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Paying for the environmental services of silvopastoral practices in Nicaragua ☆

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ABSTRACT

Agricultural landscapes can provide many valuable ecosystem services, but many are externalities from the perspective of farmers and so tend to be under-produced. This paper examines an effort to make direct payments for ecosystem services (PES) in an agricultural landscape. The Regional Integrated Silvopastoral Ecosystem Management Project is piloting the use of PES to induce adoption of silvopastoral practices in the Matiguás–Río Blanco area in Nicaragua. Silvopastoral practices could substantially improve service provision while retaining agricultural production, but they have found only limited acceptance among farmers. The Silvopastoral Project seeks to increase their adoption by paying farmers for the expected increase in biodiversity conservation and carbon sequestration services that these practices would provide. The Project developed an 'environmental services index' (ESI) and pays participants for net increases in ESI points. Although the Silvopastoral Project is still underway, it already appears to have succeeded in inducing farmers to increase substantially the use of practices that generate higher levels of ecosystem services. In the project's first two years, over 24% of the total area experienced some form of land use change. The area of degraded pasture fell by two thirds, while pastures with high tree density increased substantially, as did fodder banks and live fences. On-going monitoring indicates that these land use changes are in fact generating the desired services. Questions remain about the long-term sustainability of the approach, however. To ensure sustainability, long-term payments are likely to be needed, raising the question of how they will be financed. Payments by water users and by carbon buyers provide a partial answer to this challenge, but still leave many gaps.

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1. Introduction

Agricultural landscapes can provide many valuable ecosystem services. They can contain high levels of biodiversity, sequester substantial amounts of carbon, and affect downstream water supplies. Many of these services are externalities from the farmers' perspective, however, and so tend to be underproduced. Recent years have seen numerous efforts to devise innovative mechanisms to induce farmers to adopt practices that generate higher levels of services (Landell-Mills and Porras, 2002; Pagiola et al., 2002). An approach that has received increasing attention is to pay farmers directly to provide ecosystem services (Ferraro, 2001; Pagiola and Platais, 2007).

This paper examines one effort to make direct payments for ecosystem services (PES) in an agricultural landscape. The Regional Integrated Silvopastoral Ecosystem Management Project, financed by the Global Environment Facility (GEF), is piloting the use of PES to induce adoption of silvopastoral practices at sites in Nicaragua, Colombia, and Costa Rica (Pagiola et al., 2004). The extensive pastures that replaced the original forests in this area provide particularly low levels of services — with little biodiversity, low carbon sequestration, and adverse impacts on hydrological flows. Silvopastoral practices could substantially improve service provision while retaining agricultural production, but have found only limited acceptance among farmers. The Silvopastoral Project seeks to increase their adoption by paying farmers for the expected increase in biodiversity conservation and carbon sequestration services that these practices would provide.

This paper describes the Silvopastoral Project and its initial results at its Nicaragua site. We begin by describing the benefits of silvopastoral practices and the reasons for their limited adoption. We then discuss the PES approach, and how it is applied in this case. The first two years of the project have already resulted in substantial increases in service provision. Although this project is still underway, it is already generating important lessons for similar efforts.

2. Silvopastoral practices

Cattle production has long been an important cause of the loss of natural habitat and biodiversity in Central America (Downing et al., 1992; Kaimowitz, 1996). In addition to the environmental problems caused by the initial deforestation, extensive grazing often suffers from declining yields, diminishing grass cover, soil erosion, water supply contamination, air pollution, and landscape degradation. Declining producer income results in continuing poverty and can lead to pressure to clear additional areas.

Silvopastoral systems combine fodder plants such as grasses and leguminous herbs with trees and shrubs for animal nutrition and complementary uses. The main silvopastoral systems, either researched or implemented empirically, include planting trees and shrubs in pastures; cut and carry systems, in which livestock is fed with the foliage of specifically planted trees and shrubs ('fodder banks'); using trees and shrubs for fencing; and grazing livestock inside tree plantations. Windbreaks and pastures between tree alleys have been applied to a lesser degree (Murgueitio, 2004).

2.1. *On-site benefits*

Silvopastoral practices, like agroforestry practices, can provide many on-site benefits (Current et al., 1995; Dagang and Nair, 2003). Introducing trees in pasture areas can improve pasture productivity, as trees extract water and nutrients from soil horizons inaccessible to grasses. Trees can also provide direct benefits in the form of products such as fruit, fuelwood, fodder, and timber, while increased shade can enhance livestock productivity, especially for milk production.

2.2. *Biodiversity benefits*

Because of their increased complexity, silvopastoral practices often support much higher levels of biodiversity than traditional pastures (Daily et al., 2003; Dennis et al., 1996; Harvey and Haber, 1999; Horner-Devine et al., 2003; Lindell et al., 2004; Moguel and Toledo, 1999; Ricketts et al., 2001). Silvopastoral practices have been shown to enhance the survival of wildlife species by providing scarce resources and refuge, and to help propagate native forest plants. Food availability for wild birds is high, and the complex structure of the vegetation provides a better nesting substrate and better protection against predators than other agroecosystems. Silvopastoral practices also harbor a larger and more complex assemblage of invertebrates. They can also serve as biological corridors, helping to connect remaining habitats (Saunders and Hobbs, 1991).

