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Evaluation of the Impact of Payments for Environmental Services on Land Use Change in Quindío, Colombia

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Abstract

The growing use of Payments for Environmental Services (PES) for conservation has fostered a debate on its effectiveness, but the few efforts to date to assess the impact of PES programs have been hampered by lack of data, leading to very divergent results. This paper uses data from a PES mechanism implemented in Quindío, Colombia, to examine the impact of PES on land use change. Alone among all early PES initiatives, the Silvopastoral Project included a control group of non-participants, whose land use changes were monitored throughout the project period, as well as detailed baseline data on both PES recipients and control group members. By comparing the land use changes undertaken by PES recipients to those undertaken by control group members, we can distinguish the impact of PES from that of other factors. The results show that payments had a positive and highly significant impact on land use change, under a variety of model formulations. PES recipients converted over 40 percent of their farms to environmentally-friendly land uses over 4 years, increasing environmental service provision by almost 50 percent. In contrast, control group members converted less than 20 percent of their farms, increasing environmental service provision by only 7 percent.

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Keywords

Payments for Environmental Services (PES), impact evaluation, livestock, silvopastoral, Colombia

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Cover photo

Cows grazing in an intensive silvopastoral system (iSPS) in Quindío (Stefano Pagiola).

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Introduction

Recent years have seen growing use of Payments for Environmental Services (PES) to finance conservation in developing countries (Wunder, 2005; Pagiola and Platais, 2007; Engel and others, 2008; Wunder and others, 2008). Latin America has been particularly receptive to the PES approach, with programs being implemented in Brazil (Pagiola and others, 2013), Colombia (Blanco, 2006), Costa Rica (Pagiola, 2008), Ecuador (Echavarría, 2002; Wunder and Alban, 2008), Mexico (Muñoz-Piña and others, 2008), and elsewhere, and others under preparation or study in several countries.

The growing use of PES approaches has fostered a debate on their effectiveness (Ferraro and Pattanayak, 2006; Pattanayak and others, 2010). Do they in fact induce land use change? And do they generate the desired services? There have been few efforts to date to assess the impact of PES programs, and those that have been made have been hampered by a lack of data, leading to very divergent results. In particular, very few PES initiative had collected detailed baseline information—not even on participants, in most cases—and almost none had established control groups. Thus analyses have been forced to rely on cross-sectional analyses and on control groups selected *ex post*, typically based primarily on geographic variables rather than also on household variables.

This paper uses data from a PES mechanism implemented in the Quindío area of Colombia to examine the impact of payments on land use change. Quindío was one of three pilot sites for the *Regional Integrated Silvopastoral Ecosystem Management Project*, which used PES to encourage the adoption of silvopastoral practices in degraded pastures, so as to generate increased biodiversity conservation and carbon sequestration (Pagiola and others, 2005a). Alone among all PES initiatives, the Silvopastoral Project included a control group of non-participants, whose land use changes were monitored throughout the project period.[1] The project also collected detailed *ex ante* baseline data on both PES recipients and members of the control group. The Silvopastoral Project thus offers an excellent opportunity to assess the impact of PES. By comparing the land use changes undertaken by PES recipients to those undertaken by farmers in the control group, we can distinguish the impact of payments from that of other factors that affect land use decisions.

We begin by defining PES and examining the debate and evidence to date on its effectiveness in inducing land use change. We then describe the project and its PES mechanism, and the Quindío site. We use detailed monitoring data collected at the

1 Recent PES initiatives have also begun monitoring control groups, but it will be several years before these efforts produce results.

study site to compare the land use changes made by PES recipients to those made by control group members. We first examine the changes introduced by each group, and then undertake an econometric analysis to determine the factors that affect the extent of land use change and the role that payments played in it. We conclude by discussing the implications of our results for PES program design.

Payments for environmental services

PES programs make payments that are conditional on managing natural resources in ways that generate benefits for others (Wunder, 2005; Pagiola and Platais, 2007; Engel and others, 2008). The approach is based on the twin principles that those who benefit from environmental services (such as users of clean water) should pay for them, and that those who contribute to generating these services (such as upstream land users) should be compensated for providing them. It thus seeks to create mechanisms in which service users and service providers can undertake transactions that are in both parties' interests, internalizing what would otherwise be externalities. The PES approach is attractive in that it (i) generates new financing, which would not otherwise be available for conservation; (ii) is likely to be sustainable, as it depends on the mutual self-interest of service users and providers and not on the whims of government or donor financing; (iii) is likely to be efficient, in that it conserves services whose benefits exceed the cost of providing them, and does not conserve services when the opposite is true.

In a PES program, land users are paid to maintain or switch to land uses that provide environmental services that others value. Most PES programs in developing countries focus on forest conservation. The most common contract in Costa Rica's *Programa de Pagos por Servicios Ambientales* (PPSA) program, for example, pays land users to conserve forests (Pagiola, 2008). At the end of 2008, about 10 percent of the country's forest area was enrolled in the program. Likewise, the main window of Mexico's *Pagos por Servicios Ambientales del Bosque* (PSAB) program pays rural communities to conserve their forests (Muñoz-Piña and others, 2008). At the end of 2012, about 2.5 million ha of forest were enrolled. Many local, user-financed programs also focus on forest conservation.

Other PES programs call for active land use changes. Costa Rica's PSA program offers to pay for establishing timber plantations, for forest regeneration, and for planting trees in agroforestry systems (Pagiola, 2008). China's Sloping Lands Conversion Program (SLCP) pays land users to reforest erosion-prone areas (Bennett, 2008). By the end of 2006, the program had retired over 9 million ha of cropland, and had afforested almost 14 million ha of wasteland. Carbon sequestration projects aimed at selling carbon emission reductions to either the Clean Development Mechanism (CDM) or the voluntary market also focus primarily on reforestation and afforestation. The Scolel Té project in Mexico, for example, pays smallholders for carbon sequestration resulting from adoption of agroforestry practices (Tipper, 2002). Wunder (2005) calls these programs "asset-building", in contrast to the "use-restricting" conservation-focused programs.

Assessing the impact of PES

PES programs themselves almost universally limit assessments of their impact to reporting the number of hectares enrolled in the program. Indeed, many like to cite the cumulative area ever enrolled (usually counting areas whose contracts have been renewed twice).

PES works by increasing the returns to particular land uses, thus inducing land users to choose them rather than others. The problem, however, is that many land users might have chosen to undertake those particular land uses even if the PES program had not existed. Land users who had no intention of cutting down their forests would be particularly interested in participating in a program that paid them to conserve it, as they would not face any opportunity cost from doing so. Likewise, those who had intended to reforest would be delighted to be paid to do so. Participation in PES programs, therefore, may be heavily skewed towards land users who would have undertaken the supported land uses anyway. Sheer enrolment figures thus give very little indication of whether a PES program is actually changing the situation on the ground. This issue is known as that of *additionality*: whether the PSA program is actually resulting in land uses changes that are additional to what would have happened in the absence of the program.

Assessments of the impact of PES have generally been based mostly on casual empiricism. For example, Wunder and Albán (2008) argue that the PES mechanism being implemented at Pimampiro, Ecuador, is likely to have resulted in increased forest cover because previous deforestation in the payment area has stopped and native vegetation cover has increased markedly, in contrast to neighboring areas, where deforestation is on-going. This approach can sometimes provide a reasonable degree of confidence—especially if, as in the Pimampiro case, previous trends are reversed in areas where PES is implemented even as they continue elsewhere. But it cannot rule out the possibility that the observed reduction in deforestation was due to some idiosyncratic characteristic of the site—and the fact that PES was implemented at Pimpampiro and not in neighboring areas suggests that some idiosyncratic characteristics are at play. Similarly, Pagiola (2008) notes that no timber plantations have been established in Costa Rica except with PPSA support. Again, this is strongly suggestive but not conclusive, as anyone intending to establish a plantation would be certain to apply for PPSA funding (and would almost certainly get it, as demand for this contract is always far less than available funding would allow). Going further, the very unattractive economics of these plantations—even with PPSA support, as evidenced by the dearth of applications for such contracts—does suggest that PPSA-supported plantations are likely to be additional (Pagiola, 2010). Such analysis can also point to the likelihood of low additionality. Most participants in a PES mechanism in Los Negros, Bolivia, appear to have offered land that was at little or no risk of deforestation, making it likely that additionality was low (Asquith and others, 2008).

