Chapter 9.
Impact of the PSA Program on Land Use

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9.1 Introduction

As the only long-term, large-scale payment initiative for tropical forests, Costa Rica's Program of Payments for Environmental Services (*Pago de Servicios Ambientales,* PSA) provides a unique opportunity to evaluate direct payments as a conservation policy tool. While there has been an explosion of interest in payments for environmental services (PES) throughout the world (Landell-Mills and Porras, 2002), most experiences to date are small scale and short term. Costa Rica's PSA has been implemented throughout the country since 1997. Thus, there is sufficient experience to test the underlying hypothesis that PES increase the area of protected ecosystems.

PES is a voluntary transaction between at least one buyer and at least one seller (Wunder, 2005). Payments are conditional on maintaining an ecosystem use that provides the desired environmental services, and thus provide a direct, tangible incentive to conserve the ecosystem and prevent encroachment by others. As a result, both local resource users and conservation organizations may prefer PES to the integrated conservation and development project (ICDP) approach, which invests in targeted economic development interventions that have only indirect and often tenuous effects on conservation (Ferraro, 2001; Sierra and Russman, 2006). The simplicity of conservation payments and the failure of other policies to curb the destruction of ecosystems explain why academics, development organizations and policy-makers show increasing interest in using direct payments to protect endangered ecosystems (Pagiola, 2002; Scherr and others, 2004).

Though simple and intuitively appealing, the idea of using direct payments to protect ecosystems needs empirical testing before it can be embraced with confidence (Ferraro and Pattanayak, 2006). The ex ante promise of economic theory does not translate automatically into actual gains in ecosystem protection as a result of a specific payments program. A Blue-Ribbon Panel commissioned to evaluate Global Environment Facility (GEF) funding for PSA through the Ecomarkets Project (Hartshorn and others, 2005) found that 70 percent of PSA forest protection contracts are on land with strong limitations, or not at all appropriate, for agriculture. The panel concludes "that much of the land under PSA forest protection contracts might not have been converted to other uses in the absence of payments" (p.12). Their finding suggests that scarce conservation funds may have been used inefficiently. This concern is not unique to the

Costa Rican program; for US examples, see Goodwin and Smith, 2003; Kluender and others, 1999; Smith and Wienberg, 2004; Wu, 2000; Wu and others, 2004.

This chapter reports evidence on how much more forest has been conserved in Costa Rica as a result of PSA contracts with landowners. Such evidence requires estimating a counterfactual outcome: how much forest would have been preserved if there had been no payments. The challenge is that landowners volunteer to participate in PES programs, and PES administrators often actively target the contracts. When the characteristics that affect who receives a contract (for example, land use profitability, landowner preferences) also affect land use decisions, any direct comparison of participants and non-participants suffers from 'selection bias,' which can either over-state or under-state the program's impact. By applying rigorous program evaluation methods that have been recommended for identifying the causal effects of conservation policies (Coglianese and Bennear 2005; Frondel and Schmidt 2005), we find that the PSA program does result in a small but statistically significant increase in the area of forest conserved.

9.2 Potential impacts of PSA on land use

The PSA program offers landowners annual payments for forest conservation (and in less used modalities not considered in this chapter, for reforestation, sustainable forest management, and agroforestry).[1] Landowners are required both to maintain the land under contract in forest and to protect that forest—for example, by establishing fire breaks, excluding livestock, and refusing access to hunters. The relevant government agencies and intermediary organizations may visit the contracted area to ensure compliance.

A naïve approach to measuring the impact of PSA would be to assume that the program causes forest conservation equal to the area under contract. That is, the payments cause landowners to retain mature forest cover that otherwise would have been converted (illegally) or protect forest that otherwise would have been degraded. However, there is no restriction on landowners accepting payments to 'protect' forest that they were not going to use, due to either legal or biophysical constraints or to environmental preferences. Thus, a better approach for measuring the impact must account for what would have happened to the lands under contract without PSA.