2.3. *Carbon sequestration benefits*

Silvopastoral practices can fix significant amounts of carbon in the soil (Pfaff et al., 2000) and in the standing tree biomass (Fisher et al., 1994). Research conducted by CATIE (1999) in Panama and Costa Rica shows that silvopastoral practices can accumulate as much as 13–15 tons carbon (tC) per ha per year, compared to 1–5 tC in extensive pastures. Moreover, silvopastoral practices tend to sequester carbon deeper in the soil profile (40–100 cm depth), thus making it less prone to oxidation and loss (Fisher et al., 1994; Beinroth et al., 1996).

2.4. *Hydrological benefits*

Silvopastoral practices can also affect water services, though the effect is variable and not always as clear-cut as often supposed (Bruijnzeel, 2004). Trees generally increase infiltration, thus reducing surface runoff and soil erosion, but have higher evapotranspiration, thus tending to decrease water yield. In hilly areas, trees can also help prevent landslides by anchoring soils, particularly if a variety of species with different root depths are used.

3. Barriers to adoption

Despite their many benefits, silvopastoral practices have seen limited adoption (Dagang and Nair, 2003). Large areas remain under extensive pasture with minimal tree cover.

The low profitability of silvopastoral practices from the farmers' perspective is an important constraint to their adoption. Establishment costs in Matiguás–Río Blanco range from US$180/ha for sowing improved pasture to about US$400/ha for planting trees at high density in pastures. Establishing fodder banks costs US$170–300/ha, depending on the species. Live fences cost US$110–160/km. Increasing or improving herds to take advantage of increased fodder production entails additional costs. There are also opportunity costs resulting from the time lags before the systems become productive, particularly in systems with substantial tree components. Rates of return to adopting silvopastoral practices thus tend to be low. Estimates prepared for the Silvopastoral Project show rates of return of 4–14% (Gobbi, 2002), while White et al. (2001) found rates of return of 9–12% to adopting improved pasture in Esparza, Costa Rica. These estimates only consider the on-site benefits of silvopastoral practices.

Even if silvopastoral practices are financially viable, high initial investment costs can pose problems for credit-constrained farmers. Credit has been found to increase adoption of agroforestry practices, and its role is very often significant (Pattanayak et al., 2003).

The complexity of some silvopastoral practices means that technical assistance (TA) may help farmers adopt them. Access to extension significantly affected agroforestry adoption in 90% of studies that included it (Pattanayak et al., 2003, including two studies in Costa Rica (Thacher et al., 1997; Zbinden and Lee, 2005).

The long-term nature of investments in most silvopastoral practices often makes tenure security an important factor in their adoption (Meinzen-Dick et al., 2002). Tenure variables were significant in 72% of agroforestry adoption studies that included them (Pattanayak et al., 2003).

Many of these barriers may be more salient for poorer households, who are less likely to have secure tenure, tend to have fewer savings and less access to credit, and are less likely to receive TA (de Janvry and Sadoulet, 2000; López and Valdés, 2000).

4. Payments for environmental services

PES is a market-based approach to conservation 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 generate services should be compensated for providing them (Wunder, 2005; Pagiola and Platais, 2007). The approach seeks to create mechanisms to arrange transactions between service users and providers that are in both parties' interests, thus internalizing what would otherwise be an externality. In a PES mechanism, service providers receive payments conditional on their providing the desired environmental services (or adopting a land use thought to generate those services). Participation is voluntary.

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 funding; and (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 (Pagiola and Platais, 2007).

There has been considerable experimentation with PES and other market-based approaches in developing countries in recent years (Pagiola and Platais, 2007; Pagiola et al., 2002; Landell-Mills and Porras, 2002). Latin America has been particularly receptive to the approach, with PES programs in operation in Colombia (Echevarría, 2002), Costa Rica (Pagiola, 2005), Ecuador (Albán and Wunder, 2005), El Salvador (Díaz et al., 2002), and Mexico (Muñoz et al., 2006), at various scales, and under preparation or study in other countries.

Most PES programs focus on forests, but several have begun using the approach in agricultural landscapes. In Mexico, the Scolel Té project pays farmers to provide carbon sequestration services by undertaking agroforestry practices (Tipper, 2002). Costa Rica's PES program added an agroforestry contract in 2004 (Pagiola, 2005).

5. Implementing PES in Matiguás–Río Blanco, Nicaragua

The Silvopastoral Project is piloting the use of PES to generate biodiversity conservation and carbon sequestration by encouraging the adoption of silvopastoral practices in degraded pastures in three areas: Quindío, in Colombia; Esparza, in Costa Rica; and Matiguás–Río Blanco, in Nicaragua (Pagiola et al., 2004). The project is financed by a US$4.5 million GEF grant with the World Bank as the implementing agency. It is being implemented in the field by local non-governmental organizations (NGOs). In Nicaragua, it is being implemented by Nitlapan, an NGO affiliated with the Central American University.

5.1. *Project site*

Matiguás–Río Blanco is located in the department of Matagalpa, about 140 km northeast of Managua, on the southern slopes of the Cordillera de Darien. It has an undulating terrain, with an elevation of 300–500 m above sea level. Average temperature is about 25 °C and average annual rainfall 1700–2500 mm. Participants are clustered in the Bulbul and Paiwas microwatersheds.

Prior to project implementation, extensive grazing dominated land use, with pastures covering about 63% of the area (Table 1).[1] Of this, about half was degraded pasture, and another quarter had few or no trees. Silvopastoral practices, though not unknown, were not widely used: pastures with high tree density covered 17% of the area, and fodder banks 3%. About 20% of total area remained under forest, mostly as riparian forest.