Costa Rica's PPSA program illustrates the difficulty of assessing the impact of PES programs (Pagiola, 2008). The high percentage of forest area enrolled in the program, coupled with the country's success at reversing deforestation trends, make it tempting to attribute the latter to the former. Disentangling the effect of the PPSA Program (and its predecessors) from that of other policy measures and broader economic trends is difficult, however. The PPSA program was instituted at the same time as a package of other measures, including a ban on clearing forest land. In a sense, the PPSA program was a *quid pro quo* for legal restrictions on clearing. Without the PPSA carrot, opposition to the legal restrictions might have been much higher. Changes in the profitability of livestock production have also reduced pressure to convert forests to pasture, particularly in marginal areas (White and others, 2001; Arroyo-Mora and others, 2005).

Studies have generally found that PPSA recipients have higher forest cover than non-recipients. Zbinden and Lee (2005) found that PPSA recipients in northern Costa Rica had 61 percent of their farm under forest, compared to only 21 percent for non-recipients, and Sierra and Russman (2006) found that PPSA recipients in the Osa Peninsula had over 92 percent of their farm under forest or bush, compared to 72 percent for non-recipients. Ortiz and others (2003) found that 36 percent of a sample of 100 PPSA participants indicated that forest under conservation contracts had previously been used for pasture. These results are not conclusive, however, as they may be due to sample selection bias. Ortiz and others (2003) and Miranda and others (2003) both found that many PPSA participants stated they would have protected their forest even without the Program. FONAFIFO typically receives applications covering about three times as much land as funds allow for, suggesting that clearing forest is not very profitable in many areas. At the very least, it suggests that FONAFIFO could have enrolled a much larger area with the same budget.

Formal tests of the extent to which the PPSA program has affected forest cover have given mixed results. Tattenbach and others (2006) developed an econometric model of gross deforestation during the period 1996-2000 using district-level data from the Cordillera Volcanica Central Conservation Area. Using their model, they estimated that primary forest cover nationwide in 2005 was about 10 percent greater than it would have been without the PPSA Program. Sills and others (2006) used a propensity score matching method with farm-level data from Sarapiquí from 1997 to 2000 and found evidence that PPSA has encouraged protection of mature native forest. However, a separate test using nationwide district-level data gave inconclusive results. Pfaff and others (2008) compared areas with and without PPSA using pixel-level data from 1997-2000, and found that the PPSA Program had a minimal impact on deforestation during that period. A second analysis using the same approach with data from 2000-2005 found slightly higher but still very low impacts (Robalino and others, 2008). In the most careful study, Arriagada and others (2012) used farm-level data from the region of Sarapiquí to select comparison farms, and found that the program resulted in an increase in forest cover among PPSA recipients of about 11-17 percent of the area under contract over eight years. It is difficult to compare these results, however, as they apply to different areas, different time periods, different dependent variables, and use different methodologies.[2]

[2] In assessing the incremental land use impact of the PPSA program, it should be borne in mind that Costa Rica's PSA program does not require additionality. On the contrary, its approach is to

To date, only two formal assessments of the effect of Mexico's PSAB program on deforestation has been carried out. Alix-Garcia and others (2012) compared deforestation rates among participants enrolled in 2004 to a control group of non-recipients consisting of applicants from 2004 that were rejected on the basis of administrative or geographic details (such as missing paperwork) and participants who enrolled in the program two years later, in 2006.[3] They found that PSAB reduced deforestation among participants by about 50 percent, but that the overall effect at the national scale was not very significant, primarily because enrolled areas were not generally areas of high deforestation. Muñoz-Piña (2011) undertook a cross-sectional analysis of deforestation in Mexico between 2000 and 2007, and found that among PSAB recipients it was reduced from 1.6 percent to 0.6 percent.

Efforts to assess the impact of PES programs *ex post* are possible, but as the widely divergent results of the studies carried out in Costa Rica indicate, may not be reliable. The critical problem is that of finding a suitable comparison group to which PES recipients can be compared. Many studies simply rely on matching observable farm characteristics (slope, distance from markets etc), without considering household characteristics. Had household characteristics been used to select comparison farms, the matches used in the comparison might have been quite different, thus possibly leading to different results. But in the absence of baseline measurements, any study that attempts to use household characteristics would necessarily have to use *ex post* characteristics, which introduces many problems. Household income, for example, is likely to be affected by whether the household has been receiving PES payments, both directly because of the payments and indirectly through the impact of any land use changes that may have been induced. Other important characteristics such as herd size are similarly likely to be endogenous: PES payments could have been used to acquire more livestock, or the herd might have been reduced because less pasture is available.

Designing the impact evaluation *ex ante* avoids these problems. Control group members can be selected simultaneously with recipients, and a baseline survey can be used to collect household data prior to their enrolment in the PES program, thus avoiding endogeneity problems. The Silvopastoral Project was the first PES project to include impact evaluation in its design, by including from the start a control group of households whose behavior was monitored in the same way as that of households receiving payments.

'recognize' the environmental services being provided. If its budget was sufficient it would pay all forest owners, as it considers that all forests provide environmental services.

3 It should be noted that both of these approaches to selecting a control group have potential problems. Paperwork problems may be a symptom of characteristics that could affect land use decisions, such as low education levels, lack of land titles, or (in the Mexican context, where most applicants are communities) poor organization. Landholders who anticipate applying to the program in later years have an incentive to conserve even prior to enrolling, to maximize the eligible area (likewise, future applicants to a reforestation project have an incentive to postpone their planned planting until they enroll).

The Silvopastoral Project

The Regional Integrated Silvopastoral Ecosystem Management Project piloted the use of PES in three areas: Quindío, in Colombia; Esparza, in Costa Rica; and Matiguás-Río Blanco, in Nicaragua (Pagiola and others, 2005a). The project was financed by a US$4.5 million grant from the Global Environment Facility (GEF), and implemented by the World Bank. The project was developed with support of the multi-donor Livestock, Environment and Development Initiative (LEAD), hosted by the Food and Agriculture Organisation (FAO). It was implemented in the field by local non-governmental organizations (NGOs). In Colombia, this work was conducted by the Centre for Research on Sustainable Agricultural Production Systems (*Centro para la Investigación en Sistemas Sostenibles de Producción Agropecuaria*, CIPAV).

Cattle production has long been an important cause of the loss of natural habitat and biodiversity in Latin America (Downing and others, 1992; Kaimowitz, 1996; Murgueitio, 2003). Despite the correction of many of the policy distortions that encouraged deforestation, pressure from expanding livestock production continues to result in large-scale deforestation in many areas. In addition to the environmental problems caused by the initial loss of forest, extensive grazing is often unsustainable. After an initial period of high yields, soil fertility is depleted and grass cover diminishes, resulting in soil erosion, contamination of water supplies, air pollution, further loss of biodiversity, and degradation of landscapes. Lower income for producers results in continuing poverty and can lead to pressure to clear additional areas.

Silvopastoral practices, which combine trees with pasture, offer an alternative to prevalent cattle production systems. Silvopastoral practices include (1) planting high densities of trees and shrubs in pastures, thus providing shade and diet supplements while protecting the soil from packing and erosion; (2) cut and carry systems, in which livestock is fed with the foliage of specifically planted trees and shrubs ('fodder banks') in areas previously used for other agricultural practices; and (3) using fast-growing trees and shrubs for fencing and wind screens. These practices provide deeply rooting, perennial vegetation which 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). However, these benefits can be 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 percent, depending on the country and type of farm (Gobbi, 2002). Other studies found similar results; White and others (2001), for example, found rates of return to adoption of improved pasture in Esparza, Costa Rica, of 9 to 12 percent. These estimates, of course, only consider the on-site benefits of silvopastoral practices. The biodiversity conservation and carbon sequestration benefits are not considered in the farmers' decision making.

Because of their increased complexity relative to traditional pastures, silvopastoral practices also have important biodiversity benefits (Dennis and others, 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 and others, 1994; Swallow and others, 2007). Both biodiversity and carbon sequestration benefits are off-site, however, so land users will 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. Silvopastoral practices can also affect water services, though the impact is likely to be site specific (Bruijnzeel, 2004; Murgueitio, 2003).

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 practices. Based on this analysis, the project provided a one-time initial payment followed by annual payments conditional on, and proportional to, changes from the baseline land use. The use of short-term payments was controversial, however. Emerging guidelines for PES suggested that payments would have to be longer-term to be effective. There was concern that farmers would revert to their prior, more environmentally damaging land uses once payments ceased.