The program also could have indirect impacts on land use, either encouraging additional conservation (spill-overs) or leading to deforestation (leakages) in areas not under contract. This is especially likely on *fincas* (properties) that are only partially under PSA contract. Program participation could encourage retention of existing forest, reforestation, or maturation of secondary forest not under contract in order to obtain future payments or because the information and recognition provided by the program shifts landowner preferences towards conservation. Conversely, landowners may conclude that they should only conserve forest if they are paid to do so, encouraging deforestation of areas not under contract (Cardenas and others, 2000; Muñoz, 2004). Income from payments could be invested in off-farm enterprises, facilitating an exit from agriculture (Sierra and Russman, 2006), or it could be invested in intensification or expansion of agricultural land use on the rest of the property. Similar mechanisms could also cause indirect

[1] In addition to direct payments, participation may give landowners access to education and technical assistance provided by intermediary organizations, and may increase tenure security against potential squatters (Arriagada and others, forthcoming; Miranda and others, 2003; Porras and Hope, 2005).

positive or negative impacts in the neighborhood of *fincas* with PSA contracts (for example, in the same district).

At the national level, the program could affect prices, for example by enhancing Costa Rica's competitiveness in the international tourism market or by reducing the supply and therefore increasing prices for agricultural products (see Chapter 11). The program could also shift public opinion by raising awareness of the value of forests and rewarding good forest stewardship.

There is some evidence that PSA has an important educational function, at least for participants. For example, 36 percent of participant landowners interviewed by Muñoz (2004) reported that the program had improved their understanding and changed their attitudes towards the forest. Ortiz and others (2003) find that 95 percent of landowners in the program say that PSA has taught them to recognize the value of the forest, and 98 percent believe that PSA is important for Costa Rica. Hartshorn and others (2005) interviewed several people who argued that the PSA program has changed the general public's perception of forest ecosystems. They believe that the public now recognizes that forests provide valuable services, which must be paid for just like any other valuable service. From this perspective, even if all PSA payments are just 'rewarding' landowners for conserving forest that they would have conserved anyway (cf. Wunder 2005), the program could have a positive impact on forest conservation. These potential national level effects are not captured by our evaluation methods, which assess the impact of PSA by comparing areas (either *fincas* or census tracts) within Costa Rica.

9.3 Evaluation methods

Given the multiple potential effects of the PSA program, evaluation is not straightforward. Fundamentally, evaluation is difficult because the distribution of payments is not random, but rather arises from administrative priorities and landowner decisions. This means that the program cannot be evaluated like a scientific experiment by simply comparing "treated" farms with contracts (PSA *fincas*) to "control" farms without contracts (non-PSA *fincas*). Nonetheless, such comparisons do provide a useful starting point. Thus, in this section, we first present findings from previous studies (summarized in Table 9.1) on (a) land use on PSA *fincas* compared to non-PSA *fincas*, and (b) land use on PSA *fincas* before and after they were enrolled in the program. We describe the potential bias in these approaches, and then describe our more rigorous approach to estimating the causal impact of the program.

As shown in Figure 9.1, several studies find more forest and less agriculture on PSA *fincas* as compared to non-PSA *fincas* in the same region. The problem with this approach is that participants are known to differ from non-participants in terms of characteristics that also affect land use decisions (Ortiz and others, 2003; Miranda and others, 2003; Zbinden and Lee, 2005). For example, landowners can only obtain PSA contracts on *fincas* for which they can establish clear ownership, including a cadastral map on record with the National Land Registry (*Catastro Nacional*). Landowners without legally recognized cadastral maps might be more likely to clear forest in an attempt to establish property rights. In this case, deforestation rates would be lower on PSA *fincas* because of their tenure status – not because of PSA.