The average participating household is composed of six members, and has about 31 ha of land and about 30 head of

[1] In the discussion below, all figures refer only to the area managed by project participants, which accounts for about 60% and 40% of total area in the Bulbul and Paiwas microwatersheds, respectively. All data for which no explicit reference is given are from Silvopastoral Project files. Wherever possible, we have supplied references to published reports.

Table 1 – Land use among Silvopastoral Project participants, Matiguás–Río Blanco, Nicaragua, 2003–2005

Land Use	2003		2004		2005	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Infrastructure, housing, and roads	5.5	0.2	5.5	0.2	7.6	0.2
Annual crops	231.5	7.4	161.0	5.1	111.0	3.5
Degraded pasture	868.9	27.7	401.5	12.8	281.3	8.9
Natural pasture without trees	65.0	2.1	84.5	2.7	67.8	2.1
Improved pasture without trees	22.4	0.7	38.3	1.2	35.6	1.1
Semi-permanent crops	33.0	1.1	27.4	0.9	25.3	0.8
Natural pasture with low tree density	333.7	10.6	448.0	14.3	350.3	11.1
Fodder bank [a]	88.3	2.8	154.1	4.9	192.4	6.1
Improved pasture with low tree density	137.3	4.4	250.7	8.0	260.1	8.2
Natural pasture with high tree density [b]	381.8	12.2	471.3	15.0	507.4	16.0
Diversified fruit crops [a]	21.1	0.7	20.1	0.6	23.6	0.7
Monoculture timber plantation	1.1	0.0	2.1	0.1	3.9	0.1
Improved pasture with high tree density [b]	167.0	5.3	278.8	8.9	465.2	14.7
Scrub habitats (*tacotales*)	154.9	4.9	157.5	5.0	177.5	5.6
Secondary and riparian forest [a]	627.9	20.0	638.6	20.3	656.6	20.7
Total area	3139.4	100.0	3139.4	100.0	3165.5	100.0
Live fence (km)	128.5		239.0		332.3	

Notes: Totals may not add up because of rounding; increase in total area in 2005 due to some farmers buying land.
Land uses recognized by the project but not found at this site are omitted.
Sources: Silvopastoral Project data, based on analysis of remote sensing imagery verified in the field.
[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.

livestock. Agriculture is the main economic activity, with few households having off-farm income. The average per capita income of about US$340 is below the poverty line. Few households have water or electricity, and education levels are very low. Although most households occupy public land, long-term occupancy gives them secure tenure.

5.2. *Source of financing*

In pure PES programs, service users pay for service provision, thus creating a market-like transaction between service users and providers (Pagiola and Platais, 2007). In the Silvopastoral Project, the services being sought are biodiversity conservation and carbon sequestration. As the ultimate 'users' of these global benefits are very diffuse, the transaction costs of charging them directly would be prohibitive, so funding is provided by the GEF.[2] The GEF was established by the global community to preserve global benefits, so its financing can be considered a payment by the users' representative. Payments are made for benefits which GEF considers important, based on guidance from the Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC).

Although silvopastoral practices can also generate water services, no payments from water users were included in the Project. As discussed below, it is hoped that water payments may be implemented in the future.

5.3. *Service providers*

The Silvopastoral Project, like most developing country PES programs, chooses providers based on geographic criteria: landowners in specified areas can participate, while those outside cannot. The Matiguás–Río Blanco site was selected based on its location in a biological corridor.[3] Within the site, all households meeting minimal criteria of herd size were eligible to participate. Budget constraints limited participation to slightly over 100 households. Households were enrolled on a first-come, first-served basis until this limit was reached. Many non-participating households wanted to participate.

5.4. *Service delivery*

Ideally, PES programs would pay for actual service delivery. This is generally impractical, however. The services sought often cannot be observed by landowners, and so they cannot easily manage their land to produce them. Most PES programs thus pay for the adoption (or retention) of land uses that are thought to generate the desired services. The Silvopastoral Project follows this approach.

Most PES programs focus on very few land uses. Costa Rica's and Mexico's PES programs, for example, focus primarily on forest conservation (Pagiola, 2005; Muñoz et al., 2006). This approach has the virtue of simplicity, but fails to recognize the broad spectrum of possible effects. Pastures with low tree density provide fewer biodiversity and carbon benefits than pastures with higher tree density. Likewise, biodiversity benefits increase when a variety of native species with different canopy heights is used.

To provide payments that are closely correlated to levels of service provision, the Silvopastoral Project developed indices of biodiversity conservation and carbon sequestration under different land uses, then aggregated them into a single 'environmental services index' (ESI). This approach is similar to the Environmental Benefits Index (EBI) used in the US Conservation Reserve Program (CRP) (NCEE, 2001). The ESI

[2] Rules for land use-based carbon sequestration activities under the Kyoto Protocol's Clean Development Mechanism were not yet in place when the Silvopastoral Project was prepared.

[3] Location is irrelevant to carbon sequestration, so biodiversity conservation objectives alone were considered in selecting sites. To produce Kyoto-compliant emissions reductions, however, it would have been necessary to demonstrate that project sites had been deforested prior to 1990.

distinguishes 28 different land uses, though not all are found at Matiguás–Río Blanco (Table 2). The biodiversity conservation index was scaled with the most biodiversity-poor land uses (degraded pasture and annual crops) set at 0.0 and the most biodiversity-rich land use (primary forest) set at 1.0. Within this range, a panel of experts assigned points to each land use, taking into consideration factors such as the number of species, their spatial arrangement, stratification, plot size, and fruit production. Similarly, the carbon sequestration index assigns points to different land uses according to their capacity to sequester stable carbon in the soil and in hard wood. The index is scaled so that 1 point equals about 10 tC/ha/year. As payments in this case come solely from the GEF, only global benefits were included in the ESI.

