Open access • Other • DOI:10.4337/9781849806015.00015

Poor Household Participation in Payments for Environmental Services in Nicaragua and Colombia — Source link

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Published on: 28 Dec 2010

Topics: Extremely Poor

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World Bank

12 February 2009

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DRAFT * 12 February 2009
Prepared for submission to Luca Tacconi, Sango Mahanty, and Helen Suich, eds., *The Livelihood Impacts of Incentive Payments for Reduced Deforestation and Degradation (REDD)*

Abstract

We evaluate the extent to which poor households are able to participate in Payments for Environmental Services (PES) scheme using data from a PES scheme implemented at two sites in Latin America. This allows us to compare environmental and livelihood impacts of PES across regions with different agronomic and socio-economic characteristics. In particular, one of our sites is composed almost entirely of poor or extremely poor households, while the other has households ranging from extremely poor to very well off. The results show that poorer households are in fact able to participate—indeed, by some measures they participated to a greater extent than better-off households. Moreover, their participation was not limited to the simpler, least expensive options. Extremely poor households had a somewhat greater difficulty in participating, but even in their case the difference is solely a relative one. Transaction costs may be greater obstacles to the participation of poorer households than household-specific constraints.

Acknowledgments

Work on this paper was financed in part by a grant from the Norwegian Trust Fund for Environmentally and Socially Sustainable Development. The Nicaragua participant survey was conducted by Alfredo Ruiz García, María Raquel López Vanegas, and Yuri Marín López, and the Colombia participant survey was conducted by a team from CIPAV led by Daniel Uribe. We have benefitted from discussions with Elías Ramírez, Enrique Murgueitio R., Alvaro Zapata Cadavid, Andrés Felipe Zuluaga, Paola Agostini, José Gobbi, Cees de Haan, Muhammad Ibrahim, Mauricio Rosales, and Juan Pablo Ruíz. Any remaining errors are the authors' sole responsibility. The opinions expressed in this paper are the authors' own and do not necessarily reflect those of the World Bank Group or the Inter-American Development Bank.

9,200 words.

1. Introduction

Payments for Environmental Services (PES) schemes pay land users to undertake practices that generate external benefits, either to individual users of ecosystem services (such as downstream water users) or to society as a whole (Wunder, 2005; Pagiola and Platais, 2007; Engel *et al*., 2008). These payments represent a potential additional income source for land users, but will only bring benefits to households that are able to participate. A common fear among many observers has been that poorer households would be unable to participate in PES schemes. Several studies in Costa Rica, for example, found that many participants in that country's PES scheme are relatively well off (Ortiz *et al*., 2002; Miranda *et al*., 2003; Zbinden and Lee, 2005).

The Regional Integrated Silvopastoral Ecosystem Management Project, implemented at sites in Colombia, Nicaragua, and Costa Rica from 2003 to 2008, offers an excellent opportunity to examine the ability of poor households to participate in PES. The Silvopastoral Project used PES to stimulate the adoption of silvopastoral practices in degraded pastures by paying participating households for the biodiversity conservation and carbon sequestration services that were generated, with financing from the Global Environment Facility (GEF). Unlike many other PES schemes, the Silvopastoral Project offered a wide range of participation options, ranging from simple and inexpensive land use changes to substantial and complex changes (with correspondingly higher payments). That some of the choices offered by the project are complex and onerous provides a particularly strong test of poorer households' ability to participate.

In this chapter, we evaluate the extent to which poor households were able to participate in the Silvopastoral Project's PES scheme, using data from two of its sites. As the same payment scheme was offered in both areas, we are able to compare poor household participation in PES under different agronomic and socio-economic conditions. In particular, one site is characterized by high levels of poverty, with most households falling below the poverty line, and many below the extreme poverty line, while the other site exhibits a very wide range of income levels, including both extremely poor and very wealthy farm households. Because of the nature of the practices being promoted, we are unable at this time to assess the Silvopastoral Project's welfare impact. What we assess is the threshold issue of ability to participate: if poorer households cannot participate, they will not receive any benefits, whether large or small.

We begin by describing the Silvopastoral Project and the two project sites. We then discuss the factors that might hinder poorer households' ability to participate in PES schemes, drawing on the review by Pagiola *et al*. (2005) and on the rich literature on technology adoption by smallholders in developing countries, many of whose lessons are relevant to PES. We then use data collected at the study sites to analyze participation patterns, with particular attention to participation by poorer households. We first examine the extent to which different groups of households participate, and then undertake an econometric analysis to determine the factors that affect participation decisions. We conclude by discussing the implications of our results for the design of PES schemes.[1]

[1] Earlier analyses we conducted at these same sites are reported in Pagiola *et al*., 2007b and 2008. Those analyses used data from earlier years (from the first year only, at the Nicaragua site, and for the first three years, at the Colombia site). This paper updates those analyses to use the data from all four project years and compares results at the two sites.

2. The Silvopastoral Project

The Regional Integrated Silvopastoral Ecosystem Management Project piloted the use of PES in three sites in Colombia, Costa Rica, and Nicaragua (Pagiola *et al*., 2004). The project was financed by a US$4.5 million grant from the Global Environment Facility (GEF), through the World Bank. It was implemented in the field by local non-governmental organizations (NGOs).

2.1 PES scheme design

The Silvopastoral Project used PES to promote the adoption of silvopastoral practices in areas of degraded pastures, with the aim of generating biodiversity conservation and carbon sequestration services. Silvopastoral practices include (1) planting high densities of trees and shrubs in pastures; (2) cut and carry systems, in which livestock is fed with the foliage of specifically planted trees and shrubs ('fodder banks'); and (3) using fast-growing trees and shrubs for fencing and wind screens. These practices provide deeply rooting, perennial vegetation that is persistently growing and has a dense but uneven canopy.

The on-site benefits of silvopastoral practices to land users may include additional production from the tree component, such as fruit, fuelwood, fodder, or timber; maintaining or improving pasture productivity by increasing nutrient recycling; and diversification of production (Dagang and Nair, 2003). These benefits can be important, but are often insufficient by themselves to justify adopting silvopastoral practices—particularly practices with substantial tree components, which have high upfront planting costs and only bring benefits several years later. Estimates prepared for the project show rates of return of between 4% and 14% (Gobbi, 2002). Other studies found similar results; White *et al*. (2001), for example, found rates of return to adoption of improved pasture in Esparza, Costa Rica, of 9% to 12%. These estimates, of course, only consider the on-site benefits of silvopastoral practices.

Because of their increased complexity relative to traditional pastures, silvopastoral practices also have important biodiversity benefits (Dennis *et al*., 1996; Harvey and Haber, 1999). They have been shown to play a major role in the survival of wildlife species by providing scarce resources and refuge; to have a higher propagation rate of native forest plants; and to provide shelter for wild birds. They can also help connect protected areas. Silvopastoral practices can also fix significant amounts of carbon in the soil and in the standing tree biomass (Fisher *et al*., 1994; Swallow *et al*., 2007). Both biodiversity and carbon sequestration benefits are off-site, however, so land users tend not to include them when they decide which practices to adopt. GEF funding for the Silvopastoral Project is based on the desire to secure these biodiversity and carbon sequestration benefits.[2] Silvopastoral practices can also affect water services, though the specific impact is likely to be site specific (Bruijnzeel, 2004). The Silvopastoral Project did not include any payments for water services.

To encourage adoption of more beneficial practices, the Silvopastoral Project offered payments that are proportional to the level of services provided. To do so, it developed indices of the biodiversity conservation and carbon sequestration services that different land uses provide, then aggregated them into a single 'environmental services index' (ESI).[3] The project distinguished 28 different land uses, each with its own ESI score, and paid participants according to the change in total ESI score over their entire farm area. Remote sensing imagery, followed by

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2 In this context the GEF can be considered to be buying services on behalf of the global community.

3 The ESI is described in detail in CIPAV (2003) and Pagiola *et al*. (2004).

on-the-ground verification, was used to develop detailed baseline land use maps of each PES recipient household (as well as of members of a control group, see below), indicating the land use being undertaken on each parcel. Land use changes in each parcel were then monitored on an annual basis, and payments were made on the basis of observed land use changes.

Silvopastoral practices tend to be unattractive to land users, despite their long-term benefits, primarily because of their substantial initial investment and because of the time lag between investment and returns. This led to the hypothesis that a relatively small payment provided early on could 'tip the balance' between current and silvopastoral practice, by increasing the net present value of investments and reducing the initial period in which these practice impose net costs on land users (Pagiola *et al.*, 2004, 2008). On this basis, participating households received payments of US$75 per incremental ESI point, per year, over a four-year period.[4] Payments were made annually, after on-the-ground verification of land use changes. They also received a one-time payment of US$10/point for the baseline points.[5]

2.2 Project sites

The Silvopastoral Project's sites were in Quindío, Colombia; Esparza, Costa Rica; and Matiguás-Río Blanco, Nicaragua (Pagiola *et al*., 2004). In this paper, we focus exclusively on the Quindío and Matiguás-Río Blanco sites. See the appendix for the data sources we used.