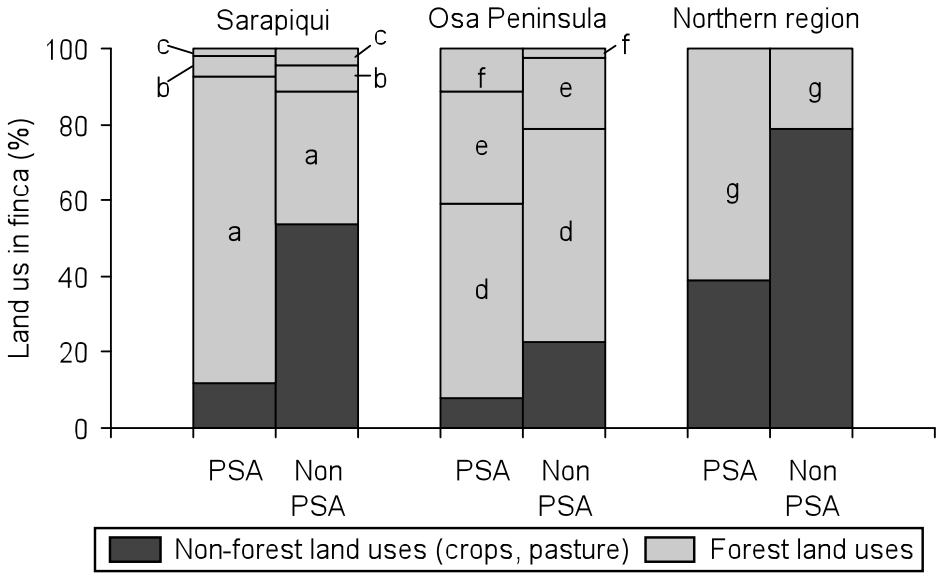
A second approach is to compare forest cover on the same PSA *finca* before and after establishment of the PSA program. In a telephone survey of 100 PSA program participants throughout Costa Rica, 43% said that the forest had already been protected and 36 percent that it

Table 9.1: Surveys of landowners in Costa Rica

	Survey		*PSA Sample*			*Non-PSA Sample*	
	Region	*Year*	*Forest protection sample*	*Reforestation and sustainable management sample*	*Sampling frame*	*Sample size*	*Sampling frame*
Miranda and others, 2003	Provinces of San José and Heredia	2001	24	8	FUNDECOR and local government agencies	14	Local agricultural centers
Muñoz, 2004	Osa Peninsula	2003	16	6	FONAFIFO, screened for smallholders with contracts signed in 1997 or 1998	0	
Ortiz and others, 2003[a]	Nationwide	2002	100	0	FONAFIFO records with valid phone numbers	0	
Porras and Hope, 2005	Arenal Watershed	2004	0	0		116	Public meetings and interviewers' personal contacts
Sierra and Russman, 2006	Osa Peninsula	2003	30	0	FONAFIFO, screened for >30ha	30	CEDARENA, screened for >30ha
Zbinden and Lee, 2005	Cantons of Los Chiles, San Carlos, Sarapiquí	2002	71	62	Local government offices	141	Neighbors of PSA (>5ha)
This study	Cantons of Sarapiquí, Guacimo, and Pococí	2005	50	0	FUNDECOR, screened for contracts signed in 1997-1999 and still in force in 2005	150	1/3 neighbors of PSA, 1/3 random sample from *catastro nacional* records in same district, 1/3 from *catastro nacional* records in 3-6km buffer around each PSA property

Notes: [a] Conducted interviews by telephone (all other surveys reported here were in-person).

had been used for grazing before being placed under contract (Ortiz and others, 2003). While this suggests that forest cover has increased on PSA *fincas*, it does not indicate whether this increase is due to PSA. Forest cover was already increasing in Costa Rica before 1996 due to a number of factors (Brockett and Gottfried, 2002; de Camino and others, 2000; Miranda and others, 2006; Sánchez-Azofeifa and others, 2001). In a variation on this approach, Sierra and Russman (2006) use land use on recently enrolled properties (with contracts signed in last two years) to approximate what land use on properties enrolled for more than five years would have been had there been no PSA. They find that PSA participants in the Osa Peninsula with recent PSA contracts have significantly more land in agricultural production than earlier participants, and conclude that payments allow landholders to invest in off-farm enterprises and accelerate exit from agriculture. However, such a conclusion is only valid if the factors that determine when landowners enroll in PSA do not also influence land use.