Most PES programs focus on very few land uses. Costa Rica’s program, for example, pays for conserving existing forest, for establishing timber plantations, and for instituting agroforestry practices (Pagiola, 2008). This approach has the virtue of simplicity, but it fails to recognize that there is a spectrum of effects. Within the broad rubric of silvopastoral practices, the extent of biodiversity conservation and carbon sequestration will depend on the density and diversity of species used. Pastures with low tree density will provide fewer biodiversity and carbon benefits than pastures with a high tree density. Likewise, biodiversity benefits will be greater when a diversity of native species with different canopy heights is used. To encourage adoption of more beneficial practices, the Silvopastoral Project offered payments that are proportional to the level of services provided. Payments were based on an ‘environmental services index’ (ESI) that estimated the magnitude of biodiversity conservation and carbon sequestration services that different land uses provide. The project distinguished 28 different land uses, each with its own ESI score (see Appendix).[4] PES recipients received US$10/point for baseline ESI points[5] and a payment of US$75 per incremental ESI point, per year, over a four-year period.

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4 The ESI is described in detail in CIPAV (2003). Not all 28 practices recognized in the ESI are relevant for Quindío.

5 The baseline payment was primarily intended to avoid perverse incentives (farmers cutting down trees in order to be paid to replant them), but also had the effect of providing initial financing for investments and to give credibility to the Project’s promise to pay for environmental services.

Table 1. Land use at the Silvopastoral Project site, Quindío, Colombia

	PES recipients				*Control group*			
	2003		*2007*		*2003*		*2007*	
	(ha)	*(%)*	*(ha)*	*(%)*	*(ha)*	*(ha)*	*(ha)*	*(%)*
Annual crops	38.7	1.3	38.2	1.3	57.0	7.7	83.2	11.3
Degraded pasture	83.6	2.8	9.1	0.3	14.1	1.9	7.2	1.0
Natural pasture without trees	730.8	24.8	239.5	8.1	49.8	6.8	27.7	3.8
Improved pasture without trees	1,099.4	37.3	895.8	30.4	377.6	51.2	314.5	42.7
Semi-permanent crops (plantain, sun coffee)	190.7	6.5	149.8	5.1	100.2	13.6	113.8	15.4
Natural pasture with low tree density (<30/ha)	6.2	0.2	10.4	0.4	0.0	0.0	10.3	1.4
Diversified fruit crops	73.0	2.5	55.2	1.9	2.5	0.3	13.6	1.8
Fodder banks[a]	4.6	0.2	28.4	1.0	0.0	0.0	3.6	0.5
Improved pasture with low tree density (<30/ha)	54.8	1.9	337.3	11.4	5.6	0.8	11.5	1.6
Natural pasture with high tree density (>30/ha)[b]	0.0	0.0	67.9	2.3	0.0	0.0	0.0	0.0
Shade-grown coffee	24.2	0.8	38.4	1.3	7.1	1.0	7.1	1.0
Improved pasture with high tree density (>30/ha)[b]	2.2	0.1	274.2	9.3	0.0	0.0	0.0	0.0
Bamboo (guadua) forest	44.2	1.5	52.8	1.8	1.4	0.2	1.4	0.2
Timber plantation[a]	0.0	0.0	5.5	0.2	2.0	0.3	2.0	0.3
Riparian forest	380.3	12.9	403.9	13.7	76.7	10.4	76.7	10.4
Intensive silvopastoral system	0.0	0.0	130.3	4.4	0.0	0.0	21.5	2.9
Primary and secondary forest[a]	214.5	7.3	210.4	7.1	43.3	5.9	42.9	5.8
Total area	**2947.1**	**100.0**	**2947.1**	**100.0**	**737.4**	**100.0**	**737.0**	**100.0**
Recently established live fence (km)	1.4		262.9		3.0		13.0	
Multistory live fence or wind break (km)	0.7		94.0		0.0		0.7	

Notes: Totals may not add up because of rounding.
Includes all land in farms of PES recipients and control group members.
Land uses recognized by the project but not found at this site are omitted.
[a] Similar land uses with small areas have been aggregated.
[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.

Sources: Silvopastoral Project mapping data.

As silvopastoral practices were practically unknown in the project site, and as some of them were technically difficult to implement, the project also offered technical assistance (TA) to participants.

Study site

In this paper, we focus on the Silvopastoral Project's Quindío site. The Quindío area is located in Colombia's Central Cordillera, in the watershed of Río La Vieja (a tributary of the Río Cauca), at an altitude of about 900-1,300m above sea level. Farms range from 10-20 ha to some of 50-80 ha. In this former coffee area, many of the larger farms are owned by urban professionals and managed by employees (*mayordomos*).

Coffee production was once the dominant land use in Quindío, but now accounts for less than 1 percent of the area, having been replaced by pasture in the last decade due to low coffee prices. As shown in Table 1, extensive grazing was the main land use in Quindío prior to project start.[6] Degraded and treeless pastures dominated the landscape, accounting for about 65 percent of the area. Livestock production was primarily for meat production, with a small proportion being used for milk production. Overall tree cover was low, although there were 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 1 ha each. Some farms—particularly lower-income farms—had small areas dedicated to other productive activities, such as semi-permanent crops (mostly bananas), fruit crops, shade-grown coffee, and annual crops.

Treatment group

As a pilot project, the Silvopastoral Project had limited funding, so only 80 households could be accepted in the treatment group in Quindío. A series of public workshops were held in the area to explain the project, with support of the Quindío livestock association. Two field visits were also organized to the Reserva Natural El Hatico in the Cauca valley, where silvopastoral practices are already in use. Households who expressed an interest were then accepted on an essentially first-come basis, provided they met some minimal criteria on herd size.

The two primary treatments of interest were payments and technical assistance (TA). There were strong debates within the project team as to which would have the greatest effect on adoption of silvopastoral practices. It was generally agreed that payments were necessary, but some believed that they had to be complemented with intensive TA, while others thought payments alone would be sufficient. Thus all households in the treatment group were offered PES, but a subgroup of households was randomly chosen to also receive on-farm TA. Although all participants received advice on which land uses might be most appropriate on their farms, the TA sub-group also received intensive guidance on how to implement the

[6] Figures in this paragraph refer only to the area managed by project participants and control group members.

selected land uses. In this way it would be possible to compare the effect of PES alone and the combination of PES and TA to the control group. The treatment group was then further sub-divided, with half receiving payments for all four years of the project, while the other half only received payments for two years. The intent was to allow an early assessment of whether land use change would prove sustainable once payments ended. Payment levels were slightly higher for the 2-year group, to compensate for the shorter duration of the payments, so that in principle the payment received to adopt a given land use should have been roughly similar in present value terms for members of both groups.[7] Households were randomly assigned to either the 4-year or the 2-year group. There were thus effectively four treatments: PES for either 2 or 4 years, both either with intensive TA or without it, as shown in Table 2.

Table 2: Number of treatment and control group households

	2-year PES	4-year PES	**Total PES**	Control	**Total**
TA	23 (0)	25 (-6)	**48** (-6)		**48** (-6)
No TA	17 (0)	7 (-2)	**24** (-2)	29 (-1)	**53** (-3)
Total	**40** (0)	**36** (-8)	**72** (-8)	**29** (-1)	**101** (-9)

Note: Number of households lost since project start shown in parentheses.

Control group

In an effort to distinguish project-induced land use changes from changes induced by other factors, the Silvopastoral Project also included control groups.[8] Randomly chosen non-participants in the project area would not necessarily make an adequate control, because of the potential for self-selection bias.

As Ferraro and Pattanayak (2006) note, the 'gold standard' in impact evaluation is the randomized trial. In this approach, applicants are randomly assigned to be either PES recipients or members of a control group. However, this approach can be hard to implement. In on-going PES programs, such as Costa Rica's PSA or Mexico's PSAB, for example, applicants assigned to the control group would have to be barred from re-applying and entering the treatment group in later years, as they would then be lost to the control group.[9] The number of applicants must also be large enough to allow randomization.

In the case of Quindío, randomly assigning applicants to either the participant or the control group was impractical for a simple reason: the selection process was already underway when the decision to include a control group was made. Reopening the process was judged to be infeasible. Fortunately, the number of applications

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7 However, participants could continue to make land use changes throughout the term of their contract, and the payment would correspondingly increase in line with their cumulative increase in ESI points. Thus members of the 4-year group clearly had greater total incentives to undertake land use changes.

8 To our knowledge, this was the first World Bank natural resource management project ever to include a control group.

9 This would not have been an issue in the Silvopastoral Project, as there was a single call for participants.

received was sufficient that a control group could be selected from among applicants that had not been accepted. As applications had been accepted on a first come, first served basis, there was no reason to expect that rejected applicants differed systematically from accepted applicants.[10] As seen below, the control group households have similar characteristics (in terms of size, type of activities, and agroecological conditions) to PES recipient households. Budget constraints, particularly on the cost of monitoring, meant that the control group had to be limited to 30 households. While a larger control group would clearly have been desirable, the available budget simply would not allow it.