The Matiguás-Río Blanco area is located in the department of Matagalpa, about 140km northeast of Managua, on the southern slopes of the Cordillera de Darien. It has an undulating terrain, with an elevation of about 300-500m above sea level. Average temperature is about 25°C and average rainfall between 1700mm and 2500mm. Participants are clustered in two adjacent microwatersheds, that of Río Bulbul and that of Río Paiwas. Farms range in size from 10-30ha to a few of over 60ha. Most households are poor, with many falling below Nicaragua's extreme poverty line.

Land use in Matiguás-Río Blanco is dominated by extensive grazing. As shown in Table 1, pastures accounted for about 63% of the area prior to project start. Of this, about half was degraded pasture, and a little over a quarter had either no or few trees. Annual crops made up a very small part of total area. It is noteworthy that about 20% of total area remained under forest, mostly along streambanks. It is also noteworthy that silvopastoral practices, though not common, were not unknown even before the project: there were some 489ha of pastures with high tree density, and 88ha of fodder banks, for example.

The Quindío area is located in Colombia's Central Cordillera, in the watershed of Río La Vieja, at an altitude of about 900-1,500m above sea level. Average temperature is about 20-25°C

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4 The Silvopastoral Project's use of short-term payments is controversial, as payments in PES schemes should generally be on-going. The use of short-term payments means that the conditionality of payments is limited to the first few years, which may well affect the long-term viability of the mechanism (Pagiola *et al*., 2007a). The use of short-term payments is not pertinent to the issue considered in this paper, which focuses on the extent of participation, and whether poverty affects it.

5 It is important to note that this initial 'baseline' payment was intended as a recognition of the environmental services that households were already providing, and not as subsidy to increased service provision. Households receiving the baseline payment were under no obligation to participate further. As noted below, however, the baseline payment did help finance some of the required investments, particularly in Matiguás-Río Blanco. It also played a very important role in establishing trust among participants that they would indeed receive the promised payments if they undertook the land use changes the Project was asking for.

and average rainfall between 1500mm and 2000mm. Farms range from 10-20ha to some of 50-80ha. In this former coffee area, many of the larger farms are owned by urban professionals and managed by employees (*mayordomos*).

Coffee production once dominated land use in Quindío, but it has been replaced by pasture in the last decade due to low coffee prices, and now accounts for less than 1% of the area. As shown in Table 2, extensive grazing was the main land use in Quindío prior to project start. Degraded and treeless pastures dominated the landscape, accounting for about 65% of the area. Livestock production is primarily for meat production, with a small proportion being used for milk production. Overall tree cover was low, although there was a significant amount of forest remnants, most of which was riparian forest. Silvopastoral practices such as pastures with trees, fodder banks, and live fences were practically non-existent. Only 7 in 110 farms surveyed had any fodder banks, for example, with an average of less than 1ha each.

Although neither Nicaragua nor Colombia is in the list of top deforesters, both have high deforestation rates, particularly Nicaragua. Conditions at the Nicaragua site are broadly representative of those observed in many parts of Central America, while conditions at the Colombia site are broadly representative of conditions found in parts of Venezuela, Brazil, and Ecuador.

All households in the study sites that met minimal farm and herd size criteria were eligible to participate. Participants were selected on a first-come basis until the maximum number allowed by available funding was reached. The characteristics of participating households are summarized in Tables 3 and 4. At Matiguás-Río Blanco, the average participating household is composed of six members and has about 34ha of land and about 23 livestock units.[6] The average per capita income of about C$2,000 is below the poverty line. Other indicators confirm the low living standards of the area's households: few have water or electricity, and education levels are very low. Agriculture is the main economic activity, with few households having off-farm income. In Quindío, the average household is composed of slightly less than five members, and has about 36ha of land and a herd of about 57 livestock units. Average per capita income is about COP10 million, but with very high variation across the sample.

To assess relative participation levels, we classify households at each site into three groups based on their estimated income.[7] The small size of our sample precluded a finer breakdown (for example, into quintiles). In Matiguás-Río Blanco, we use the national poverty lines for 2001 (World Bank, 2003), adjusted for inflation, to divide households into groups: those with incomes below the extreme poverty line ("extremely poor"), those with incomes between the extreme poverty line and the poverty line ("poor"), and those with incomes above the poverty

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6 Livestock are converted into livestock units (*Unidad Gran Ganado*, UGG) using the following conversion factors: adult cows, 1.0 UGG; oxen or breeding bulls, 1.55 UGG; calves, 0.33 UGG; yearlings, 0.7 UGG.

7 We computed household income by adding all income sources reported by participants, including net income from agricultural, forest, and dairy production; livestock sales; off-farm work; net income from non-farm enterprises; and remittances. Dairy, agricultural, and forest products consumed by the household are included in the calculation of income using market prices, and the value of family labor is imputed using local wage rates for unskilled labor. Expenditure is generally preferred over income as an indicator of household welfare, as it tends to be less variable (Ravallion, 1992). However, the baseline survey only collected data allowing income to be computed. Moreover, these data are based largely on information self-reported by the farmers, and so are subject to both recall problems and possible biases. These biases are unlikely to affect our results as long they are similar across income groups.

line ("non-poor"). In Quindío, with its much greater spread of income levels, there is a clear jump in income levels above 20 million Colombian Pesos (COP), so we group households with income above this level into a "high income" group. Below this income level, there is no apparent clustering, so we divide the remaining households into two groups of similar size, with the division falling at COP2 million. We classify households with income between COP2 million and COP20 million into a "middle-income" group, and those with incomes below COP2 million into a "low-income" group. About half of the latter group falls below Colombia's official poverty line (World Bank, 2002).

Breaking down participants into income groups shows both similarities and differences. At both sites, poorer households have significantly less land and smaller herds than better-off households. Poorer households also have larger households and more dependents per adult, although in Quindío the proportion of dependents is highest among middle income households. In Matiguás-Río Blanco, differences in educational level and experience are minimal and not statistically significant; these differences are much greater in Quindío, but they are also not statistically significant. In Matiguás-Río Blanco, average access to services is low, but poorer households are less likely to have either electricity or water; in contrast, average access to services is high in Quindío, but low income households are less likely to have water services and more likely to live further from the nearest village. Particularly important for what follows, access to credit and technical assistance is highest among better-off households at both sites, although the differences are not significant. The topography of farms is broadly similar across income groups at both sites.

2.2 PES implementation

The Silvopastoral Project made its first payments at both sites, for baseline ESI points, in July 2003. It made its first payment for changes in land use in May 2004. Additional payments were made in 2005, 2006, and 2007.

Tables 1 and 2 compare land use by PES recipients prior to the project and after four years of payments. Overall, there was substantial land use change at both sites. In Matiguás-Río Blanco, 1,343ha (48% of total area) experienced some form of land use change, while in Quindío 1258ha (44% of total area) experienced some form of land use change.[8] A wide variety of changes were observed, ranging from minor changes such as sowing improved grasses in degraded pastures to very substantial changes such as planting high-density tree stands or establishing fodder banks. The area of degraded pasture experienced the largest fall at both sites, being reduced by over 80% in Matiguás-Río Blanco and by over 90% in Quindío. The area natural pastures without trees also declined strongly–by a third in Matiguás-Río Blanco and by two thirds in Quindío. In Matiguás-Río Blanco, the greatest increase was in the area of pasture with high tree density, which increased by 570ha. The area of fodder banks increased by almost 160ha, and about 210km of live fencing were established. In Quindío, most of the gains were experienced in pastures with high tree density, which increased by 334ha. The area of fodder banks increased relatively little (from less than 5ha to over 28ha), but that of intensive silvopastoral systems (*Leucaena* planted at 5,000 trees/ha) increased substantially (from 0ha to 130ha). About 346km of live fencing were established. Overall, these changes increased the total

8 The figures quoted actually under-state the extent of change, as they show *net* changes. In addition, existing silvopastoral practices were often upgraded to more intensive practices (for example, increasing the density of trees in pastures).

ESI score of PES recipients by 53% in Matiguás-Río Blanco and by 49% in Quindío. Thus households in Matiguás-Río Blanco made more substantial changes on a smaller proportion of their land than households in Quindío.

In Quindío, the land use changes undertaken by PES recipients were vastly greater than those observed in the control group, among whom less than 13% of land area experienced any change, for an increase in ESI points of only 7%. The lack of a proper control group at Matiguás-Río Blanco prevents a similar comparison, but casual observation suggests that land use changes among non-recipients in nearby areas were substantially less extensive, in both area affected and degree of change.

3. Participation in the Silvopastoral Project's PES scheme

PES schemes pay land users to maintain or switch to land uses that provide environmental services that others value. Participation is voluntary, and participants receive payments for doing so. This creates a *prima facie* presumption that participants are at least no worse off by joining than they would be by not joining. Were this not the case, they could simply decline to participate. The potential benefits of PES schemes will only be realized by those who participate, however. Determining whether poorer households will in fact be able to participate in a PES scheme is thus critical to any potential impact such schemes might have on poverty.