Notes: a. Mature forest; b. Regenerating forest; c. Plantations; d. Primary forest; e. Intervened forest; f. *Charral*; g. Forest (all types). For Sarapiqui and Osa, the graphs show land use allocation of an average finca. For Northern region, the graph shows the percent of total area of all sample fincas.

Sources: Sarapiquí from authors' study; Osa from Sierra and Russman (2006); northern region from Zbinden and Lee (2005).

Figure 9.1: Land use as reported by PSA and non-PSA landholders

The problem with all of these approaches could be characterized as missing data: it is not possible to observe the forest cover of PSA participants had they not participated. One approach that directly addresses this problem is matching (Shadish and others, 2002; Pattanayak and others, forthcoming). Matching is used to identify a comparison group that is 'very similar' to program participants (the 'treatment' group) with only one key difference: the comparison group did not participate in the program of interest. For example, participants could be matched to non-participants with *fincas* of similar size, distance to market, and management history. In propensity score matching, participants are matched to non-participants based on their

probability of participation, typically estimated with a probit or logit model that relates participation to set of characteristics (Rosenbaum and Rubin, 1983). Matching methods generally require detailed information on both participants and a large sample of non-participants in order to estimate the propensity score and find good matches. 'Pre-matching' the sample can facilitate this process (Rao and Ibanez, 2005; Shadish and others, 2002; Pattanayak and others, forthcoming). Once matches are identified, the causal effect of PSA on program participants can be estimated by finding the average difference in land cover outcomes between matched pairs of PSA participants and non-participants with similar propensity scores.

Propensity score matching has been widely applied in developing countries to estimate the causal impacts of social policies. There is a small but growing literature that applies this method in the natural resources field, including the impacts of individual transferable quotas on fisheries collapse (Costello and others, 2008), protected areas on forest cover in Costa Rica (Andam and others, forthcoming) and on forest fragmentation in Thailand (Sims, 2008), community participation on fuelwood consumption in India (Bandyopadhyay and Shyamsundar, 2004), forest disturbance on forest amenities in the USA (Pattanayak, 2004), prescribed burning on wildfire in the USA (Butry and others, 2005), decentralized management on forest cover in India (Somanathan and others, 2005), devolution of forest management on household income from forests in Malawi (Jumbe and Angelsen, 2006), the Endangered Species Act on species recovery in the USA (Ferraro and others, 2007), and a recent analysis of PSA on land use using pixels as the unit of analysis (Pfaff and others, 2008).

In our case study, we use geographic pre-matching and propensity score matching to estimate the impact of PSA on land use. We focus on how land use on a *finca* is affected by a PSA contract on that *finca*. For comparison, we also discuss the impact of PSA contracting on land cover at the more aggregate level of census tracts.

9.4 Evidence on land use impacts at the finca level

Data

The ideal database for a rigorous empirical evaluation of PSA's impact on land use would include observations on land use and characteristics of both participant and non-participant landowners and their properties, hereafter called *fincas*, both before and after the program. Because this type of evaluation was not planned prior to implementation of the program, ex post evaluation of the program requires re-constructing historical land use, either via remote sensing or retrospective survey questions.

For our analysis, we conducted a case study of the first phase of PSA (1997-1999) in the region of Sarapiquí, which consists of the *cantones* of Sarapiquí, Guacimo, and Pococí (see Figure 9.2). We selected this region because it has a sufficient number of PSA contracts to analyze quantitatively and excellent records on PSA participants maintained by a non-governmental organization, the Foundation for the Development of the Central Volcanic Range (*Fundación para el Desarrollo de la Cordillera Volcánica Central*, FUNDECOR). FUNDECOR is the only PSA intermediary that has attempted to target areas under greater threat of deforestation, increasing the chance of finding a causal impact of PSA on forest cover.