Data collection

We use data from three data sets to examine participation decisions in Quindío. A baseline survey conducted in late 2002, during project preparation, collected detailed information on household characteristics. A second survey, conducted in March-May 2004, collected information on land use changes and factors affecting it in the first year of implementation. These surveys include all PES recipients at the site as well as the control group. The baseline survey included data on 110 households. However, 9 observations were discarded because households sold their land and left the area, leaving 72 households receiving payments and 29 members of the control group, for a total of 101 observations (see Table 2).

Finally, detailed land use maps were prepared annually for each farm in the PES recipient and control groups, using remote sensing imagery. Quickbird imagery with a 61cm resolution was used to prepare detailed land use maps for each farm, which were then extensively ground-truthed to match each plot to one of the ESI's 28 land uses. These mapping data give accurate and consistent measures of area and ensure that land uses are classified consistently into the project's categories.

Participating households

The characteristics of participating households are summarized in Table 3.[11] The average household in the sample is composed of 4.5 members, and has about 36 ha of land and a herd of about 57 livestock units.[12] The average per capita income is about COP10 million.[13] However, there was considerable variation among participants.

As can be seen, the average characteristics of the sub-group of PES recipient households differ slightly from those of the control group. This is not surprising, given the relatively small sample size and the wide range of conditions in the area. Among PES recipients, there are no significant differences in household characteristics among the sub-groups.

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[10] Rejected applicants are often used as a source of controls. Alix-Garcia and others (2012), for example, used rejected applicants from Mexico's PES program in their evaluation of that program.

[11] Throughout this paper, 'participants' includes both treatment and control group members.

[12] 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.

[13] In August 2004, US$1 = COP2,670.

Table 3: Characteristics of households at the Silvopastoral Project site, Quindío, Colombia

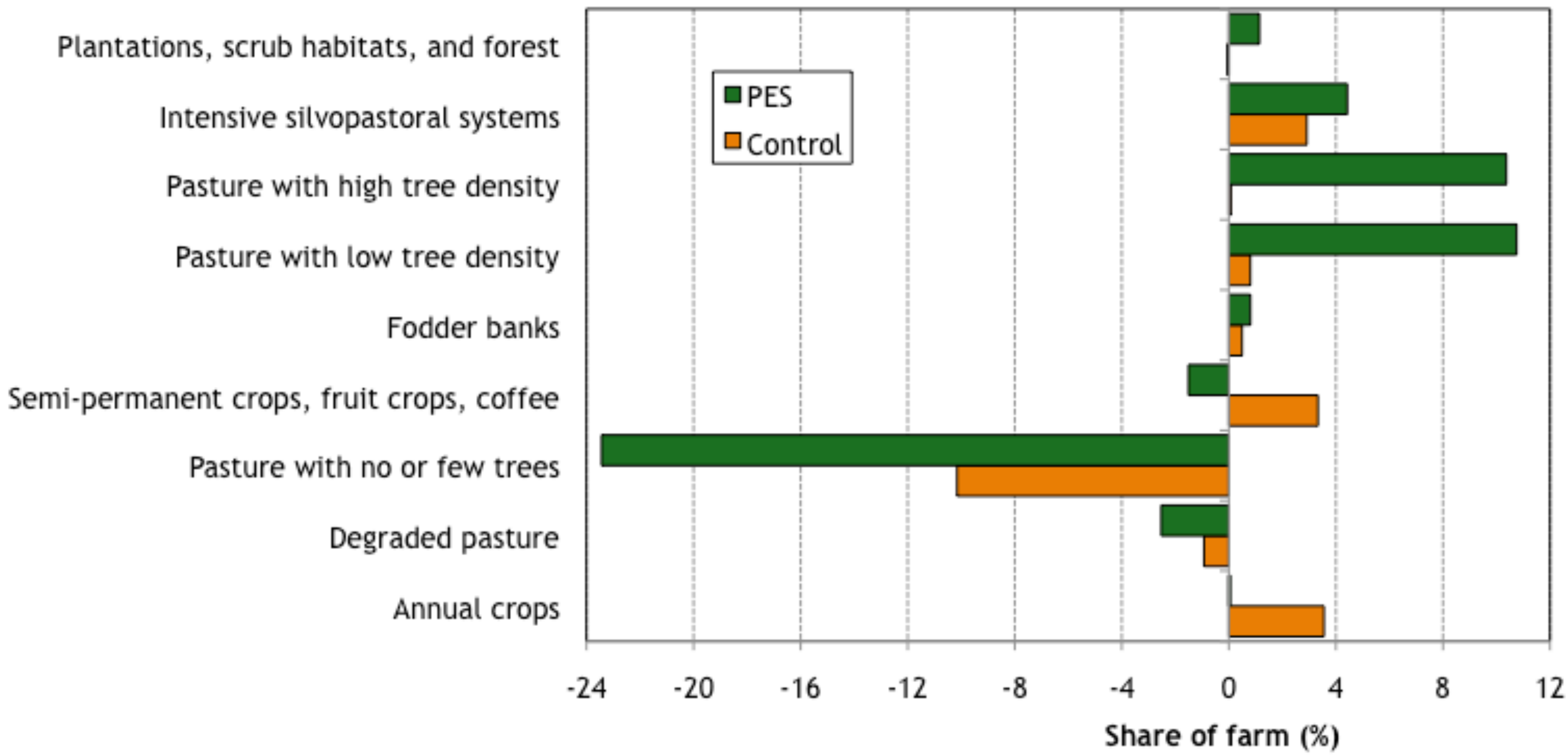
	PES recipients						
Variable	*PES 2 yr*	*PES 4 yr*	*PES only*	*PES and TA*	*All*	*Control group*	*Entire sample*
Income per capita (million COP)	10.7	5.1	5.1	9.8	8.2	14.3	10.0
Assets (million COP)	10.2	6.1	9.4	7.9	8.4	8.7	8.5
Farm area (ha)	43.6	35.9	25.8	47.4	40.2[a]	25.4[a]	36.0
Cattle (livestock units)	65.7	53.0	59.7	60.3	60.1	48.5	56.8
Flat (% farm area)	21.7	24.4	26.2	21.3	22.9[a]	36.9[a]	26.9
Distance to nearest village (km)	7.6	6.5	6.7	7.3	7.1[a]	5.24[ab]	6.6[b]
Water (% with water service)	95.0	93.8	95.8	93.8	94.4	96.6	95.0
Farm resident (%)	30.0	31.3	33.3	29.2	30.6	17.2	26.7
Family labor (man-days/ha/yr)	7.2	9.7	7.2	8.9	8.3	nd	nd
Household size (members)	4.7	5.1	5.1	4.7	4.9[a]	3.7[ab]	4.5[b]
Dependency ratio (children per adult)	0.40	0.40	0.40	0.40	0.40[a]	0.22[ab]	0.35[b]
Age of household head (years)	41.1	45.2	45.2	41.8	42.9	43.9	43.2
Literacy of household head (%)	95.0	96.9	100	93.8	95.8	93.1	95.1
Education of household head (years)	5.5	4.7	5.2	5.1	5.2	4.3	4.9
Off-farm work (% with off-farm employment)	15.0	12.5	12.5	14.6	13.9	10.3	12.9
Technical assistance (% with current access)	40.0	31.3	45.8	31.3	36.1[a]	10.3[ab]	28.7[b]
Credit (% with access to credit)	22.5	31.3	20.8	29.2	26.4	13.8	22.8
Number of observations	40	32	24	48	72	29	101

Notes: [a],[b] indicate means are significantly different in paired t-test at 10% test level. nd = no data
Children are household members under 12

Changes in land use

The Silvopastoral Project made its first payments, for the baseline ESI points, in July 2003. After monitoring land use changes, it made annual payments for incremental ESI points in 2004, 2005, 2006, and 2007 (always in May).

Table 1 compares land use by PES recipients at the project's start (in 2003) and end (in 2007). Overall, the PES program has induced substantial land use change: Almost 1260 ha (almost 44 percent of total area) experienced some form of land use change. A wide variety of changes were observed, ranging from very small changes such as sowing improved grasses in degraded pastures to very substantial changes such



Source: Authors' computations from Silvopastoral Project mapping data.

Figure 1: Cumulative land use changes, Quindío, 2003-2007

as planting high-density tree stands or establishing fodder banks. The area of degraded pasture fell by 71 ha (over 90 percent of its original area) and that of natural pasture without trees by 480 ha (two thirds of its original area).[14] Most of the gains were experienced in pastures with high tree density, which increased by 334 ha. The area of fodder banks also rose dramatically, from less than 5 ha to over 28 ha, while that of intensive silvopastoral systems (*Leucaena* planted at 5,000 trees/ha) went from 0 ha to 130 ha. About 346 km of live fencing were established. Semi permanent crops, fruit crops, and coffee found little favor, with their overall area declining by 39 ha, while timber plantations and pure forest uses fared little better, their total area increasing by only 29 ha. Overall, these changes increased the total ESI score of PES recipients by over 49 percent.