Pagiola *et al*. (2005) group the factors that might affect a household's participation in a PES scheme into three categories: factors that affect eligibility to participate; factors that affect households' desire to participate; and factors that affect their ability to participate. The three categories form a logical sequence: ability to participate only become an issue for households that wish to do so, and that in turn is only relevant for households that are eligible to participate.[9] In this paper, we focus on the factors that affect the participation of eligible households, and particularly on how they affect the participation of poorer households.

3.1 Constraints to the participation of poor households in PES schemes

Eligibility to participate is affected by the scheme's targeting and by requirements it may impose. Costa Rica's PES scheme, for example, requires that applicants be located in a priority conservation area (based primarily on biodiversity criteria) or in a watershed covered by an agreement with an individual water user, and to meet a variety of requirements (such as not being in arrears with the country's social security system). It once also required most participants to have land titles, but this requirement has been eliminated (Pagiola, 2008). Similarly, Mexico's PES scheme defines eligible areas in terms of their importance to water supplies and other criteria (Muñoz *et al*., 2006). The eligibility of poorer households will thus likely often be an important consideration. Pagiola and Colom (2006), for example, find that the areas in Guatemala that are important for water service provision do not always have high poverty rates. It is not an issue in our study, however, as we focus on areas that were selected for inclusion in the project.

Assuming that a given household is eligible to participate, the next question is whether it desires to participate. This is likely to depend primarily on whether it expects to be better off as a

9 Wunder (2008) adds a fourth 'filter': whether households are competitive in terms of transaction costs. This filter affects whether the PES scheme will select particular households, and thus is closely related to eligibility criteria. We return to this issue in the conclusions.

result. Participation in PES can be thought of as adopting a particular production technique, whose returns include payments from the scheme. The literature on technology adoption and program participation thus provides many insights into the factors likely to affect participation (Feder *et al*., 1985). The literature on adoption of agroforestry practices (Pattanayak *et al*., 2003; Mercer, 2004) is particularly pertinent here, as the practices promoted by the Silvopastoral Project are very similar. Previous analyses confirm the significance of factors that tend to affect the benefits or the costs of participation, such as prices faced, farm characteristics, and the opportunity cost of household labor, the fit in the farming system, or the risk involved (Pattanayak *et al*., 2003). Factors such as slope, for example, can affect the extent to which productivity is threatened under current practices, thus increasing incentives to adopt land uses that are less vulnerable to degradation. As developing-country PES schemes typically offer fixed payments per hectare for adopting a given practice, the payment itself is unlikely to differentially affect the desirability of participation across households.

A household may want to participate in a PES scheme and yet be unable to do so, for a variety of reasons. Participation in a PES scheme requires adoption of the land uses promoted by the scheme. This may be simple and cheap, if the scheme calls for retaining existing land uses (as in the Costa Rica scheme's forest protection contract), or it may be complex and costly, if the scheme calls for switching to new practices (as in the PES scheme studied here). Tenure issues are often critical, particularly in cases where PES schemes require long-term investments, such as reforestation or adoption of silvopastoral practices. Tenure variables were significant in 72% of agroforestry adoption studies that included them, with greater tenure security being consistently associated with greater adoption (Pattanayak *et al*., 2003). In Costa Rica, both Thacher *et al*. (1997) and Zbinden and Lee (2005) found tenure-related variables to be highly significant in explaining participation in the country's PES scheme and its predecessors. When the new practices to be adopted are complex, access to technical assistance may be an issue. Access to extension was found to significantly affect agroforestry adoption in 90% of studies that included it (Pattanayak *et al*., 2003). This was the case in two studies in Costa Rica, for example (Thacher *et al*., 1997; Zbinden and Lee, 2005). Adopting new land use practices may also prove difficult if households cannot finance the necessary investment. Savings, remittances, or off-farm income may help some households undertake the necessary investments. Assets and credit both tend to increase adoption of agroforestry practices, and their role is very often significant (Pattanayak *et al*., 2003).

Many of the factors that affect a household's ability to participate in PES may well be more salient for poor households. Poorer households are less likely to have secure tenure, tend to have fewer savings and less access to credit, and are less likely to receive technical assistance (de Janvry and Sadoulet, 2000; López and Valdés, 2000). Whether poor households will be able to participate in PES schemes (assuming that they are eligible and interested in doing so) is thus a legitimate source of concern.

3.2 Poor household participation in the Silvopastoral Project's PES scheme

The Silvopastoral Project induced substantial land use change at its sites. The question of interest here is the extent to which poorer households were able to participate in this success.

Figures 1 and 2 break down observed land use changes by household income group. At both sites, poorer households accounted for a substantial share of land use changes. At Matiguás-Río Blanco, poor and extremely poor households accounted for 49% of the decline in degraded pasture. In Quindío, low income households accounted for 35% of the decline in degraded pastures and 45% of the decline in improved pasture without trees. They only accounted for 9% of the decline in natural pasture without trees, but this is primarily due to their having the least area in this use of any of the income groups.

Moreover, land use changes by poorer households at both sites were not limited to adopting technically simpler and less onerous practices. In Matiguás-Río Blanco, for example, extremely poor households established 60ha of fodder banks (38% of the total), and poor households another 37ha (23%).[10] Extremely poor households also established 153ha (40%) of pastures with high tree density, with poor households providing another 78ha (20%). Similarly, in Quindío low income households adopted many complex land uses, including 70ha of pastures with high tree density and 31ha of fodder banks and intensive silvopastoral systems (*Leucaena* planted at 5,000 trees/ha). Indeed, it was the middle income group that made the simplest possible change on almost half of the land they converted, replacing natural with improved grasses (mainly star grass, *Cynodon plectostachyus*) in pastures with no or few trees.

Tables 5 and 6 examine various indices of household participation across income groups. In terms of area converted, poorer households perform poorly at both sites. At Matiguás-Río Blanco, non-poor households converted just under 20ha each, on average, almost double the 10ha converted by extremely poor households, while in Quindío high income households converted about 34ha each, over three times the 9ha converted by low income households. It is interesting to note, however, that poor (but not extremely poor) households in Matiguás-Río Blanco converted practically as large an area as the non-poor (18ha).

Data on total land use changes by households in each income group are affected by the different land endowments of each group, however, making total area converted a poor measure of relative participation. The differences across income groups shrink considerably when changes are expressed in terms of proportion of farm area converted. In Matiguás-Río Blanco, poor households converted the greatest proportion of their farm: 57%, compared to 49% for non-poor households. Although extremely poor households converted the smallest proportion of their farm (42%) of any of the groups, the difference was less marked than in absolute terms. In Quindío, high income households converted the greatest proportion of their farms (55%) but low and middle income farms were not far behind (40% converted). Moreover, these differences in proportion of farm converted are not significantly different (at 5% level).

Whether expressed in hectares or in proportion of farm area converted, area-based indicators fail to measure whether the changes are large or small. Sowing improved pasture grasses in a treeless pasture requires substantially less effort than converting it to pasture with high tree density, yet will have the same value in terms of either area converted or percent of farm area converted. Area-based indicators also omit investments in live fencing. One option to incorporate a measure of intensity is to weight the area converted by the ESI of the land use change, and then add the points for live fencing. The ESI is not intended as a measure of effort, but higher-ESI land uses tend to involve more effort than lower-ESI uses. This measure is also appealing as it is the outcome of interest to the buyer of the environmental services being sought. The increase in total ESI is the simplest measure (and is readily available, as it forms the basis

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[10] The popularity of fodder banks among poorer households in Matiguás-Río Blanco may be due to the greater availability and lower opportunity cost of labor in such households. The cut-and-carry practices that such banks imply require substantial amounts of labor.

for payments to participants), but like the area converted it is constrained by total farm size. Stating it in terms of increase in ESI per hectare or percent increase in ESI addresses this problem.

In Matiguás-Río Blanco, the increase in ESI points is greatest in absolute terms for non-poor households, but poor households follow close behind, and the difference is not statistically significant. Poor households do even better in proportional change in ESI. Extremely poor households trail, but the difference is not statistically significant. Extremely poor households had the highest initial ESI/ha, however, so they may have had less scope for substantial improvements. In Quindío, the absolute increase in ESI points is smallest for low income households and largest for high income households, but in relative terms the 55% increase achieved by low income households exceeded the 41% achieved by middle income households and rivaled the 67% of high income households. Once again, these differences are not statistically significant.

3.3 Explaining participation decisions

Examination of observed land use change indicates that poorer households are in fact able to participate quite extensively in the Silvopastoral Project's PES scheme, even though it requires some technically complex and onerous land use changes. Participation rates by poorer households are broadly similar to those of better off households at both sites—lower by some measures, but higher by others. To shed further light on participation decisions and the factors that may affect them, we undertook econometric analyses of participation rates at both sites.