For the case study, we integrated qualitative interviews, a quantitative survey, and remote sensing. First, we developed a detailed description of program administration through careful observations, conversations, and review of records at FUNDECOR, the National Fund for

Forestry Financing (*Fondo Nacional de Financiamento Forestal*, FONAFIFO), and the National System of Conservation Areas (*Sistema Nacional de Areas de Conservación*, SINAC), complemented by a review of the substantial literature on the program (for example, Castro and others, 2000; Ortiz, 2003; Rodríguez, 2003; Rojas and Aylward, 2003; Snider and others, 2003). The qualitative component also included in-depth interviews with seven landowner participants and similar non-participants, using an iterative interview process, review of records, and observations of their land to understand how and why they decided whether to participate in PSA and to conserve or convert forest.

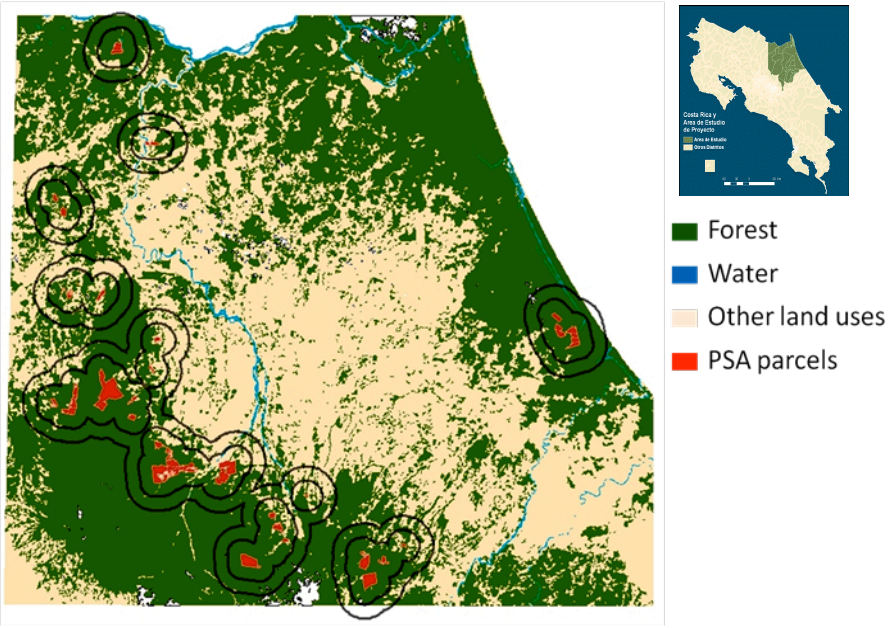


Figure 9.2: PSA *fincas* and surrounding zones where non-PSA buffer sample was selected

For the quantitative survey, we contracted the survey firm Borge y Asociados to interview 50 program participants and 150 non-participants. The 50 program participants all had current PSA contracts that had first been signed between 1997 and 2000 with assistance from FUNDECOR and since renewed (see Figure 9.2 for locations). The sampling frame for the non-participant farms is described below. The survey elicited information on socio-economic and *finca* characteristics, including land cover, in 1996 and 2005. Borge y Asociados also collected Global Positioning System (GPS) readings on the *fincas*, which we subsequently linked to maps from the *Catastro Nacional* that we were able to locate. For the *fincas* that we could map, we determined forest cover in 1992 and 2005 from aerial photographs as well as other spatial characteristics such as distance to market and elevation from the *Atlas Digital de Costa Rica 2004* (ITCR, 2005).

For the non-PSA sample, we needed a sampling frame that included all *fincas* potentially eligible for PSA. We evaluated many potential sampling frames, including landowners with pending, cancelled, and rejected PSA contracts, landowners who had submitted forest management plans for approval, and landowners surveyed as part of a Screwworm Eradication Program. However, we concluded that all of these included only sub-sets of the *fincas* eligible for PSA. Thus, we opted to use a geographic sampling rule and *Catastro Nacional* records. In both cases, we further screened landowners to ensure that they (a) had owned or managed the

property in the sampling frame since 1996; (b) had at least some natural forest cover on that property in 1996; and (c) had never held a PSA forest protection contract.