Figure 1 shows the cumulative land use changes at the end of the project, in terms of percentage of the farm area. Land uses in the figure are ranked with the most environmentally damaging (in terms of the ESI) at the bottom and the most environmentally benign at the top. This ranking is also proportional to the payment offered for changes to particular land uses. There were substantial reductions in the proportion of farms dedicated to pasture with few or no trees, with those areas being converted to pasture with low or high tree density, and to a smaller extent to intensive silvopastoral systems. It is interesting to note that forest-like practices were only adopted to a minimal extent, despite having the highest offered payment. The differences in the land use choices of PES recipients that received TA compared to those that did not were very minor. The differences between the 2-year and 4-year PES groups (not shown) were likewise minor.

Table 1 and Figure 1 also show the equivalent changes undertaken by control group members over the same time period. It is immediately evident that the changes undertaken by PES recipients were vastly greater than those of the control group, who changed just over 18 percent of land area, for an increase in ESI points of only 7 percent. Some control group households also expanded the use of environmentally damaging land uses like annual crops and cut back on environmentally benign land uses like existing scrub habitat, whereas no treatment households did so.

Table 4 examines various indices of land use change across the different groups. PES recipients converted about 44 percent of their farms, compared to about 18 percent for control group members. PES recipients had very similar levels of ESI/ha as control group members (0.66/ha vs 0.63/ha) prior to project start, but much higher levels at the end (0.99/ha vs 0.68/ha). These results suggest a strong impact of the project. Figure 2 shows the change in ESI/ha for all PES recipient households compared to control group households.

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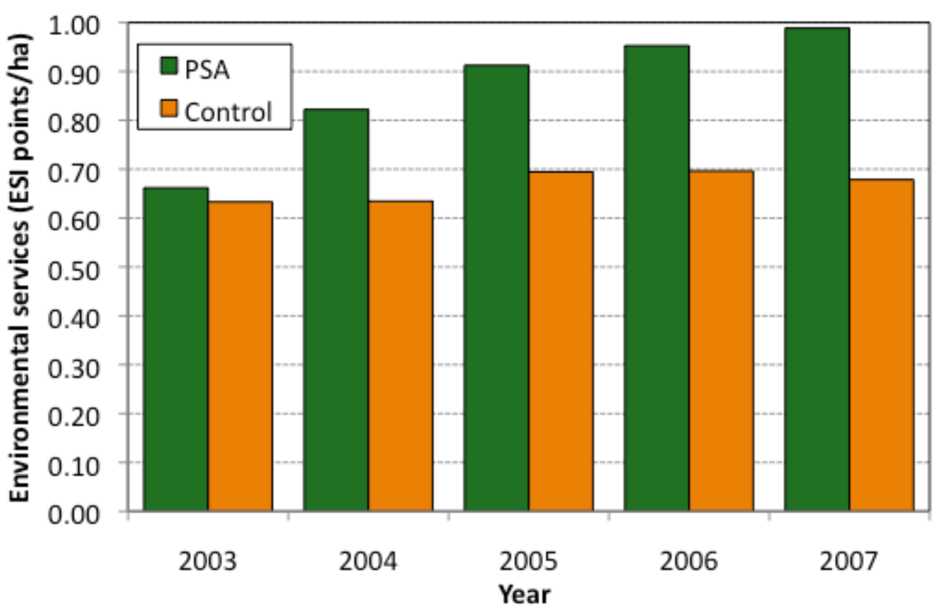
[14] These figures are for *net* changes in the area under each practice, and so understate total changes. For example, while some natural pastures with few or no trees were converted to natural pastures with high tree density, some natural pastures that already had high tree density were converted to improved pastures with high tree density, reducing the apparent net change in natural pastures with high tree density.

Table 4: Indicators of land use change per household, 2003-2007

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 (%)*
PES recipients without TA	47.4	21.4	45.3	0.04	5.40	31.5	15.6	0.67	0.33	49.4
PES recipients with TA	25.8	9.5	36.9	0.01	3.63	16.7	8.2	0.65	0.32	49.3
All PES recipients	**40.2**	**17.5**	**43.5**	**0.03**	**4.81**	**26.6**	**13.1**	**0.66**	**0.33**	**49.4**
PES recipients for 2 years	43.6			0.03	4.67	29.2	13.6	0.67	0.31	46.5
PES recipients for 4 years	35.9			0.02	4.99	23.4	12.6	0.65	0.35	53.8
Control group	25.4	4.6	18.2	0.10	0.37	16.1	1.2	0.63	0.05	7.2
All	**35.9**	**13.8**	**38.3**	**0.05**	**3.53**	**23.6**	**9.7**	**0.66**	**0.27**	**41.1**

Notes: Totals may not add up because of rounding.
Sources: Computed from Silvopastoral Project data.



Source: Authors' computations from Silvopastoral Project mapping data.

Figure 2: Changes in ESI per hectare, 2003-2007

The results in Table 4 also suggest that the differences between treatments had little impact. PES recipients with TA converted slightly more of their farms (45 percent vs 37 percent) but the increase in ESI/ha was almost identical for both (49 percent). Likewise, 2-year PES recipients converted slightly smaller portions of their farms and had slightly lower increases in ESI/ha than 4-year PES recipients (47 percent vs 54 percent) but the differences were not statistically significant.

Econometric analysis

A simple examination of the data on land use change indicates that PES recipients undertook substantially more land use change than control group members, and that moreover they undertook substantially more ambitious land use changes. The differences in land use change between PES recipients and control group members are both large and statistically significant.

As the control group was chosen from among farmers who had applied to the project (and who would have been accepted had the budget allowed it), self-selection bias is unlikely to account for the observed differences in land use. Many studies have shown that farm and household characteristics often have an important impact on adoption decisions. Despite efforts to select a control group that was similar to the treatment group, it is possible that characteristics that favored adoption were stronger among PES recipients. If that were the case, the apparent effect of PES would be spurious. This is a source of concern, as an examination of Table 3 shows that PES recipient households differed from those of the control group in several ways. Notably, PES recipient households had slightly larger farms, on average, of which a smaller proportion was flat; they tended to live further from the nearest village; and they had larger households. There were also other differences, for example in the size of herd, although these were not statistically significant. To verify that these differences are not driving our results, we conduct an econometric analysis of adoption decisions and a difference-in-differences analysis.

Adoption decisions

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 examines how different factors affect the probability of adoption (Pattanayak and others, 2003). This approach is not relevant in our case, for two reasons. First, the pilot nature of the Silvopastoral Project means that the participation decision is not entirely up to farm households. The project only had funds for a fixed number of participants; many non-participants wanted to participate. Second, a binary adoption/non-adoption choice would fail to capture the nature of participation decisions in the Silvopastoral Project. As noted, the ESI recognizes 28 different land uses, and the project pays participants according to the increase in their total ESI score. Rather than participation per se, what is of interest here is the intensity of participation. The formal question we want to pose, then, is how household characteristics affect the intensity of participation. Our approach is similar to that of Nkonya and others (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.

The dependent variable for our analysis can be formulated in many different ways. The simplest formulation is to use the *area converted*: the greater the area converted, the higher the participation. Households with less land, such as those in the control group, may score poorly on this indicator, however, simply because they have less land that can be converted. Investments such as establishment of live fences are also difficult to incorporate into an area-based indicator. Using the *proportion of farm area converted* avoids this problem, but faces others. Converting 5 ha of land to improved practices takes greater effort and has a greater environmental impact than converting 1 ha, yet if the first household has 10 ha and the second only has 1 ha, the first household (50 percent converted) will appear to be participating 'less' than the second (100 percent converted). However expressed, area-based indicators also fail to measure whether changes are large or small. Sowing improved pasture grasses in a treeless pasture requires substantially less effort, and has substantially less environmental impact, 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. This measure is also appealing as it is the outcome of interest to the buyer of the environmental services being sought. As adopting higher-ESI land uses tend to be more difficult than adopting lower-ESI uses, using the ESI also provides a rough measure of effort. This measure can also be stated in different ways. The *increase in total ESI* is the simplest measure (and is readily available, as it forms the basis for payments to participants), but like the area converted it is constrained by farm size. Stating it in terms of *increase in ESI per hectare* or *percent increase in ESI* addresses this problem. As each of these alternatives has its advantages and disadvantages, we use them all in separate models.