5.5. *Payment contracts*

Participating landowners enter into contracts under which they receive annual payments, over a four-year period, based on their net increase in ESI points (computed over the entire farm) relative to the baseline for their farm. Payments are made after land use changes have been monitored in the field. Thus the project differs substantially from earlier approaches that relied primarily on subsidizing the cost of adopting the desired practices. In contrast, Silvopastoral Project payments are proportional to the level of services provided (as measured by changes in the ESI), irrespective of the cost of providing them.

As with all other developing country PES programs, the Silvopastoral Project offers fixed payments for eligible land uses. A procurement auction, as employed for example in the CRP, might have reduced costs by allowing the lowest-cost providers to be identified (Ferraro, 2005). However, this approach was deemed too complex for the setting.

Unlike many PES programs, payments under the Silvopastoral Program are explicitly short-term. Silvopastoral practices tend to be unattractive to farmers, despite their long-term benefits, primarily because of their substantial initial investment and the time lag between investment and returns. This led to the hypothesis that a relatively small payment provided early on could 'tip the balance' of profitability between current and silvopastoral practices, by increasing the net present value of investments in silvopastoral practices and by reducing the initial period in which these practices impose net costs on farmers. The payments also alleviate the liquidity problems faced by many farmers and help them finance the required investments.

5.6. *Payment levels*

In principle, payments should be no less than the difference in returns compared to the landowners' best alternative land use (or they will not participate), and no more than the value of the benefit provided (or it would not be worthwhile to provide the service). In practice, the value of services is extremely difficult to estimate, particularly for biodiversity conservation. In contrast, opportunity costs can usually be estimated relatively easily. For this reason, and to limit budgetary requirements, all existing PES programs implicitly or explicitly base payments

Table 2 – Environmental service indices used in the Silvopastoral Project (points per hectare, unless otherwise specified)

Land use	Biodiversity index	Carbon sequestration index	Environmental services Index (ESI)
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)	0.3	0.2	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
Improved pasture with recently-planted trees (>200/ha)	0.3	0.4	0.7
Monoculture fruit crops	0.3	0.4	0.7
Fodder bank	0.3	0.5	0.8
Improved pasture with low tree density (<30/ha)	0.3	0.6	0.9
Fodder bank with woody species	0.4	0.5	0.9
Natural pasture with high tree density (>30/ha)	0.5	0.5	1.0
Diversified fruit crops	0.6	0.5	1.1
Diversified fodder bank	0.6	0.6	1.2
Monoculture timber plantation	0.4	0.8	1.2
Improved pasture with high tree density (>30/ha)	0.6	0.7	1.3
Diversified timber plantation	0.7	0.7	1.4
Scrub habitats (*tacotales*)	0.6	0.8	1.4
Riparian forest	0.8	0.7	1.5
Disturbed secondary forest (>10 m^2 basal area)	0.8	0.9	1.7
Secondary forest (>10 m^2 basal area)	0.9	1.0	1.9
Primary forest	1.0	1.0	2.0
New live fence or established live fence with frequent pruning (per km)	0.3	0.3	0.6
Wind break (per km)	0.6	0.5	1.1

Notes: The ESI is the sum of the biodiversity and carbon sequestration indices.
Land uses recognized by the project but not found at this site are omitted.

on the opportunity costs of the main alternative land uses. The Silvopastoral Project's 'tip the balance' approach follows this approach. Based on analyses of the relative profitability of different practices, payment levels were set at US$75 per incremental ESI point, per year.

These payments were compared to payment levels for similar services elsewhere to ensure they were reasonable. In terms of carbon emissions reductions, the US$75/point/year payment is equivalent to paying US$7.5/tC. This compares favorably to world prices at the time of project launch of US $14–20/tC (World Bank, 2004). Similar comparisons for biodiversity conservation are difficult. The highest possible payment, for converting degraded pasture to forest (an increase of 2.0 ESI points), would be US$75/ha/year, assuming that half the payment is for biodiversity conservation, or a total of US $300/ha over four years. At a 10% discount rate, this is equivalent to a long-term annual payment of about US$30/ ha/year. In comparison, Costa Rica's PES Program paid US$42/ ha/year and Mexico's program paid US$36/ha/year for cloud forests and US$27/ha/year for other forests (Pagiola, 2005; Muñoz et al., 2006). In fact, the implicit price of biodiversity conservation under the Silvopastoral Project is effectively even lower, as it is only paid for incremental conservation. In contrast, neither Costa Rica nor Mexico require incremental actions, and recent studies suggest that their actual impact on land use has been limited (Sills et al., 2006).

5.7. *Avoiding leakage and perverse incentives*

That environmentally damaging activities will only be displaced rather than curtailed is a common concern in PES programs. The Silvopastoral Project avoids the problem by computing changes in ESI over the entire farm — any switch to land uses that reduce service provision would thus incur negative points, reducing the total payment. Induced leakage outside participating farms through price effects are unlikely at this stage due to the very small size of the project area, but may become a concern if the approach were to be expanded.

Initially, land users were to be paid only for the increase in ESI points over the pre-project score. It soon became clear that this would create perverse incentives. "Bueno, corto todo," was a common reaction by landowners when told they would not be compensated for existing trees: "fine, I'll cut them all." As a result, the initial plan was modified to include a one-time payment of US$10/point for baseline points. Coming before implementation began, this payment may have been particularly helpful in alleviating financing constraints.