Because of our small sample size, it was particularly important to 'pre-match' samples to ensure that we would be able to find non-PSA *fincas* with similar propensity scores to PSA *fincas*. We used three rules to sample non-PSA *fincas* likely to be in similar biophysical and market conditions as the PSA *fincas*: 50 immediate neighbors, 50 landowners in buffer zones, and 50 landowners in the same district.[2] To select immediate neighbors, interviewers proceeded clockwise from the PSA property, following roads until they located a neighbor who fit the sampling criteria. We applied the other two sampling rules to *Catastro Nacional* records, after filtering out properties smaller than 5ha, properties listed in FONAFIFO's records as having PSA contracts, and properties owned by the state and large companies. Then we randomly selected a group of 50 landowners with properties located in buffers around each PSA property (See Figure 9.2).[3] This buffer method was designed to pre-match landowners for characteristics that are spatially correlated, including biophysical factors and access to markets and public services, but avoid spill-over effects due to communication among neighbors or stricter enforcement of environmental laws near properties with PSA contracts. For comparison, we also randomly selected one landowner in the same district as each PSA property.

Findings

The first step in evaluating the PSA program is to understand how landowners come to participate in the program, so that we can control for differences between participants and non-participants. Our case studies and interviews with representatives of government agencies and intermediary organizations serve this purpose. For PSA contracts to be put in place, landowners must volunteer to participate in the program, and the program administrators must accept their applications. In Sarapiquí, FUNDECOR also plays a fundamental role as an intermediary organization.

Arriagada and others (forthcoming) report that the lack of alternative uses for contracted land appears to have the greatest influence on decisions to participate in PSA. The logic is that "if I am not going to do anything with the forest, why not enroll in PSA and receive an additional payment?" In focus groups conducted by Ortiz and others (2003), PSA participants reported that the program reduces the temptation to cut down forests for short-term benefits, particularly when alternative uses of the land would bring only marginal benefits. Another possible determinant of participation is landowner attitudes towards the environment. 72 percent of landowners in our survey credited their participation to environmental factors, rather than economic factors, as did 65 percent of participants in Heredia and San José (Miranda and others, 2003) and 57 percent of participants in a nationwide sample (Ortiz and others, 2003).

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2 Borge y Asociados identified and excluded six properties that had been invaded, subdivided, or converted to pineapple, one that became part of a hydroelectric project, four that are part of a national park, and several more that were of difficult access. While none of these properties are included in our matching analysis, the fact that six of the non-PSA *fincas* in our sampling frame had been subdivided, invaded, or converted to pineapple plantations already suggests that outcomes for non-PSA vs. PSA *fincas* may be significantly different. While many landowners initially selected for the sample could not be located, only one landowner refused to participate in the survey.

3 The buffer regions had an inner radius of 1920m and an outer radius of 3840m. We had to filter out *fincas* that did not have geographic coordinates listed in the *Catastro Nacional* for this sub-sample.

Conversations with forestry professionals and government officials in northeastern Costa Rica indicate that during 1997-99, no applications that met all of the requirements for PSA were rejected. MINAE did not promote the program at the time, so that applications generally were only submitted by people already familiar with the MINAE offices—for example, because they had previously submitted forest management plans. In Sarapiquí, however, the story was somewhat different, as FUNDECOR promoted PSA in zones identified as facing greater threats of deforestation (Guapiles, Horquetas, Virgen del Socorro, and Guacimo).

This description of the administrative selection process is consistent with survey results from non-participant landowners, many of whom say that they do not participate in PSA simply because they lack information about the program (Table 9.2), and with Zbinden and Lee's (2005) finding that education, access to extension, and participation in meetings are key determinants of which landowners enroll in PSA. In Sarapiquí, 28 percent of landowners not currently in the program indicated that they plan to apply in the future. These findings suggest that it would be possible to expand the area covered by the program without necessarily increasing the payment level.[4] However, one key constraint identified by Miranda and others (2003) and Porras and Hope (2005) is the land tenure requirement, which was enforced most strictly between 1999 and 2002. In Sarapiquí, we limited our sample to *fincas* with titles, since *fincas* without title were clearly not eligible for PSA contracts.[5]