We thus run five separate regressions, one with each dependent variable. We follow Rajasekharan and Veeraputhran (2002) in using a one-tailed Tobit to model farm area, as this variable is restricted to non-negative values. We employ 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 OLS.[15] In all cases, we use data from the baseline survey—collected in 2003, prior to the project's start—as explanatory variables, to avoid potential endogeneity problems. Herd size, for example, can increase following the adoption of silvopastoral practices, due to greater fodder availability.

Our choice of explanatory variables draws on the factors identified by Pagiola and others (2005b) as likely to affect participation in PES, and by Pattanayak and others (2003) and the studies they cite as likely to affect adoption of agroforestry

[15] In principle, percent change in ESI could not be less than -100 percent. In practice, however, this limit is not binding, as no household even approached it. Indeed, only four households had a negative change in ESI.

practices, with modifications for the particularities of Quindío.[16] Eligibility is not an issue in our study, as we focus on an area that was selected for inclusion in the project. The desire to participate *per se* is also not an issue, as we are only looking at households who chose to participate (or, in the case of the control group, applied to participate but were not accepted due to project budget constraints). However, as the Silvopastoral Project supports a wide range of land use practices, variables that affect desire to participate remain relevant, as they may affect the desire to undertake more intensive practices. Among the factors that may impede a household's ability to participate, tenure is not an issue in Quindío, as the site was selected partly for the absence of such problems.

Table 5 presents the estimation results. The first two columns of 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. Except for the OLS model of change in ESI, 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).[17]

The results for most explanatory variables are as expected, and are broadly similar to those of other studies on the adoption of agroforestry practices (Pattanayak and others, 2003; Mercer, 2004). Farm area, for example, is positively associated with intensity of adoption measured in area converted or ESI increases, as expected, but it has a small and non-significant impact on the proportion of the farm converted, and a negative impact on proportional changes in ESI and changes in ESI per hectare. This suggests that the correlation between farm size and area converted is simply due to larger farms having more area to convert (and, hence, being able to accumulate a larger absolute increase in ESI) rather than to economy of scale effects. Herd size has a significant positive impact in the ESI models but not in the area models, suggesting that its impact is primarily through demand for fodder rather than through a contribution to financing. The availability of family labor (adults/ha) is significant and positive in the farm area model, but is not significant in the farm share and ESI models. This is not surprising: whereas converting a larger area requires more labor than converting a smaller one, switching to higher ESI land uses does not necessarily increase labor use. Experience has a small positive impact on intensity of participation in some formulations and a small negative impact in others, but is not

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[16] We face limitations in the number of explanatory variables that can be included because of the relatively small sample size. In this case, increasing the sample was not an option: our data include every single project participant.

[17] Tobit were tested for heteroscedasticity in the error distribution using the Wald test, and OLS models using the Breusch-Pagan test. Results for these tests rejected the null hypothesis of homoscedasticity of errors, which if ignored would result in inconsistent Tobit estimates (Maddala, 1983) and loss of optimality of the OLS estimator (Greene, 2000; Mittelhammer and others, 2000). In the absence of prior information about the structure of the heteroscedasticity, we used White's heteroscedasticity-consistent covariance matrix estimator (White, 1980). We found no evidence of either moderate or strong multicollinerarity in any of the regression models using the Belsley (1991) diagnostic in the Tobit models and the Belsley and others (1980) diagnostics in OLS models.

significant in any model.[18] Lower accessibility has a significant negative impact on the extent of area converted, perhaps because higher input costs and lower output prices at the farm gate make more productive silvopastoral practices relatively less desirable, but the impact on ESI is not significant. The percentage of farm area with flat topography has a negative impact, but it is not significant except in some of the ESI models. These results suggest that more intensive silvopastoral measures may be more attractive on steeper slopes, perhaps because higher levels of tree cover provide better protection against degradation. The value of assets has a very small but negative sign. Dummies for whether households are in low or middle income groups show some 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.[19]

In terms of our primary interest in the impact of PES, the very clear result is that receiving PES had a positive and significant impact under every formulation of the model.[20] This confirms the observed sharp contrast in land use change between PES recipients and control group members, and indicates that the contrast was not due to differences in characteristics across groups.

To examine the relative impact of receiving payments for only 2 years rather than four, we included a dummy variable for members of the 2-year group. We find no statistically significant difference between the 2-year and 4-year payment plans. This may reflect that the strategy of offering higher payments under the 2-year plan was successful in providing essentially similar incentives to undertake land use changes. It also suggests that the concern that PES recipients might abandon the newly-adopted land uses once payments cease was misplaced in this instance. Had this been the case, we would have seen a significant negative impact of being in the 2-year group, relative to being in the 4-year group, in results measured the end of year 4.

Similarly, we added a dummy variable for members of the group that received TA. We find that access to TA has a positive impact in every model, but is only significant in one case. The lack of significance is somewhat surprising, given the complexity of some of the practices being promoted, and their near-total absence from the landscape prior to the project.[21] We discuss this further below.

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18 Education (in years) gave very similar results to age.

19 The role of poverty in the adoption of land use changes in the Silvopastoral Project is examined in more detailed in Pagiola and others (2010).

20 Pattanayak and others (2010:262) misread an early draft of this paper as finding 'modest positive impact on a stylized index of environmental services and no impact on land-use change'. As shown, the impact of PES on both is in fact positive and statistically significant on both the index and land use change.

21 A similar result was found at the Nicaragua site of the Silvopastoral Project, but the result is less surprising there, as silvopastoral practices were already relatively well known in the area prior to project start (Pagiola and others, 2007).

Table 5: Estimation results

Independent Variable	*Dependent variable:*	*Area changed (ha)*	*Proportion of farm changed (%)*	*Change in ESI (points)*	*Change in ESI (%)*	*Change in ESI per ha*
	Model:	*Tobit*	*Tobit*	*OLS*	*OLS*	*OLS*
Constant		-20.286*	25.431	-12.856**	42.961	0.241
		(10.700)	(20.909)	(6.381)	(30.428)	(0.146)
Farm area (ha)		0.423***	-0.001	0.181***	-0.359***	-0.002***
		(0.070)	(0.056)	(0.035)	(0.094)	(0.000)
Livestock units		0.052	0.003	0.087***	0.303***	0.002***
		(0.036)	(0.043)	(0.020)	(0.082)	(0.000)
Family labor (adults/ha)		9.795**	22.074	3.858	12.010	0.071
		(4.438)	(14.491)	(2.719)	(19.117)	(0.102)
Age of household head (years)		0.120	0.012	0.098	-0.235	-0.002
		(0.090)	(0.255)	(0.063)	(0.329)	(0.002)
Male-headed household (1=yes, 0=no)		6.016	18.809*	1.756	-17.460	-0.045
		(4.067)	(10.847)	(2.288)	(21.415)	(0.077)
Distance to nearest village (km)		-0.454**	-1.345**	-0.209	-0.303	-0.005
		(0.230)	(0.543)	(0.173)	(1.012)	(0.005)
Flat topography (% farm area)		-0.027	-0.089	-0.015	-0.275**	-0.001**
		(0.042)	(0.087)	(0.029)	(0.122)	(0.001)
Income share of off-farm job		3.462	-5.585	-0.358	-19.940	-0.122
		(8.465)	(28.578)	(5.230)	(43.412)	(0.294)
Assets ('000 COP)		-0.000**	-0.000**	-0.000	-0.001	-0.000*
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Low income (1=low income)		0.847	-12.102	0.946	1.196	-0.028
		(6.223)	(8.578)	(4.289)	(13.460)	(0.069)
Middle income (1=middle income)		0.090	-14.478*	0.702	2.567	0.003
		(5.794)	(7.779)	(3.840)	(11.365)	(0.062)
PES recipient (1=yes)		7.602*	21.667**	6.162***	50.556***	0.331***
		(3.992)	(9.118)	(2.005)	(13.575)	(0.070)
PES with technical assistance (1=yes)		2.985	8.089	3.703**	12.152	0.065
		(2.231)	(6.058)	(1.502)	(13.129)	(0.065)
PES 2 years (1=yes)		0.486	-4.537	0.260	-10.193	-0.050
		(2.763)	(5.648)	(1.802)	(12.013)	(0.061)
R^2				0.792	0.297	0.380
Pseudo R^2		0.83	0.22			
Number of observations		101	101	101	101	101

Notes: Robust standard errors in parentheses.
*, **,*** indicate coefficient estimates significantly different from zero at 90%, 95%, 99% confidence level.