The literature on adoption decisions usually looks at the binary choice of whether or not to adopt a given practice, using cross-sectional data on adopters and non-adopters, and the effect of different factors on the probability of adoption (Pattanayak *et al.*, 2003). This approach is not relevant in our case because project funding limited the number of participants and because a binary adoption/non-adoption choice would fail to capture the nature of participation in the project. Rather than participation per se, what is of interest here is how household characteristics affect the intensity of participation, with a particular focus on whether poorer households are less able to participate than better-off households. Our approach is similar to that of Nkonya *et al.* (1997), who examined the intensity of adoption of improved seed in Tanzania using continuous variables (hectares planted with improved maize seed or amount of fertilizer applied per hectare of maize), and of Rajasekharan and Veeraputhran (2002), who examine the share of farms using intercropping in Kerala, India.

We run five different regressions for each site, using the indices of participation discussed earlier (area converted, share of farm converted, absolute change in ESI points, percent change in ESI points, and change in ESI points/ha). Similar to Rajasekharan and Veeraputhran (2002)[11], we employed a one-tailed Tobit to model farm area, as this variable is restricted to non-negative values. Likewise we employed a two-tailed Tobit model to model the percentage of the farm area converted, as this ranges between 0 and 100. Change in ESI, change in ESI per hectare, and percent change in ESI can take any value, and so are modeled using ordinary least squares (OLS).

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[11] Rajasekharan and Veeraputhran (2002) employed a one-tailed Tobit to study the adoption of intercropping in three regions in Kerala, India using the share of farm area under intercropping as the dependent variable.

Our choice of explanatory variables draws on the factors identified by Pagiola *et al*. (2005) as likely to affect participation in PES, and by Pattanayak *et al*. (2003) and the studies they cite as likely to affect adoption of agroforestry practices, as discussed below. The number of explanatory variables that could be included was limited by the relatively small sample size at both sites. In this case, increasing the sample was not an option: our data include every single PES recipient at both sites. Fortunately, the small size of the sites means that many potential explanatory variables vary little across households, and thus can be safely omitted.

Tables 7 and 8 present the estimation results for the two sites.[12] The first two columns in each table report the results of Tobit models for area changed and proportion of farm changed, and the last three columns the results for the OLS models for change in ESI, percentage change in ESI, and change in ESI per hectare. Measures of model fit are relatively low, but this is not surprising with cross-sectional data, particularly when sample sizes are small. They are comparable to those obtained by Rajasekharan and Veeraputhran (2002) and Ervin and Ervin (1982).

The first group of independent variables examines the effect of farm characteristics. Many previous studies report a positive effect of farm size on adoption of various practices, which has been interpreted as indicating higher flexibility of the farming system or the existence of economies of scale (Rajasekharan and Veeraputhran, 2002; Thacher *et al*., 1997; Nowak, 1987). At our sites, farm area is positively associated with intensity of adoption measured in area converted at both sites, but has a small and non-significant impact on most other indicators of participation. This suggests that the correlation between farm size and area converted is simply due to larger farms having more area to convert.

Labor availability would seem likely to be important, although it is not often significant (Pattanayak *et al*., 2003). We include a measure of the hours per week worked on the farm. Family labor is significant and positive in the farm area model in Quindío, but gives non-significant results in the farm share and ESI models, and in all the models in Matiguás-Río Blanco. This is not surprising, as the relationship between land use change and labor use is complex: switching to higher ESI land uses does not necessarily increase labor use. Interestingly, the age of the household head has a consistent, statistically significant negative impact on intensity of participation in all models in Matiguás-Río Blanco, but generally small and non-significant impacts in Quindío. Other studies have often found a positive effect, though rarely a significant one and have generally attributed it to experience reducing the risk of adoption (Pattanayak *et al*., 2003); an alternative explanation, and one consistent with the Matiguás-Río Blanco results, is that older farmers may be less inclined to make changes. Whether households were male-headed did not have a significant impact on participation at either site under all formulations.

The second group of independent variables concerns factors likely to affect the profitability of adoption. As our study areas are small (particularly Matiguás-Río Blanco), most

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[12] OLS models were tested for heteroscedasticity in the error distribution using the Breusch-Pagan test. Results for these tests rejected the null hypothesis of homoscedasticity of errors, which if ignored would result in the lost of optimality of the OLS estimator (Greene, 2000; Mittelhammer *et al*., 2000). In the absence of prior information about the structure of the heteroscedasticity, we used the OLS estimator with White's heteroscedasticity-consistent covariance matrix estimator (White, 1980). We found no evidence of either moderate or strong muticollinerarity in any of the regression models using the Belsley *et al*. (1980) diagnostics in OLS models and the Belsley (1991) diagnostic in the Tobit models.

farms face similar prices for inputs and outputs, and have similar yield potentials. The profitability of the various silvopastoral practices should thus be broadly similar throughout each area. Farmers with lower accessibility will tend to face higher input costs and lower output prices at the farm gate. Indeed, we find that distance from the nearest village has a significant negative impact on the extent of area converted in Quindío, though the impact on ESI is not significant. In Matiguás-Río Blanco, where distances are smaller but roads are worse, whether farms have year-round access had strong positive impacts on changes expressed in ESI, but not on area-based indicators.

The proportion of the farm on flat terrain has a negative impact in Quindío, but it is not significant except in some of the ESI models. In Matiguás-Río Blanco we expressed this variable as a proportion of the farm on hilly terrain, but found it not to be significant in any model. In general, there is no strong a priori reason to expect a particular sign on topography variables. Land on steep slopes may benefit more from silvopastoral practices in that it is more vulnerable to degradation under traditional extensive grazing. On the other hand, the cost of implementing practices may be higher.

In Quindío, herd size has a significant positive impact in the ESI models but not in the area models, suggesting that its impact is primarily through its demand for fodder rather than through its contribution to financing.

The third group of independent variables includes factors that have been hypothesized to affect the ability of households to participate in the scheme.[13] The ability to finance the necessary investments is one potential obstacle. To examine whether initial investment costs affect ability to participate, we include variables a measure of assets in the Quindío analysis. In Matiguás-Río Blanco, where initial assets vary relatively little, we use access to credit, measured as a binary indicator of whether a household had access to credit during the five years prior to project implementation.[14] We also include off-farm income, measured as the income share of off-farm jobs held by all household members. Off-farm income can be a financing source for investment in new practices, but can also result in a higher opportunity cost of labor.

In Matiguás-Río Blanco, both access to credit and off-farm income had a positive impact on intensity of participation in every model, although only that of off-farm income was significant. The non-significance of credit is surprising, given the cost of implementing some of the practices promoted by the Silvopastoral Project and the low income levels of most households. The first-year survey of participants provides the explanation for this result: most households, even in poor areas such as Matiguás-Río Blanco, have a variety of ways of finance investments (Pagiola *et al*., 2008). Some investments were undertaken entirely with family labor and so did not require financing. Unsurprisingly in a livestock-producing area, the sale of animals was the most frequently mentioned source of funds (61% of all households). The project's initial 'baseline' payment also played an important role for many households (53%). Although almost no households mentioned off-farm income as a source of financing, it is

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[13] Within these factors, tenure is not an issue at either site, as both were selected partly for the absence of such problems.

[14] The endogeneity of credit was tested using the Wu-Hausman and Hausman tests in the OLS models and the Smith-Blundell test in the Tobit models. Exogeneity of credit was not rejected in any model at the 90% confidence level.

possible that such income contributed primarily through its contribution to savings, which was an important source of financing for 41% of households.

In Quindío, household assets had a very small but negative sign, in all formulations, but they are not significant. Off-farm income had a mostly negative, but also not significant, effect on adoption intensity in Quindío. These results are consistent with an interpretation of off-farm employment increasing the opportunity cost of labor. Savings were the most often cited source of financing for first-year investments in Quindío, followed by animal sales; baseline payments played a very small role, probably because low initial ESI points meant that these payments were small.

The technical difficulty of adopting silvopastoral practices is the other main potential obstacle to household participation. To test the importance of this factor, the project provided technical assistance (TA) to a randomly-selected subset of PES recipients. The results were strikingly different across the two sites. In Matiguás-Río Blanco, access to the project's TA wasn't significant under any formulation, while in Quindío it was significant under every formulation. The explanation for the lack of significance in Matiguás-Río Blanco is probably twofold: first, as noted above, silvopastoral practices were already relatively well known in the area prior to the project. Second, the very small size of the site probably made it much easier for households who did not receive TA directly to learn from their neighbors who did. In contrast, silvopastoral practices were practically unknown in Quindío prior to the project, and the larger spatial size of the site (and, hence, the much lower density of recipients in the overall farm population) made TA play a much more important role.

The strongest result in the Quindío models is that being a PES recipient has a large positive impact on the extent of adoption of silvopastoral measures, irrespective of how adoption is measured. This confirms the observed sharp contrast in land use change between PES recipients and control group measures, and indicates that the contrast was not due to self-selection of strongly motivated land users into the scheme or to differences in characteristics across groups. The Matiguás-Río Blanco results also show a strong positive impact of being a PES recipient, but given the concerns over the quality of the control group we cannot treat this result as more than suggestive.