6. Results

The Silvopastoral Project made its first payments, for baseline ESI points, in July 2003. After monitoring land use changes, it made its first payment for increases in ESI scores in May 2004, and a second payment in May 2005. Additional payments will be made in 2006 and 2007.

Three data sets are available to study the impact of PES in Matiguás–Río Blanco. 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 in the first year of implementation.[4] Finally, detailed land use maps are prepared annually for each farm using remote sensing imagery.[5] These mapping data give accurate and consistent measures of area and ensure that land uses are classified consistently into the project's categories.

All three data sets include a control group of non-participants. The main intended purpose of this group was to distinguish project-induced land use changes from changes induced by other factors, as recommended in emerging guidelines for conservation project evaluation (Ferraro and Pattanayak, 2006).[6] Upon analysis, however, control group members were found to have been poorly chosen, differing from participants in many important characteristics (such as income, farm size, and herd size). Because of these differences, we decided that using the control group would not be useful. Our analysis, therefore, focuses entirely on participants.

6.1. *Land use changes*

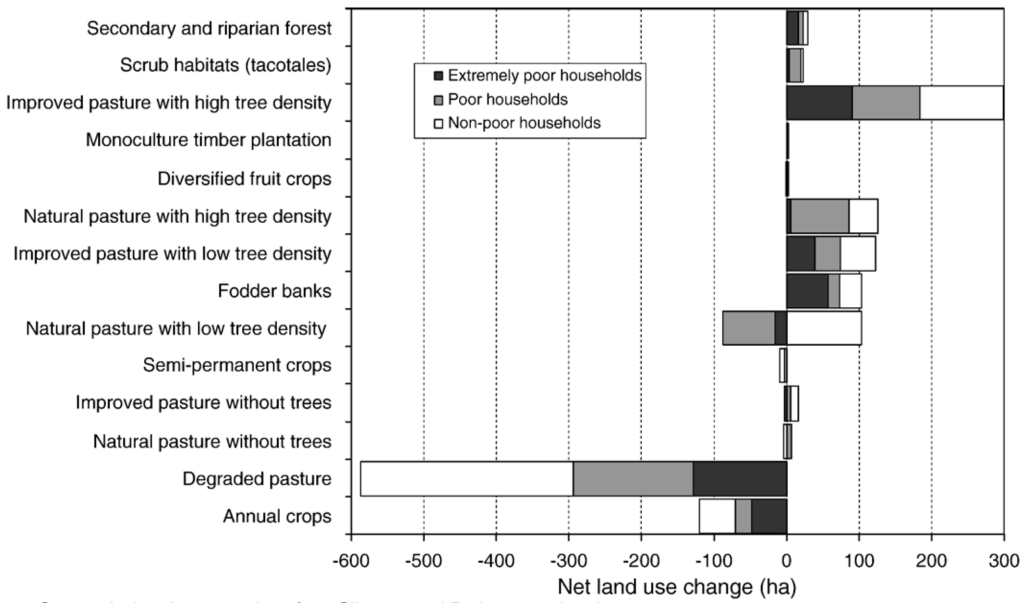
Table 1 and Fig. 1 show that participants made substantial land use changes during the Project's first two years, affecting over 24% of total area. Changes ranged from minor changes such as sowing improved grasses in degraded pastures to very substantial changes such as planting high-density tree stands or establishing fodder banks. The area of degraded pasture was reduced by 68%, and that of annual crops by 52%. Pastures with low tree density experienced a net increase of 19%, and pastures with high tree density of 23%. The area devoted to fodder banks more than doubled, and the length of live fences increased by 160%. Moreover, these net figures understate the changes. Some existing pastures with low tree densities were upgraded to higher tree densities, for example. More traditional silvicultural practices such as timber plantations or fruit orchards found little favor, with farmers preferring to plant timber and fruit trees in pastures and along fencelines.

Land use changes were more extensive in the first year: 467 ha of degraded pasture were converted to other uses, compared to 121 ha in the second year. Because the project only pays for four years, participants have an incentive to undertake land use changes as early as possible. The second year did see a greater expansion of the more complex land uses. Over half the net increase in the area of pastures with high tree density occurred in the second year, for example.

[4] The questionnaires for both surveys are available from the authors on request.

[5] Quickbird imagery with a 61 cm 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.

[6] Assigning applicants randomly to either the participant or the control group, as recommended by Ferraro and Pattanayak (2006), was judged to be infeasible because of strong household desire to participate. Accordingly, a matching approach was adopted (as also recommended by Ferraro and Pattanayak), with control group households selected from nearby communities in similar areas. Even there, Nitlapan encountered substantial animosity among control group members who demanded to be full participants and resisted providing the access and cooperation needed for proper monitoring.



Source: Authors' computations from Silvopastoral Project mapping data.

Fig. 1 – Land use changes by Silvopastoral Project participants, by income group, Matiguás–Río Blanco, Nicaragua, 2003–2005.

The lack of a proper control group prevents a formal comparison to land use changes elsewhere, but casual observation suggests that land use changes in nearby areas were substantially less extensive, in both area affected and degree of change. It is certainly possible that some of the changes observed would have occurred even without the project, but it is unlikely that all would have. A more critical question, as discussed below, is whether the changes are sustainable.