Difference in differences

To further verify our findings, we also ran difference-in-differences models, which compare the performance of two groups before and after one of the groups received a treatment (Wooldridge, 2002). In our case we compare PES recipients to the control group, before and after the project. Data availability restricts our selection of dependent variables to total ESI and ESI per hectare. We also use a natural logarithm transformation on the dependent variables to get an approximate percentage effect of the explanatory variables. We use the same explanatory variables as in the other models. Table 6 presents the difference-in-difference estimation results. The results here are very consistent with those of the prior models. Once again, the treatment effect is positive and highly significant under every formulation, as shown by the interaction term between being a PES recipient and year 4. Here, too, we find that there are no statistically significant differences between the 2-year and 4-year PES recipients, nor between those given TA and those that were not.

Discussion

These results thus indicate that PES had a significant positive impact on land use decisions among recipients, leading them to convert greater portions of their farm and to adopt practices that generated higher levels of benefits than non-recipients. Within this overall picture, several points are worth noting.

First, although PES resulted in the adoption of more environmentally beneficial practices, as implemented in the Silvopastoral Project it failed to induce adoption of the most environmentally beneficial practices, despite offering its highest payments for these practices. Pure forest land use did not change at all, with the sole exception of tiny increases in the area under riparian forest, by a total of less than 24 ha across the entire project area. The reason is simple: these environmentally very valuable practices generate little or no income for landholders. As the Silvopastoral Project only offered short-term payments, it is not surprising that landholders disdained practices that would generate them no income once the PES project ended and instead preferred practices which had lower PES payments, but higher long-term benefits. For PES to successfully induce the adoption of such practices, long-term payments are needed. This lesson has been incorporated into a follow-up project in Colombia, the *Mainstreaming Sustainable Cattle Ranching Project*. In this project, short-term PES is only offered for environmentally-beneficial practices that are expected to be profitable for landholders once in place. The most environmentally-beneficial practices that do not also generate significant on-site benefits will only receive PES when a long-term funding source (such as water users) is available to allow long-term payments to be made.Similar reasoning suggests the reason for members of the 2-year PES group not abandoning their newly-adopted practices after payments ceased, and offers hope that members of the 4-year PES group will likewise retain them. Unlike traditional conservation or technology adoption projects, the Silvopastoral Project did not focus on a small set of chosen technologies, but rather

Table 6: Difference in differences estimation results

Independent variable	*Change in ESI*	*Change in ESI per ha*	*Ln(change in ESI)*	*Ln(change in ESI per ha)*
Constant	-13.276	0.615***	2.654***	-0.538***
	(8.913)	(0.136)	(0.313)	(0.177)
Farm area (ha)	0.742***	-0.001*	0.009***	-0.001*
	(0.061)	(0.000)	(0.001)	(0.001)
Livestock units	0.014	0.001	0.001**	0.001
	(0.033)	(0.000)	(0.001)	(0.000)
Family labor (adults/ha)	0.038	0.004	-1.969***	-0.002
	(3.927)	(0.084)	(0.312)	(0.109)
Age of household head (years)	0.113	-0.001	0.001	-0.001
	(0.107)	(0.001)	(0.004)	(0.002)
Male-headed household (1=yes, 0=no)	4.927*	0.074	-0.185	0.070
	(2.885)	(0.077)	(0.119)	(0.099)
Distance to nearest village (km)	-0.195	-0.003	0.005	-0.002
	(0.182)	(0.004)	(0.007)	(0.005)
Flat topography (% farm area)	0.044	-0.000	0.003***	0.000
	(0.029)	(0.001)	(0.001)	(0.001)
Income share of off-farm job	-1.281	0.122	-0.342*	0.214
	(5.784)	(0.140)	(0.191)	(0.182)
Assets ('000 COP)	-0.000	-0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Low income (1=low income)	-1.741	-0.064	-0.211*	-0.087
	(5.029)	(0.062)	(0.127)	(0.081)
Middle income (1=middle income)	0.959	-0.004	-0.215*	0.002
	(4.487)	(0.054)	(0.109)	(0.070)
Year 4	1.160	0.041	0.050	0.050
	(2.010)	(0.058)	(0.128)	(0.076)
PES recipient (1=yes)	-1.627	0.057	0.141	0.114
	(2.532)	(0.068)	(0.152)	(0.088)
Year 4*PES recipient	11.422***	0.392***	0.457***	0.457***
	(3.017)	(0.081)	(0.166)	(0.104)
PES 2 years	0.564	0.008	-0.031	0.004
	(2.864)	(0.056)	(0.124)	(0.072)
Year4*PES 2 years	0.981	-0.072	-0.098	-0.098
	(4.562)	(0.075)	(0.158)	(0.097)
PES with technical assistance (1=yes)	3.165	0.033	0.080	0.021
	(1.931)	(0.043)	(0.096)	(0.055)
R^2	0.908	0.445	0.791	0.405
Number of observations	202	202	202	202

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

offered a very broad menu of options. Under these circumstances, participants are free to select those practices that are most attractive for their farming systems. It makes sense that they would take advantage of the offered support to adopt those practices that would be profitable even once payments end.

Though these results appear to validate the tip-the-balance hypothesis, close examination suggests that in some cases, no outside support may actually be needed to tip the balance. As we pointed out, intensive silvopastoral practices were adopted not just by PES recipients, but also by some members of the control group. Yet such practices were completely unknown at the project site prior to the project. This strongly suggests two things: that adoption by the control group members may have been due to the project's demonstration effect[22], and that adoption is attractive even without external payments.

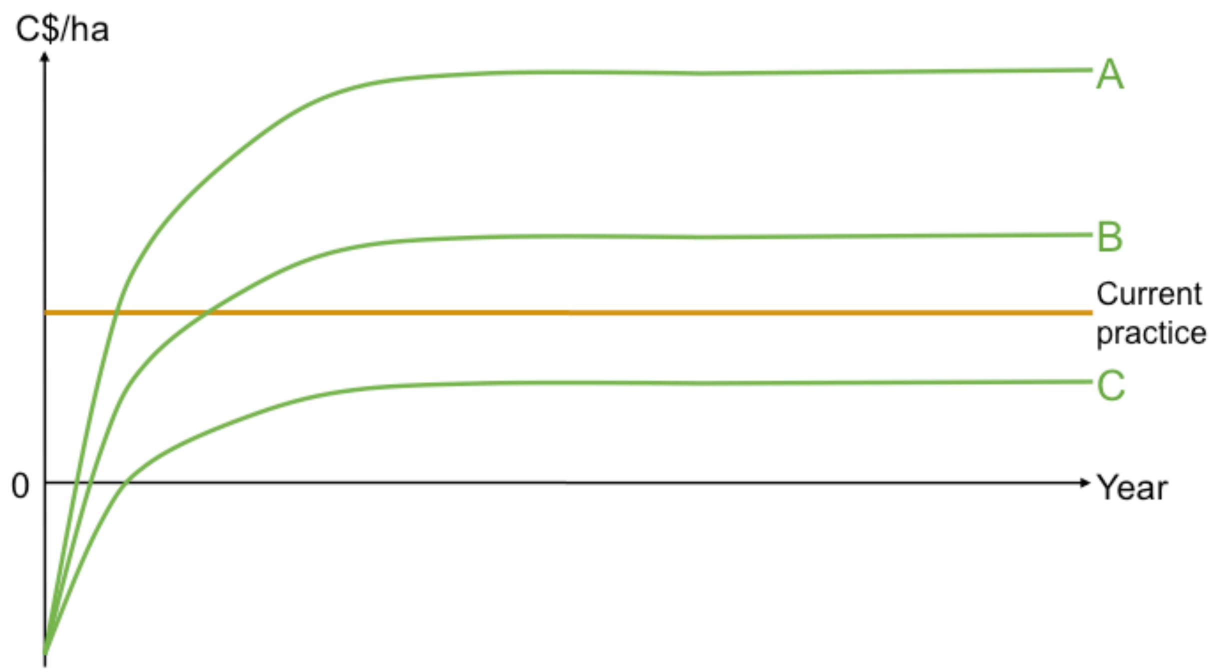

Figure 3: Typology of alternative land uses

Based on the experience of the Silvopastoral Project, the possible land use changes that generate environmental services can thus be divided into three groups, as shown in Figure 3. Some practices are potentially very attractive to landholders, compared to current practices (alternative A). A second group of practices are profitable for landholders once they are established, but high initial costs limit their

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22 If this interpretation is correct, the already strong apparent impact of the project on land use change is actually an underestimate, since some of the positive changes observed among the control group would also be a project impact.

attractiveness (alternative B). A third group is unattractive even once established (alternative C).[23]

Previous conservation projects have often fallen short of their objectives because they tended to assume that the socially desirable land uses they promoted were either uniformly of type A (and so would be readily adopted with little outside support except for credit and/or TA) or uniformly of type B (and so would be sustainably adopted with only short-term outside support). There was strong resistance to acknowledging that many socially-desirable land uses may be of type C and thus would require sustained, long-term support, in part perhaps because until the advent of PES there were few tools to provide such support. It is said that all problems look like a nail when one has a hammer; similarly, the lack of a hammer may make all problems look like something other than a nail.