As poverty is multidimensional, we also include dummies for the income groups, with the best-off income group omitted, to capture other aspects of poverty that may not be captured by the previous variables. These dummies show some interesting patterns at both sites. In Matiguás-Río Blanco, poor (but not extremely poor) households have higher levels of participation than non-poor households in every model. Extremely poor households, on the other hand, have lower levels of participation than non-poor households in terms of area converted and in most ESI models. None of these differences is statistically significant, however. These results confirm the patterns seen in Table 5. In Quindío, both the low income and the middle income group dummies have a mix of positive and negative coefficients, but except in one case the effect isn't statistically significant. This suggests that income level has relatively little impact on participation that isn't already captured by other variables (such as farm size) which may be correlated with poverty. The only significant impact is that middle income households convert a lower share of their farm than high income households. This may well be due to that group using a portion of their farm for other productive activities – indeed, low income households actually expanded the area under shade-grown coffee to a small extent, and replaced part of their monoculture fruit crop areas with diversified fruit crops.

4. Conclusions

Can poorer households participate in PES scheme? The experience of the Silvopastoral Project in both Matiguás-Río Blanco and Quindío indicates that they can. Not only did poorer households participate quite extensively, but by some measures they participated to a greater extent than better-off households in Matiguás-Río Blanco. Participation by poorer households was somewhat lower in Quindío, but the differences were not statistically significant. Even the poorest households at both sites participated at high rates in the project. And again their participation was not limited solely to the simpler and cheaper practices. These results are particularly strong in that the Silvopastoral Project imposes much greater burdens on participants than most PES schemes. They bode well for the prospects of poor households being able to participate in PES schemes financed from Reduced Emissions for Deforestation or Forest Degradation (REDD) payments, as these schemes are likely to focus on much simpler and less costly forest conservation measures.

This conclusion obviously needs to be approached with some caution. It is possible that the high levels of participation by poorer households are due to self-selection bias: only those households able to participate may have joined. We believe this is unlikely, for two reasons. First, the project offered a very wide range of participation options, including many that are not very onerous, even for poorer households. Indeed, households could in principle have done absolutely nothing; they would then have received the baseline payment but would not have received any payment beyond that. In fact, no household chose that route. Second, many non-participating households at both sites wanted to participate as well, but were prevented from doing so by the project's own limits on the number it could accept. But even if there were some self-selection at play, it is significant that in a poor area such as Matiguás-Río Blanco there are many poor households—including many extremely poor households—that are able to participate in a PES schemes, and even to undertake expensive and technically challenging land use practices.

Nevertheless, one should not jump to the sanguine conclusion that all poor farm households everywhere will always be able to participate in PES schemes.[15] Both PES schemes and local conditions differ from case to case, and there may well be cases where otherwise eligible poor households may find it difficult or impossible to participate. Indeed, results at both sites show that the poorest households – although by no means shut out – do appear to have had greater difficulty in participating as intensively as better-off households.

Our detailed results help us identify several specific factors that tend to affect participation. This information can help design PES schemes to reduce potential obstacles to the participation of poorer households. There is little that a PES scheme can do about poorer farms being less accessible, but it can do something about financing constraints and technical difficulty.

The significance of credit underlines an important potential constraint for poorer households. This constraint will not always be present in PES schemes. When schemes require maintaining existing practices—as in the majority of contracts in Costa Rica's scheme, for example, and as in prospective REDD-financed schemes—there are few or no investment

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[15] It is also important to recall that this case study does not speak to possible differences in eligibility to participate, due to spatial considerations or tenure problems. Pagiola and Colom (2006) find that the areas in Guatemala that are important for the provision of water services do not always have high poverty rates.

requirements.[16] Financing constraints may be important when land use changes are required for participation, however, as in Costa Rica's Reforestation or Agroforestry contracts. Our results suggest that this constraint is not absolute, as it is sometimes made out to be. Even poor households such as those in Matiguás-Río Blanco often have a variety of ways to finance profitable investments. Nevertheless, it is likely that poorer households will have fewer such alternatives: fewer savings, fewer assets that might be sold, worse access to credit. Providing some initial financing (such as the baseline payment made by the Silvopastoral Project) may be desirable for PES schemes that involve initial investments in areas with many poor households.[17]

Our results also highlight the need to understand whether TA may be required. The need for TA appears to be linked more with prior experience than with poverty, however. When PES schemes require participants to adopt relatively well known practices, TA may be of minor importance. Conversely, when participation requires adoption of practices that are not widely used, even relatively well off households such as those in Quindío may need TA.

The availability of multiple options in the Silvopastoral Project may well have contributed to high participation by poorer households, as they were able to choose the options that work best for them, in light of their particular constraints. When there are multiple ways of providing a service (or different levels of a service), it makes sense to offer multiple ways in which households can participate, as long as transaction costs do not increase unduly. It is interesting to note, however, that at our sites the poorest households did not choose the cheaper and easier land uses – in fact, it was the better off households that did so in Matiguás-Río Blanco, and the middle income group that did so in Quindío.

In general, transaction costs are likely to be a bigger threat to the participation of poorer households in PES schemes then their own ability to participate (Pagiola *et al.*, 2005). Our results illustrate this. As can be seen in Table 6, low income households in Quindío converted 40% of their farms, on average, and increased their ESI score by about 55%. These participation rates are not far below those of high income households, who converted 55% of their farms and increased their ESI score by 67%. But from the perspective of the service buyer, what matters is the total absolute increase in environmental service generation (whether proxied by area, as is commonly the case, or by more sophisticated measures such as the ESI), and the unit cost of achieving it. The cost, in turn, has two components: the cost of the payment, which is identical for a given increase in ESI for all households, and the transaction cost of contracting with each household. This second cost is likely to be largely fixed per household, irrespective of farm size. Thus high income households converted a total of 342ha and achieved a total increase in ESI of 259 points. At first glance, the results for low income households appear similar: they converted a total of 283ha and achieved a total increase in ESI of 242 points. The number of low income households is much larger, however, so on a per contract basis, the comparison is less favorable: low income households converted 9.4ha and increased ESI by 8.1 points per contract, while high income households converted 34.2ha and increased ESI by 25.9 points per contract. It takes more than three contracts with low income households, therefore, to achieve the same results as a single contract with a high income household. Very similar relationships can be seen in the

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16 Even forest conservation may require out-of-pocket expenditures by participating households, for example to fence off forests receiving conservation contracts or undertake measures to prevent forest fires. These costs are much lower, however, than those that they would face if land use changes were required.

17 Costa Rica frontloads payments under its timber plantation contract for this reason. Frontloaded payments, however, introduce other problems, as they reduce the conditionality of the scheme.

Matiguás-Río Blanco case (Table 5). Thus, the larger the transaction costs, the more attractive it will be for PES schemes to focus on large land holdings. As farm size tends to be highly correlated with income, in practice this will mean focusing on better-off households. This is not a purely hypothetical concern: In Ecuador, the PROFAFOR scheme has decided to adopt a 50ha minimum size for the forest plantations from which it buys carbon sequestration services (Wunder and Albán, 2008).

Keeping transaction costs low—in addition to being desirable in itself—is thus imperative if poorer households are not be shut out of many PES schemes.[18] But the smaller farm size of many poor households means they will always have relatively higher transactions costs. It is thus important to attempt to devise mechanisms to overcome them. Costa Rica, for example, experimented with collective contracting, under which groups of small farmers joined the country's PES scheme collectively rather than individually, thus spreading transaction costs over a large group. This approach ran into problems, however, as non-compliance by a single group member resulted in payments being halted to all members. The approach has thus been revised to process the applications of such groups together, but then issue individual contracts; this avoids the partial compliance problem, but has much smaller savings in transaction costs (Pagiola, 2008). This is clearly an area in which more work—and some imaginative solutions—will be necessary. This is also an area in which development aid could be used to leverage PES schemes by providing support to the participation of poorer households, and in particular by underwriting some of the transaction costs involved.

[18] The Silvopastoral Project as presently conducted is a poor example of this, as it has relatively high monitoring costs dictated in part by its pilot nature and in part by the need to distinguish small differences in land use so as to compute ESI scores. Work is underway under the project to determine the nature of the tradeoff between monitoring costs and effectiveness.

Appendix: Data sources

To examine participation decisions, we used three data sets. The first is the baseline survey conducted in October-November 2002, during project preparation. This survey included very detailed information on household characteristics. A second survey of participants was conducted in March-May 2004, after the first year of project implementation. This survey collected information on land use changes that occurred in the intervening period. The questionnaires for the surveys are available from the authors on request.

Information from these two surveys was complemented with detailed land use data for each farm, derived from maps prepared annually by the project between 2003 and 2007 for each farm using remote sensing imagery. Quickbird imagery with a 61cm resolution was used, providing very high levels of detail. Land use maps for each farm derived from these images were then extensively ground-truthed to match each plot to one of the 28 different land uses recognized by the project. These maps provide accurate and consistent measures of area.