The extent of land use change is surprising given the cost of the required investments. Data from the first-year participant survey show that animal sales (61% of households) and the project's initial 'baseline' payment (53%) were the main funding sources, followed by savings (41%) and credit from a local community bank (32%). Some changes were undertaken entirely with family labor and did not require financing. These results indicate that even poor households like those in Matiguás–Río Blanco often have many ways to finance profitable investments. Nevertheless, providing some initial financing, such as the baseline payment made by the Silvopastoral Project, or frontloading payments, as the reforestation contract in Costa Rica's PES program does (Pagiola, 2005), may be desirable.

To test the importance of TA, participants are divided into two groups. While most participants receive both payments and TA, a randomly selected subgroup of 30 households do not receive TA. A test of factors affecting the adoption of silvopastoral practices in the project's first year found TA not to be significant (Pagiola et al., 2007). As shown in Table 1, silvopastoral practices were already known in the region. Even the more complex practices, such as fodder banks, were already in use, albeit on a small scale. Many households thus already knew how to implement them, reducing the importance of TA. TA may, however, help farmers choose more appropriate practices and implement them better. It is too early to assess whether this is the case in Matiguás–Río Blanco.

6.2. *Impacts on environmental services*

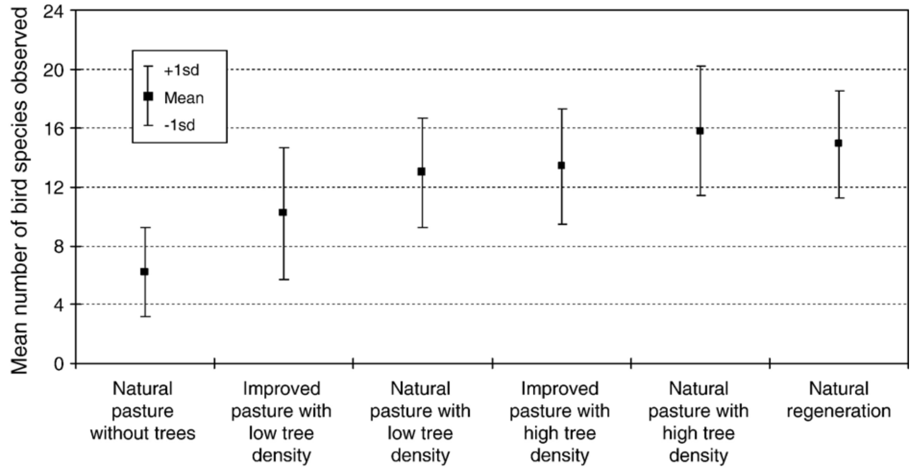
The total ESI score of participants increased by 42% (Table 3). To verify that the desired ecosystem services are actually being generated, biodiversity and carbon sequestration are

Table 3 – Environmental service generation by Silvopastoral Project participants, Matiguás–Río Blanco, Nicaragua, 2003–2005

(ESI points)

Land use	2003	2004	2005
Infrastructure, housing, and roads	0.0	0.0	0.0
Annual crops	0.0	0.0	0.0
Degraded pasture	0.0	0.0	0.0
Natural pasture without trees	13.0	16.9	13.6
Improved pasture without trees	11.2	19.2	17.8
Semi-permanent crops	16.5	13.7	12.7
Natural pasture with low tree density	200.2	268.8	210.2
Fodder bank [a]	75.8	138.0	186.6
Improved pasture with low tree density	123.5	225.7	234.1
Natural pasture with high tree density [b]	378.6	454.4	484.5
Diversified fruit crops [a]	21.0	19.1	19.1
Monoculture timber plantation	1.3	2.5	2.5
Improved pasture with high tree density [b]	210.5	347.5	570.5
Scrub habitats (*tacotales*)	216.8	220.5	248.5
Secondary and riparian forest [a]	966.9	986.4	1019.3
Live fence	77.2	169.7	267.4
Total	2312.7	2882.3	3286.6

Sources: Silvopastoral Project data, based on analysis of remote sensing imagery verified in the field.
[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 but ESI points reflect their current condition.



Source : Silvopastoral Project data

Fig. 2 – Bird species richness of different land use systems in Matiguás–Río Blanco, Nicaragua.

being monitored in all land uses. In this regard, the Silvopastoral Project differs from most other PES programs, who have generally been content to assume that the land uses they support are generating the desired services.

For biodiversity, counts of bird species are the main indicator, complemented by studies of butterflies, ants, and mollusks. Factors such as endemicity and rarity are taken into consideration.[7] Initial plot-level results are very promising (Pérez et al., 2006). Fig. 2 illustrates one of the indicators of alpha diversity collected (diversity within a particular area, see Whittaker, 1972), the number of bird species. Other indicators show broadly similar results. Landscape-level results (beta diversity) are still pending, but here too initial results are promising. A total of 151 different bird species were observed in project-supported land uses, including 29 species considered endangered under Central American Development Committee (CCAD) criteria. 39% of species observed were highly forest dependent and another 35% of medium-high forest dependence.

Monitoring of carbon sequestration is still underway; it will take time to determine the extent to which silvopastoral practices sequester carbon in deep soil.

Funding constraints prevented monitoring of water quality at Matiguás–Río Blanco. Water impacts could only be monitored at the project's Colombia site. Results there show a rapid drop in turbidity, biological oxygen demand (BOD), and coliform counts when riverbanks are reforested and protected from livestock entry, as well as the return of invertebrates indicative of unpolluted water (Chará et al., 2006).

[7] Biodiversity monitoring methodologies were developed with the assistance of the American Bird Conservancy and are described by Pérez et al. (2006). A baseline survey of bird species was undertaken prior to project start; and samples of plots are resurveyed every year.