These results suggest a three-pronged strategy to interventions designed to generate environmental services, targeting each of the broad alternatives.

- *Win-win land uses*. A strategy to encourage the adoption of win-win agricultural practices (those in group A) could be implemented by making available credit and TA. This would be a 'no regrets' strategy, in that the on-site benefits alone would justify it, even if other benefits are low.
- *Short-term PES*. Adoption of practices that are profitable to farmers once established (group B) can be induced with a short-term PES program. Short-term PES would increase the profitability of such practices from the landholder's perspective by reducing the initial costs and reducing the time before the practices are profitable. It may also help finance the initial investments needed. The experience of the Silvopastoral Project suggests that payments of between US$30 and US$80/ha for 2-4 years may be needed.
- *Long-term PES*. Land uses that because of their nature or location are particularly valuable for environmental services, such as riparian forests, but that provide low returns to farmers require a long-term PES program. Short-term PES would not be sufficient, as once payments cease these practices would once again be unprofitable from the landholder's perspective. Landholders would thus either not adopt these practices or adopt them only as long as payments last, and then abandon them. Only long-term PES could induce sustainable adoption of these practices.

Based on these results, such three-pronged strategies have already been adopted in several projects financed by the World Bank, in Brazil, Colombia, and Nicaragua.

The differences between these three prongs have significant implications for funding requirements. The first prong clearly has the lowest financing requirements,

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[23] It is very likely that pure conservation practices that generate very few direct returns to landholders are always in group C. However, differences in local soils, climate conditions, and other factors that affect productivity; and in access to markets and other factors that affect returns, mean that the specific practices that fall within groups A and B may differ from place to place.

though even they are non-zero. Providing credit and TA on a sufficient scale requires substantial resources. Such efforts lend themselves well to donor financing, however. The second prong has higher financing requirements, as it must make payments to participating landholders, in addition to having to provide credit and TA. Because only short-term support is necessary, however, donor support could also be used for this approach. In contrast, in a long-term PES program the required payments to farmers would have to last indefinitely. Such a program could not, therefore, rely on funding from donors, as such funding is always of limited duration.

The apparent non-significance of TA requires further thought. This result is inconsistent with many other studies. Access to extension was found to significantly affect agroforestry adoption in 90 percent of studies that included it (Pattanayak and others, 2003), including two studies in Costa Rica (Thacher and others, 1997; Zbinden and Lee, 2005). It is also inconsistent with the opinions of many Silvopastoral Project participants, who stated that they considered TA to be very important. It may be that the lessons of TA were able to diffuse easily from those who received it to those who did not. That intensive silvopastoral systems (the most technically complex practice proposed by the Project) was adopted by some control group members is consistent with this hypothesis. While PES recipients are unlikely to share the payments they receive, TA recipients may well be quite willing to share what they have learned with neighbors or friends. Any such diffusion to farms who did not receive TA from the project would tend to make the impact of TA, and of the project itself, appear less significant. Further evaluation would thus be warranted before any recommendation be made that TA should be dispensed with.

The result that 2-year payments appear to be as effective as 4-year payments is significant in terms of future project design, as it suggests that a shorter project could be equally effective. A shorter project would be attractive as it would spend fewer resources on monitoring. But here, too, some caution is warranted. A longer project would allow greater opportunities for farmers to learn from experience or the example of others which practices work best for their situation. It would also allow for a gradual conversion process, which may be important if constraints affect the rate at which land use changes can be undertaken. Farmers may only be able to finance a finite amount of change at any given time, for example, or there may be limits on the quantities of seedlings and other inputs available.

That PES had an impact on land use change does not necessarily mean that it had an impact on the generation of environmental services. A significant impact on land use could fail to have an impact on environmental services if either the wrong areas or the wrong land uses are targeted. Evidence from Mexico and Costa Rica, for example, suggests that many PES contracts have been awarded in areas of relatively low importance for ecosystem service generation (Muñoz-Piña and others, 2011; Pagiola, 2008; Zhang and Pagiola, 2011). As a small-scale pilot program, the Silvopastoral Project clearly did not expect to have a significant impact on actual service generation. However, extensive monitoring efforts documented that project-supported land uses did in fact have significant effects on biodiversity conservation *in situ*, on carbon sequestration, as well as on other environmental services such as water quality. Armed with such knowledge, it is safer to assume that an impact on land use change can in fact improve the generation of desirable environmental services.

Conclusions

The experience of the Silvopastoral Project in Quindío indicates that PES had a marked effect on land use—not just in terms of area affected, but also in terms of the extent of the changes. This effect is strongly statistically significant under a range of model formulations. As this is the first impact evaluation of a PES program to have benefitted from a control group—albeit a small, less-than-perfect control group—the result is important and promising.

Nevertheless, further assessment of such efforts will be needed to ensure that the conclusion that PES can have a significant impact is broadly applicable—or to identify the conditions under which it is.[24] In particular, three aspects of this study require caution in generalizing its results. First, it was carried out at a particular site, with specific agro-ecological and socio-economic characteristics. Second, the PES program implemented in Quindío had its own particularities, differing in many ways from many other such programs. In particular, it was a short-term PES program focusing on restoration of degraded habitats rather than conservation of intact habitats. Third, the specific set of treatment and control households may not be fully representative of households in Quindío, as all these households self-selected to participate.

The results provide much more information than a simple, yes, PES can work. By examining difference in the level of impact across types of land uses, it was already possible to improve the design of new PES projects, focusing short-term PES payments on practices where they are most likely to be both useful and necessary, and turning to other tools to induce the adoption of practices that may not require payments.

An important question that remains unresolved concerns the longer-term permanence of land use changes induced by the project after PES ended. That farmers who only received PES for 2 years do not appear to have reverted to prior land uses offers some reassurance in this regard, but the concern remains. Farmers may still have been evaluating the new practices, for example, and may not yet have decided to abandon them in the relatively short time between the end of the 2-year payments and the end of the 4-year payments, when all monitoring ended. To assess the longer-term sustainability of the practices adopted under the project, all participants are currently being re-surveyed.

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[24] PES recipients at the other Silvopastoral Project sites, at Esparza, Costa Rica, and Matiguás-Río Blanco, Nicaragua, had broadly similar patterns of land use change to PES recipients in Quindío (Pagiola and others, 2007). However, problems with the control groups at these sites preclude a full impact evaluation.

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Appendix: Environmental Services Index

Table A1: Environmental Services Index (ESI) used by the Silvopastoral Project

(points/ha except where stated)

Land use	*Carbon index*	*Biodiversity index*	*Environmental services index*
Annual crops	0.0	0.0	0.0
Degraded pasture	0.0	0.0	0.0
Natural pasture without trees	0.1	0.1	0.2
Improved pasture without trees	0.4	0.1	0.5
Semi-permanent crops (plantain, sun coffee)	0.2	0.3	0.5
Natural pasture with low tree density (<30/ha)	0.3	0.3	0.6
Natural pasture with recently planted trees (>200/ha)	0.3	0.3	0.6
Recently established or frequently pruned live fences	0.3[a]	0.3[a]	0.6[a]
Improved pasture with recently planted trees (>200/ha)	0.4	0.3	0.7
Monoculture fruit tree plantation	0.4	0.3	0.7
Gramineous fodder bank	0.5	0.3	0.8
Improved pasture with low tree density (<30/ha)	0.6	0.3	0.9
Fodder bank with woody species	0.5	0.4	0.9
Natural pasture with high tree density (>30/ha)	0.5	0.5	1.0
Multi-story live fence or windreak	0.5[a]	0.6[a]	1.1[a]
Diversified fodder bank	0.6	0.6	1.2
Monoculture timber plantation	0.8	0.4	1.2
Shade-grown coffee	0.7	0.6	1.3
Improved pasture with high tree density (>30/ha)	0.7	0.6	1.3
Bamboo (*guadua*) forest	0.8	0.5	1.3
Diversified timber plantation	0.7	0.7	1.4
Early secondary growth (*tacotal*)	0.8	0.6	1.4
Riparian forest	0.7	0.8	1.5
Intensive silvopastoral system (iSPS)	1.0	0.6	1.6
Disturbed secondary forest	0.9	0.8	1.7
Secondary forest	1.0	0.9	1.9
Mature forest	1.0	1.0	2.0

Source: CIPAV (2003)