Both the baseline and follow-up surveys included a control group, as does the mapping dataset. The main intended purpose of this group was to attempt to distinguish project-induced land use changes from changes induced by other factors (Ferraro and Pattanayak, 2006). In an earlier paper (Pagiola *et al*., 2008), we found that control group members in Matiguás-Río Blanco differed from PES recipients in many important characteristics (such as income, farm size, or herd size), as so we decided that using the control group would not be useful. We retain the Matiguás-Río Blanco control group here to ease comparability with the Quindío analysis, but caution against placing much significance in differences between the control group and PES recipients.

At the beginning of the project, US$1=C$14.25 and US$1=COP2,670. All exchange rates and inflation adjustments are based on the World Bank's *World Development Indicators* database.

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Table 1: Land use among Silvopastoral Project PES recipients, Matiguás-Río Blanco, Nicaragua

(ha, unless otherwise noted)

Land use	*Environmental services index (points/ha)*	*Before project (2003)*		*Year 4 of project (2007)*	
		(ha)	*(%)*	*(ha)*	*(%)*
Infrastructure, housing, and roads	0.0	11.4	0.4	14.8	0.5
Annual crops	0.0	212.0	7.6	78.6	2.8
Degraded pasture	0.0	780.6	28.0	147.6	5.3
Natural pasture without trees	0.2	43.0	1.5	27.9	1.0
Improved pasture without trees	0.5	22.6	0.8	25.6	0.9
Semi-permanent crops	0.5	37.0	1.3	18.8	0.7
Natural pasture with low tree density	0.6	279.3	10.0	231.5	8.3
Fodder bank[a]	0.8	79.8	2.9	238.9	8.6
Improved pasture with low tree density	0.9	134.4	4.8	213.6	7.7
Natural pasture with high tree density[b]	1.0	338.1	12.1	522.4	18.7
Diversified fruit crops[a]	1.1	18.5	0.7	23.8	0.9
Monoculture timber plantation	1.2	1.1	0.0	4.7	0.2
Improved pasture with high tree density[b]	1.3	151.3	5.4	537.8	19.3
Scrub habitats (tacotales)	1.4	137.7	4.9	134.3	4.8
Secondary and riparian forest[a]	1.7	543.2	19.5	569.8	20.4
Total area		**2,790.0**	**100.0**	**2,790.0**	**100.0**
Live fence (km)	1.1	115.8		325.5	

Notes: Totals may not add up because of rounding

Land uses recognized by the project but not found at this site are omitted.

Includes land use by PES recipients only.

[a] Similar land uses with small areas have been aggregated; ESI shown is for use with largest area.

[b] The project distinguishes land uses with recently planted trees from the same land uses with mature trees for the purpose of computing the ESI score; here these land uses have been aggregated to their mature state, and the corresponding ESI score is shown.

Sources: ESI score from Silvopastoral Project manual (CIPAV, 2003); land use from Silvopastoral Project, based on analysis of remote sensing imagery verified in the field

Table 2. Land use among Silvopastoral Project PES recipients, Quindío, Colombia

	Environmental services index (points/ha)	*Before project (2003)*		*Year 4 of project (2007)*	
		(ha)	*(%)*	*(ha)*	*(%)*
Annual crops	0.0	37.9	1.3	37.2	1.3
Degraded pasture	0.0	78.3	2.7	7.1	2.7
Natural pasture without trees	0.2	721.5	24.9	239.5	24.9
Improved pasture without trees	0.5	1,078.8	37.3	873.0	37.3
Semi-permanent crops (plantain, sun coffee)	0.5	184.1	6.4	148.4	6.4
Natural pasture with low tree density (< 30/ha)	0.6	6.2	0.2	10.4	0.2
Diversified fruit crops	0.7	73.7	1.9	59.7	1.9
Fodder banks[a]	0.8	4.6	0.0	27.5	0.0
Improved pasture with low tree density (< 30/ha)	0.9	54.8	2.5	333.4	2.5
Natural pasture with high tree density (>30/ha)[b]	1.0	0.0	0.2	67.9	0.2
Shade-grown coffee	1.3	23.5	0.8	33.8	0.8
Improved pasture with high tree density (>30/ha)[b]	1.3	2.2	0.1	266.5	0.1
Bamboo (*guadua*) forest	1.3	43.9	1.5	52.6	1.5
Timber plantation[a]	1.4	0.0	0.0	5.5	0.0
Scrub habitat (*tacotales*)	1.4	48.8	1.7	42.0	1.7
Riparian forest	1.5	369.2	12.8	392.8	12.8
Intensive silvopastoral system	1.6	0.0	0.0	130.2	0.0
Primary and secondary forest[a]	2.0	165.7	5.7	165.7	5.7
Total area		2,893.2	**100.0**	2,893.2	**100.0**
Recently established live fence (km)		1.4		255.5	
Multistory live fence or wind break (km)		0.7		92.9	

Notes: Totals may not add up because of rounding.
Includes all land in farms of PES recipients.
Land uses recognized by the project but not found at this site are omitted.
a. Similar land uses with small areas have been aggregated; ESI shown is for use with largest area.
b. The project distinguishes land uses with recently planted trees from the same land uses with mature trees for the purpose of computing the ESI score; here these land uses have been aggregated to their mature state, and the corresponding ESI score is shown.

Sources: ESI from CIPAV (2003); land use from Silvopastoral Project mapping data.

Table 3: Characteristics of participating households, Matiguás-Río Blanco, Nicaragua

Variable	*PES recipients* Extremely poor	Poor	Non-on-poor	All	*Control group*	*Entire sample*
Income per capita ('000 C$)	-2.9[ab]	4.2[ac]	15.8[bc]	4.5	-7.5	2.0
Assets ('000 C$)	7.3	11.7	2.6	6.8	21.4	9.8
Farm area (ha)	23.7[b]	30.9	40.1[b]	30.3[d]	48.2[d]	34.0
Cattle (livestock units)	13.7[b]	14.0[c]	32.8[b]	19.8[d]	36.8[d]	23.3
Hilly topography (% farm area)	16.2	15.0	24.9	18.7	23.0	19.6
Water (% with water service)	20.5[b]	21.1	41.4[b]	27.2	25.0	26.7
Electricity (% with electric service)	2.3[b]	0.0[c]	17.2[bc]	6.5	16.7	8.6
Access by road all year round (%)	79.5[b]	84.2	96.6[b]	85.9[d]	100.0[d]	88.8
Paved road (%)	6.8	10.5	20.7	12.0	20.8	13.8
Family labor (hours/ha/week)	5.4[ab]	3.1[a]	3.1[b]	4.2	3.4	4.0
Household size (members)	7.7[ab]	6.2[ac]	4.8[bc]	6.4[d]	5.1[d]	6.2
Dependency ratio (children per adult)	1.0[ab]	0.6[a]	0.6[b]	0.8	0.7	0.8
Experience (years)	10.0	13.7	13.3	11.8	10.0	11.4
Education of household head (years)	2.3	3.4	3.1	2.8	3.8	3.0
Male headed household (%)	86.4	94.7	96.6	91.3	87.5	90.5
Off-farm work (% with off-farm employment)	22.7	26.3	10.3	19.6[d]	4.2[d]	16.4
Off-farm income (% of total income)	-0.8	0.1	0.0	-0.4	0.0	-0.3
Non-farm enterprise (% owners)	18.2	10.5	24.1	18.5[d]	4.2[d]	15.5
Technical assistance (% with current access)	25.0	31.6	31.0	28.3[d]	12.5[d]	25.0

Notes: [a],[b],[c],[d], indicate means are significantly different in paired t-test at 10% test level. Extremely poor < C$2943; poor >=C$2943, < C$5639; non-poor >= C$5639. Children are household members under 12.