6.3. *Impact on the poor*

Although PES can contribute to poverty reduction by making payments to poor farmers, there has been concern over the ability of poorer households to participate (Landell-Mills and Porras, 2002; Pagiola et al., 2005). Matiguás–Río Blanco provides a strong test of poorer households' ability to participate. Unlike most PES programs, the Silvopastoral Project requires investments to be undertaken by participants, some of them complex and onerous.

An earlier analysis showed substantial participation by poorer households during the Project's first year (Pagiola et al., in press), a pattern which continued in the second year. As shown in Fig. 1, poor and extremely poor households accounted for a substantial share of land use changes, including 50% of the decline in degraded pasture and 58% of the decline in annual crops. Moreover, land use changes by poorer households were not limited to adopting technically simpler and cheaper practices. Poorer households established 71% of fodder banks and 64% of pastures with high tree density. Indeed, it was the non-poor who focused on the simpler practices, such as establishing natural pasture with low tree density.

It is too soon to judge whether the Silvopastoral Project will have a significant and lasting impact on the welfare of participating farmers. This will largely depend on the sustainability of the project-supported practices (see discussion below). If these practices, once established, are indeed more profitable for farmers than current practices, then payments will have helped farmers move to a higher income path. Conversely, if the new practices are not profitable enough to be retained once payments end, then the impact of payments on welfare will likewise prove fleeting.

6.4. *Transaction costs*

Transaction costs play a critical role in the cost-effectiveness, sustainability, and replicability of PES mechanisms (Pagiola and Platais, 2007), and in the extent to which poorer farmers can participate (Pagiola et al., 2005). Because of its pilot nature, the Silvopastoral Project has relatively high costs for detailed monitoring and other activities that would not necessarily be needed in a scaled-up project. The ESI allows payments to be closely tied to expected benefits, but also imposes relatively high monitoring costs. To reduce these costs, the project is testing proxy indicators that are highly correlated with biodiversity conservation but are easy and cheap to monitor, ideally using remote sensing. A crucial question that is being explored concerns the tradeoff between the precision of the index and the transaction costs involved in implementing it.

7. Sustainability and replicability

Initial results from the project suggest that PES can induce land use change, and that silvopastoral practices can generate environmental services. But are these changes sustainable? And can the approach be extended to other areas?

7.1. *Are short-term payments sufficient?*

Payments in a PES program should generally be on-going rather than finite (Pagiola and Platais, 2007). The logic for this is simple: if environmental services are externalities, they will only be generated as long as payments are received. Indeed, previous approaches that relied on short-term payments have often resulted in farmers reverting to previous land uses once payments ended (Lutz et al., 1994).

The Silvopastoral Project departed from this logic based on the hypothesis that silvopastoral practices, once established, were privately more profitable than current practices, and so would be retained. If this hypothesis is correct, the short-term payments offered by the project will be sufficient to induce a sustainable change in land use.[8]

It is too soon to judge the profitability of silvopastoral practices for participants, as many practices are still being implemented. Several indicators suggest they may well be: milk production in participating farms has increased from 3.4 to 3.7 l/cow in winter and from 3.2 to 3.4 l/cow in summer, and stocking rates have increased from 1.5 to 2.0 livestock units/ha. Livestock mortality in the summer (when it tended to be high due to limited fodder availability) has declined.

To try to determine the long-term sustainability of the project's PES mechanism, a randomly-selected sub-group of participants was given a modified contract: rather than being paid over a four-year period, they received a similar amount over a two-year period. The early results of this test are not encouraging: at least two participants with 2-year contracts cut back some of the trees they had planted soon after they had received their second and final payment.

In general, farmers can be divided into three groups: (1) farmers for whom silvopastoral practices are sufficiently profitable to justify adoption with no additional inducement; (2) farmers for whom silvopastoral practices are profitable once established, but for whom initial costs make adoption unattractive; and (3) farmers for whom silvopastoral practices are not profitable, even once established.[9] Only for farmers in group 2 would short-term payments be sufficient to sustainably 'tip the balance'. Farmers in group 3 may adopt the practices while receiving payments, but would abandon them once payments cease. Farmers in group 1 would adopt the practices even without payments, so PES would not change their behavior; at best, it might accelerate changes that would have occurred anyway.

How large the middle group is remains to be determined, in Matiguás–Río Blanco itself and more generally. Overall, it is highly unlikely that the profitability of silvopastoral practices in a country as large and varied as Nicaragua, let alone region-wide, is always such that a short-term payment would 'tip the balance' in their favor. Thus, while there may well be some cases in which short-term payments are sufficient, long-term payments will often be necessary to induce many farmers to sustainably change their land use choices in ways that provide more ecosystem services.[10] Even in the case of farmers for whom short-term payments are sufficient to induce long-term adoption of silvopastoral practices, longer-term payments may still be desirable because of the conditionality they allow on other land use decisions, such as preventing burning fields or cutting trees in other parts of the farm. Cases in which short-term payments are sufficient are thus likely to be the exception rather than the rule. This has important implications for the financing needs of PES programs.

7.2. *Who will pay?*

If long-term payments are needed to generate ecosystem services, long-term financing is needed. The PES approach proposes to secure such financing from service users.[11]

[8] Short-term payments of this nature are not uncommon in developing country PES programs. Costa Rica's reforestation contract pays for five years but expects the resulting plantations to be maintained for up to 20 years (Pagiola, 2005), while the PROFAFOR reforestation program in Ecuador pays for three years but expects forests to be retained for 99 years (Albán and Wunder, 2005). In both of these cases, as in the Silvopastoral Program, timber and other products are expected to make plantations profitable once payments cease. Mexico's PES program also has de facto short-term payments as its five-year contracts are not renewable (Muñoz et al., 2006). In this case, the motivation was political: to spread payments as widely as possible. As in the Silvopastoral Project, sustainability is a concern in each of these cases.

