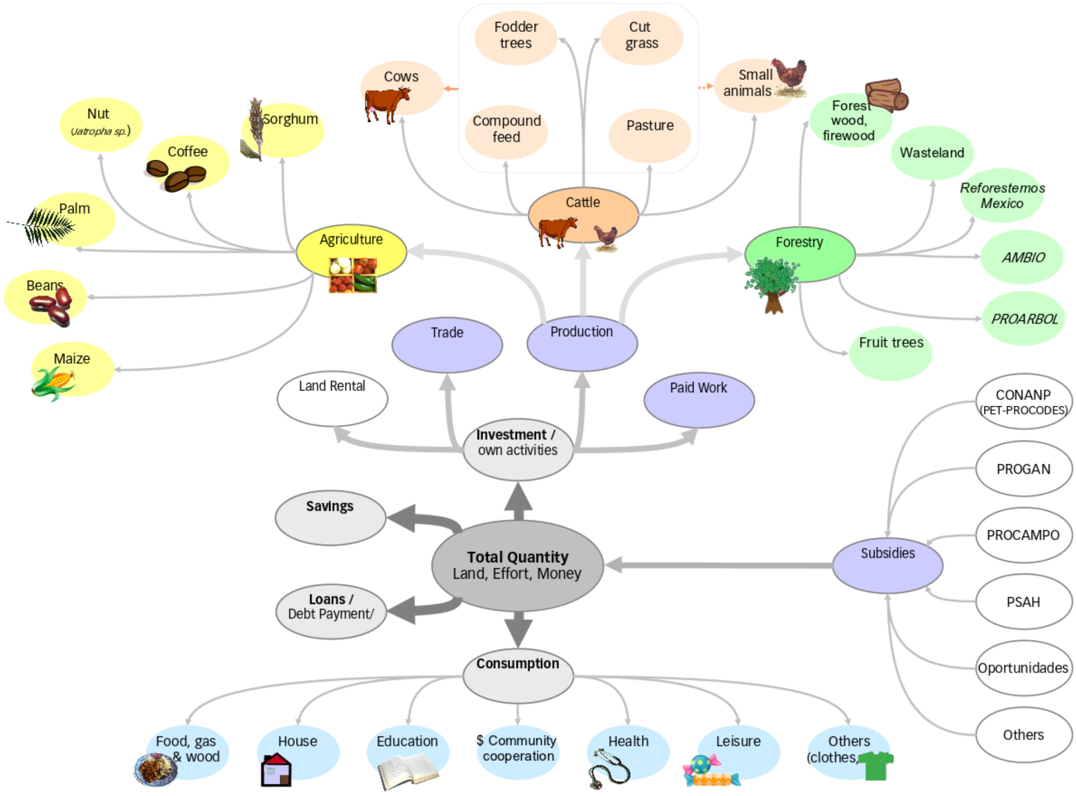

Figure 4: Livelihood strategies based on the proportion of income provided by each of the main activities: agriculture, cattle-farming and off-farm activities (Each dot represents an observation)

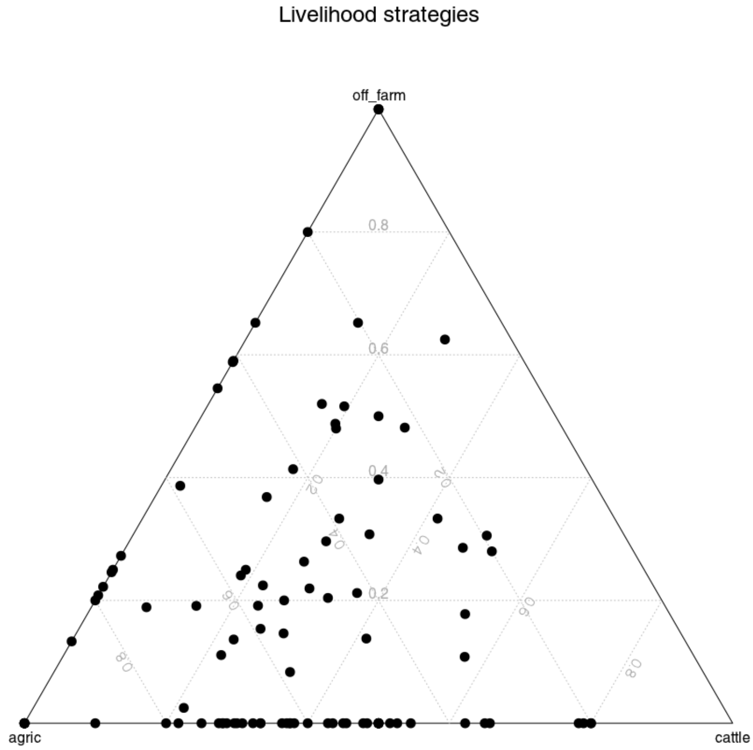

Figure 5: Participation by income level (left) and adoption by income level (right, excludes not participants)