Table 4: Characteristics of participating households, Quindío, Colombia

Variable	*PES recipients* *Low income*	*Middle income*	*High income*	*All*	*Control group*	*Entire sample*
Income per capita (million COP)	-0.7[ab]	7.0[ac]	39.9[bc]	8.2	14.3	10.0
Assets (million COP)	4.8[ab]	8.8[a]	17.9[b]	8.4	8.7	8.5
Farm area (ha)	23.3[ab]	49.2[a]	62.1[b]	40.2[d]	25.4[d]	36.0
Cattle (livestock units)	44.3[a]	77.4[b]	184.2[ab]	60.1	48.5	56.8
Flat (% farm area)	19.1	25.9	24.5	22.9[d]	36.9[d]	26.9
Distance to nearest village (km)	7.9[a]	7.2	4.3[a]	7.1[d]	5.24[d]	6.6
Water (% with water service)	90.0[a]	96.9	100.0[a]	94.4	96.6	95.0
Farm resident (%)	36.7	22.0	40.0	30.6	17.2	26.7
Family labor (man-days/ha/yr)	11.1[a]	7.4[b]	3.1[ab]	8.3	nd	nd
Household size (members)	5.2[a]	4.9[b]	3.6[ab]	4.9[d]	3.7[d]	4.5
Dependency ratio (children per adult)	0.25[a]	0.55[a]	0.36	0.40[d]	0.22[d]	0.35
Age of household head (years)	46.8[ab]	40.7[a]	38.7[b]	42.9	43.9	43.2
Literacy of household head (%)	96.7	93.8	100.0	95.8	93.1	95.1
Education of household head (years)	4.0[a]	5.2	8.6[a]	5.2	4.3	4.9
Off-farm work (% with off-farm employment)	10.0	15.6	20.0	13.9	10.3	12.9
Technical assistance (% with current access)	33.3	34.4	50.0	36.1[d]	10.3[d]	28.7
Credit (% with access to credit)	23.3	25.0	40.0	26.4	13.8	22.8
Number of observations	30	32	10	72	29	101

Notes: [a],[b],[c],[d] indicate means are significantly different in paired t-test at 10% test level. nd = no data. Low income < COP2 million; middle income >= COP2 million, < COP20 million; high income >= COP20 million. Children are household members under 12

Table 5: Participation rates among PES recipients by income group, Matiguás-Río Blanco, Nicaragua

Income group	*Total land (ha)*	*Change in land use (ha)*	*Change in land use (%)*	*Live fencing Initial (km)*	*Live fencing Increase (km)*	*Live fencing Increase (%)*	*Environmental services index (total points) Initial*	*(total points) Increase*	*(points/ha) Initial*	*(points/ha) Increase*	*Change (%)*
Per household:											
Extremely poor	23.7	10.0	42.2	0.93	1.96	212	19.0	7.9	0.80	0.33	41.6
Poor	30.9	17.7	57.4	1.24	2.32	N/A	21.4	15.3	0.69	0.50	71.4
Non-poor	40.1	19.5	48.8	1.77	2.73	154	28.4	16.0	0.71	0.40	56.1
All	**30.3**	**14.6**	**48.2**	**1.26**	**2.28**	**181**	**22.5**	**12.0**	**0.74**	**0.39**	**53.2**
Total area:											
Extremely poor	1,041.9	440.1	42.2	40.81	86.44	212	837.0	348.5	0.80	0.33	41.6
Poor	586.5	336.6	57.4	23.53	44.02	187	407.3	290.7	0.69	0.50	71.4
Non-poor	1,161.6	566.8	48.8	51.46	79.20	154	824.9	462.6	0.71	0.40	56.1
All	**2,790.0**	**1,343.5**	**48.2**	**115.80**	**209.66**	**181**	**2,069.3**	**1,101.8**	**0.74**	**0.39**	**53.2**

Notes: Totals may not add up because of rounding.

Sources: Computed from Silvopastoral Project mapping data.

Table 6: Participation rates among PES recipients by income group, Quindío, Colombia

Income group	*Total land (ha)*	*Change in land use (ha)*	*Change in land use (%)*	*Live fencing Initial (km)*	*Live fencing Increase (km)*	*Environmental services index (total points) Initial*	*(total points) Increase*	*(points/ha) Initial*	*(points/ha) Increase*	*Change (%)*
Per household:										
Low income	23.3	9.4	40.4	0.02	3.62	14.6	8.1	0.63	0.35	55.3
Middle income	49.2	19.8	40.3	0.04	5.38	34.2	13.9	0.69	0.28	40.7
High income	62.1	34.2	55.0	0.04	6.55	38.4	25.9	0.62	0.42	67.3
All	**40.2**	**17.5**	**43.5**	**0.03**	**4.81**	**26.6**	**13.1**	**0.66**	**0.33**	**49.4**
Total area:										
Low income	698.8	282.5	40.4	0.49	108.71	437.4	241.7	0.63	0.35	55.3
Middle income	1,573.3	633.8	40.3	1.21	172.03	1,093.1	444.8	0.69	0.28	40.7
High income	621.1	341.6	55.0	0.37	65.54	384.5	258.7	0.62	0.42	67.3
All	**2,893.2**	**1,257.9**	**43.5**	**2.07**	**346.28**	**1,915.0**	**945.2**	**0.66**	**0.33**	**49.4**

Notes: Totals may not add up because of rounding.

Sources: Computed from Silvopastoral Project mapping data.

Table 7: Estimation results, Matiguás-Río Blanco, Nicaragua

		Dependent variable				
		Area changed (ha)	*Proportion of farm changed (%)*	*Change in ESI (points)*	*% change in ESI*	*Change in ESI per ha*
Independent Variable	*Model:*	*Tobit*	*Tobit*	*OLS*	*OLS*	*OLS*
Constant		-1.085	41.370***	54.572	0.137	-8.310**
		(3.997)	(9.622)	(35.037)	(0.110)	(3.883)
Farm area (ha)		0.374***	0.068	0.176	0.002	0.410***
		(0.075)	(0.094)	(0.318)	(0.001)	(0.081)
Family labor (hours/week/ha)		-0.039	-0.219**	-0.612	-0.003**	-0.105
		(0.072)	(0.109)	(0.380)	(0.001)	(0.075)
Livestock units		-0.080	0.314	-0.355	-0.000	0.076
		(0.165)	(0.566)	(1.456)	(0.006)	(0.170)
Age of household head (years)		-0.203**	-0.583***	-1.779***	-0.005**	-0.169**
		(0.084)	(0.152)	(0.620)	(0.002)	(0.082)
Male-headed household (1=yes, 0=no)		1.792	-1.548	14.579	0.079	3.283
		(2.750)	(4.725)	(18.895)	(0.048)	(2.675)
Year-round access by road (1=yes)		-0.783	3.860	36.796**	0.145**	3.263*
		(2.703)	(5.853)	(17.804)	(0.061)	(1.784)
Hilly topography (% farm area)		-0.004	0.073	-0.021	0.000	-0.035
		(0.023)	(0.053)	(0.204)	(0.001)	(0.026)
Access to credit (1=yes)		2.127	5.998*	12.713	0.079*	2.304
		(1.546)	(3.261)	(14.034)	(0.043)	(1.481)
Income share of off-farm job		0.081**	0.235**	1.970***	0.012***	0.188***
		(0.040)	(0.103)	(0.389)	(0.001)	(0.041)
Technical assistance from project (1=yes)		-1.114	-2.147	-6.648	-0.058	-1.616
		(1.650)	(3.652)	(13.664)	(0.043)	(1.541)
PES recipient (1=yes)		7.579***	11.744***	-7.395	0.103*	6.548**
		(2.432)	(4.548)	(17.829)	(0.059)	(2.534)
Poor (1=poor)		1.753	1.797	18.599	0.075	3.465
		(2.392)	(5.287)	(22.324)	(0.066)	(2.421)
Extremely poor (1=extremely poor)		-2.700	-5.444	-0.962	0.004	-1.761
		(1.812)	(4.252)	(15.576)	(0.057)	(1.941)
R^2				0.016	0.092	0.527
Pseudo R^2		0.639	0.211			
Number of observations		116	116	116	116	116

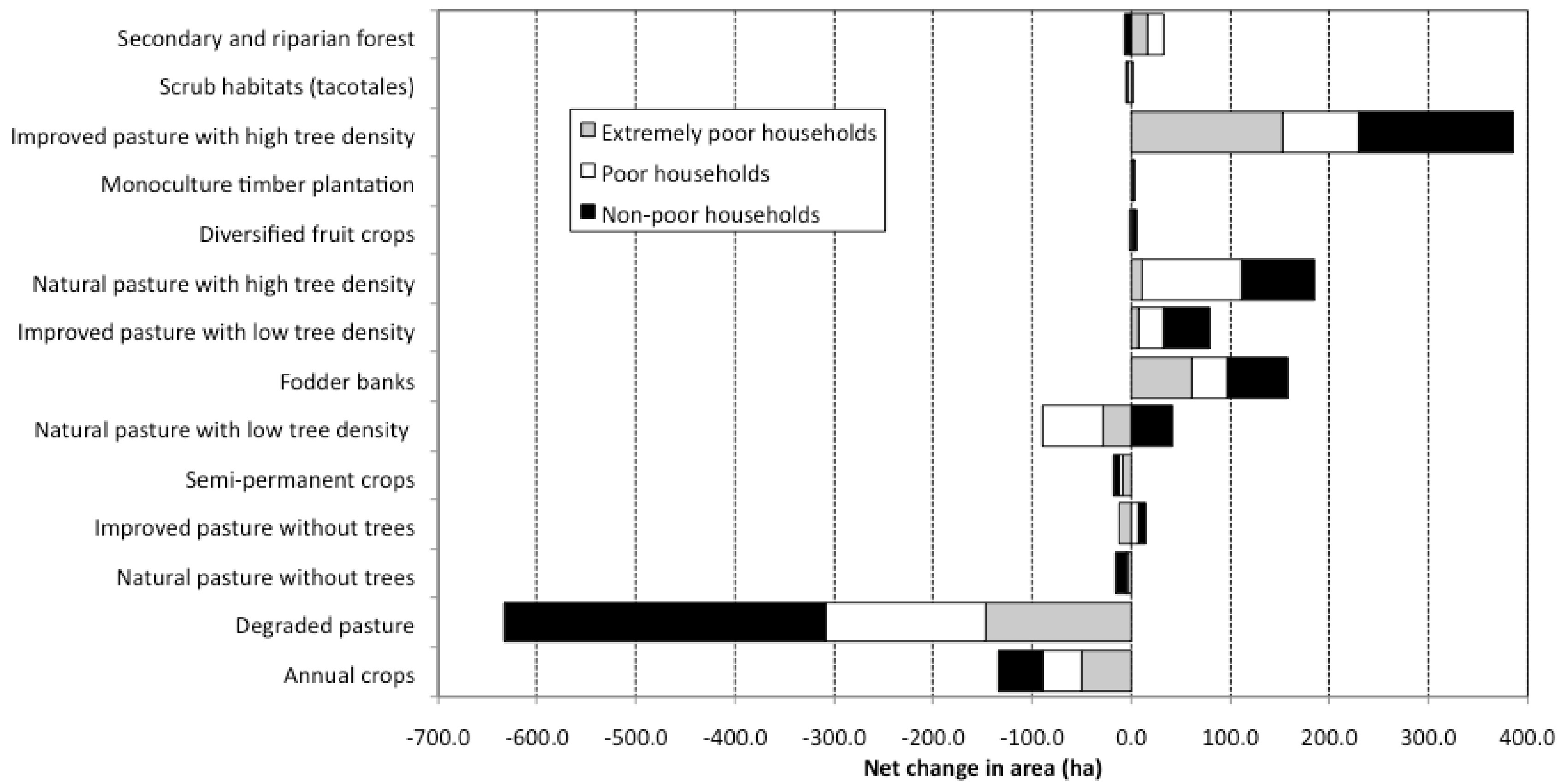
Notes: Standard errors in parentheses; robust standard errors for OLS coefficients.
*, **, *** indicates coefficient estimate is significantly different from zero at 90%, 95%, or 99% confidence level.