[9] In fact, the relative profitability of silvopastoral practices may well differ from field to field, so it would be more correct to say that some fields are in group 1, while other fields (perhaps including some belonging to the same farmer) are in groups 2 or 3.

[10] Conversely, another group would require no payments at all. Distinguishing such farmers from those who do remains a major challenge.

[11] In addition to generating the required financing, making users pay has the desirable characteristic that financing embodies information about what the users find valuable, and the magnitude of this value (Pagiola and Platais, 2007). When PES programs are financed from government budgets, their efficiency depends on the degree to which governments are able to identify valuable services. Moreover, even when governments do undertake careful prior analyses to do so, political considerations may overwhelm technical ones, as occurred in Mexico's PES program (Muñoz et al., 2006).

Making users pay for ecosystem services is difficult, however, when the services of interest bring global benefits, as in the case of the biodiversity conservation and carbon sequestration benefits provided by silvopastoral practices.

The carbon sequestration services provided by establishing silvopastoral practices could, in principle, be sold to carbon buyers under the Clean Development Mechanism (CDM), which would provide payments over a reasonably long period. The initial results of the Silvopastoral Project suggest that carbon financing could be a viable source of funding, even if it had to bear the whole burden of payments. The project has demonstrated that a US$75/point/year payment induces substantial land use change. If such a payment were solely for carbon sequestration, it would correspond to US$15/tC — quite compatible with observed prices of US$14–20/tC (World Bank, 2004), as long as transaction costs are kept low. Several projects that plant trees in agricultural landscapes are being submitted to the CDM (Bosquet and François, 2006). The scope for such projects is limited, however, by overall limits on the emission reduction credits that can be generated by land use-based activities. Funding for carbon sequestration might also be sought from the voluntary (or 'retail') market. The Scolel Té project, for example, is financed by sales to the voluntary market (Tipper, 2002). This market is more flexible than the CDM market, but is also smaller and tends to pay less. Its mean price of US$5/tC (World Bank, 2004) implies a payment of US$25/point, which would likely induce much less land use change than occurred at Matiguás–Río Blanco.

Water services offer the most promising avenue for financing long-term PES programs, as water users are easy to identify; receive clear, well-defined benefits; and often already have financing mechanisms (Pagiola and Platais, 2007). However, demand for water services tends to be very site-specific (Pagiola et al., 2007). The site-specificity of water services is illustrated in the project area. Both Matiguás and Río Blanco face a variety of problems because of degradation in the watersheds from which they draw their water. Neither the Bulbul nor the Paiwas microwatersheds contributes to their water supply, however, and so neither would be eligible for any payments these municipalities might make.

In cases where neither carbon payments nor water payments are possible (or sufficient) but there is a need to improve biodiversity conservation in agricultural landscapes, options are limited. Available biodiversity-specific financing sources, such as the GEF and environmental NGOs, tend to have limited funding and to only provide short-term funding. Bioprospecting was once thought to be a promising source for long-term financing, but has proven disappointing in practice. Tourism may provide another source of financing for biodiversity conservation, in some instances, but so far no PES program has succeeded in tapping it.[12] Another option is to place short-term financing from GEF or other donors in an endowment fund, thus converting it into a long-term payment stream. This approach is being pursued in PES projects supported by the World Bank and GEF in Costa Rica and Mexico. The Worldwide Fund for Nature (WWF) has also established such an endowment fund to help protect the Monarch Butterfly (*Danaus plexippus*) wintering grounds in Mexico.

[12] A PES project in Mexico supported by the World Bank and GEF will attempt to secure payments from the tourism industry (Pagiola and Platais, 2007).

8. Conclusions

Because most ecosystem services are externalities from the farmers' perspective, they tend to be underproduced. PES approaches such as that being piloted in Matiguás–Río Blanco have considerable potential for helping to increase the generation of ecosystem services in agricultural landscapes. Although the Silvopastoral Project is still underway, it already appears to have succeeded in inducing farmers to increase substantially the use of practices that generate higher levels of ecosystem services, and on-going monitoring indicates that these land use changes are in fact generating the desired environmental services.

Ensuring that these changes are sustainable is challenging, however. Short-term payments such as those offered by the Silvopastoral Project may sometimes be sufficient to 'tip the balance' towards adoption of the desired land use changes, but in most cases longer-term payments are likely to be required. This creates the challenge of finding suitable long-term funding sources to make such payments. The best opportunities for developing such long-term funding are likely to be found when the services being provided are private goods (as in the case of water), or where regulations create a market for public goods (as in the case of carbon, thanks to the Kyoto Protocol and regulations in some individual countries). Where these conditions do not hold, as is largely true for biodiversity services, use of PES will be much more difficult. Of course, other approaches to these vexing problems also suffer from their own limitations. In most cases, it is likely that a range of approaches will be needed. PES promises to be a useful and powerful new tool, but it is not a silver bullet.

In addition to making payments appropriately, PES programs may need to ensure that other barriers to adoption of practices that generate environmental services are addressed. These may include insecure tenure, lack of credit, or lack of knowledge of the new practices. Initial results in Matiguás–Río Blanco suggest that such barriers are not always as insuperable as they are sometimes made out to be, even for poor households. Nevertheless, addressing such problems, where they exist, may be important to the success of PES programs.

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