Table 8: Estimation results, Quindío, Colombia

		Dependent variable				
		Area changed (ha)	*Proportion of farm changed (%)*	*Change in ESI (points)*	*Change in ESI (%)*	*Change in ESI per ha*
Independent Variable	*Model:*	*Tobit*	*Tobit*	*OLS*	*OLS*	*OLS*
Constant		-20.433*	26.779	-12.931**	45.900	0.255*
		(10.755)	(20.745)	(6.375)	(29.207)	(0.141)
Farm area (ha)		0.423***	-0.005	0.181***	-0.366***	-0.002***
		(0.070)	(0.054)	(0.036)	(0.097)	(0.000)
Livestock units		0.052	0.004	0.087***	0.306***	0.002***
		(0.036)	(0.044)	(0.020)	(0.086)	(0.000)
Family labor (adults/ha)		9.844**	21.615	3.886	10.923	0.065
		(4.451)	(14.450)	(2.747)	(19.461)	(0.103)
Age of household head (years)		0.119	0.024	0.098	-0.210	-0.002
		(0.089)	(0.254)	(0.062)	(0.341)	(0.002)
Male-headed household (1=yes, 0=no)		6.202	17.067	1.858	-21.439	-0.065
		(3.837)	(10.597)	(2.306)	(20.936)	(0.074)
Distance to nearest village (km)		-0.447*	-1.407***	-0.205	-0.428	-0.006
		(0.242)	(0.517)	(0.179)	(0.946)	(0.005)
Flat topography (% farm area)		-0.028	-0.083	-0.016	-0.263**	-0.001**
		(0.043)	(0.088)	(0.030)	(0.126)	(0.001)
Assets (1,000 COP)		-0.000*	-0.001**	-0.000	-0.001*	-0.000*
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Income share of off-farm job		3.602	-6.877	-0.286	-22.742	-0.136
		(8.430)	(29.262)	(5.106)	(42.335)	(0.287)
Technical assistance from project (1=yes)		7.957**	18.360**	6.355***	42.998***	0.294***
		(3.110)	(8.259)	(1.547)	(11.031)	(0.059)
PES recipient (1=yes)		2.850	9.350	3.630**	15.007	0.079
		(1.961)	(5.995)	(1.504)	(12.790)	(0.065)
Low income (1=low income)		0.774	-11.424	0.905	2.824	-0.020
		(6.144)	(8.509)	(4.315)	(13.441)	(0.068)
Middle income (1=middle income)		0.054	-14.135*	0.680	3.445	0.008
		(5.782)	(7.726)	(3.843)	(11.200)	(0.060)
R^2				0.794	0.298	0.382
Pseudo R^2		0.83	0.22			
Number of observations		101	101	101	101	101

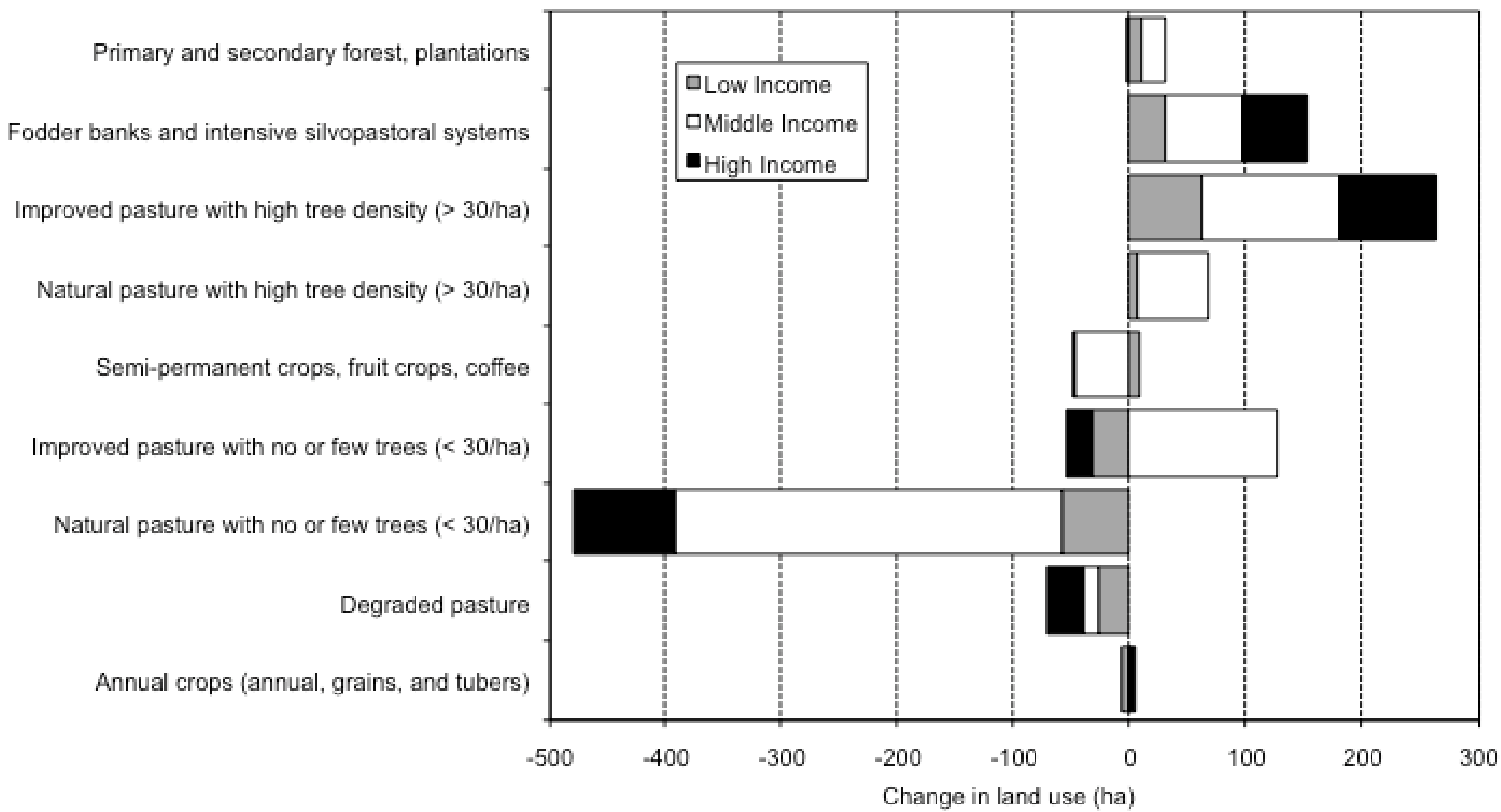
Notes: Robust standard errors in parentheses.
*, **, *** indicates coefficient estimate is significantly different from zero at 90%, 95%, or 99% confidence level.

Figure 1: Land use change during Silvopastoral Project, by income group, Matiguás-Río Blanco, Nicaragua



Source: Authors' computations from Silvopastoral Project mapping data.

Figure 2: Land use change during Silvopastoral Project, by income group, Quindío, Colombia



Source: Authors' computations from Silvopastoral Project mapping data.