Table 9.2: Reasons for not enrolling land in PSA

(% of respondents)

		Heredia and San José provinces	*Arenal watershed*	
	Sarapiquí		*Coffee Farmers*	*Cattle Farmers*
Lack of information	66	15	30	60
Payment too low	9	5	32	17
Distrust system	2	20		
Too complicated	15			
Land restrictions/ lack title		15	28	7
Farm/forest size		35		
Not prepared to commit			9	13
Cannot pay for application	2			

Sources: Sarapiquí from authors' study; Heredia and San José from Miranda and others (2003); Arenal from Porras and Hope (2005).

[4] While better information, education, and outreach could bring many landowners in PSA, there clearly are cases where higher payment levels would be required. For example, Porras and Hope (2005) found that coffee farmers in the Arenal watershed did not participate in PSA because payments are insufficient.

[5] Since 2003, landowners without formal title but with clear possession of their land have been eligible to apply for PSA, as long as they meet other priorities established in Decree No. 30761. Likewise, in 1997 and 1998, applicants without title could use a sworn statement signed by two witnesses as proof of possession. However, these landowners could still have difficulty getting forest management plans accepted by MINAE, which also required land title.

Table 9.3: Comparison of PSA and non-PSA landowners in Sarapiquí

	PSA sample		*Non-PSA sample*			*Most similar*
Variable description[a]	*Mean*	*Std. dev.*	*Mean*	*Std. dev.*	*P-value*	*sub-sample*[a]
Percent from Central Valley	70.0	46.29	37.3	48.51	0.000***	N
Percent resident on *finca* in 2005	22.0	41.84	48.9	50.17	0.001***	D
Percent resident on *finca* in 1996	26.1	44.40	44.7	49.91	0.026**	D
Years of education of respondent	9.16	5.84	9.02	5.16	0.875	B
Percent family members with university education	40.0	49.49	6.0	23.78	0.000***	N
Age of respondent (years)	53.62	11.21	52.86	12.12	0.698	B
Number of men in family	1.82	1.35	1.76	1.29	0.789	N
Number of women in family	2.42	2.62	1.67	1.16	0.007***	N
Number of children in family	0.96	1.37	0.63	1.04	0.080*	D
Percent owned *finca* 25 yrs +	38.0	49.03	24.8	43.35	0.073*	N
Percent sole owner of *finca*	74.0	44.31	69.3	46.28	0.528	D
Percent inherited *finca*	24.0	43.14	16.3	37.09	0.225	B
Percent who expect children to maintain *finca*	94.0	23.99	95.0	21.80	0.779	N
Percent owned auto in 1996	38.0	49.03	47.5	50.15	0.262	N
Percent own auto currently	68.3	46.69	53.1	50.42	0.055*	B
Percent who had experience with plantations before 1996	40.0	49.49	48.6	50.16	0.297	D
Index of environmentalism (1 to 10)	2.85	1.37	2.78	0.91	0.688	D
Family members working on finca	1.54	1.79	1.20	1.29	0.158	N
Percent who sell crops	10.0	30.30	25.4	43.67	0.023**	D
Percent with land title	70.0	46.29	81.1	39.32	0.101	N
Area mature native forest in 1996 (ha)	139.19	315.53	29.77	53.16	0.000***	D
Area regenerating forest in 1996 (ha)	4.47	12.62	4.57	19.76	0.964	N
Area plantation in 1996 (ha)	3.03	13.69	1.40	5.94	0.247	D
Area pasture in 1996 (ha)	18.84	51.91	26.83	61.09	0.408	N
Percent forest fenced in 1996	21.9	41.91	53.7	50.13	0.000***	N
Years experience with agriculture	20.15	17.27	18.21	15.76	0.487	N
Head of cattle on finca in 1996	16.42	44.31	34.42	61.67	0.088*	N
Hired workers in 1996 (1=yes, 0=no)	54.00	50.35	50.45	87.25	0.789	N
Percent who cultivated crops on finca in 1996	8.0	27.01	29.1	0.45	3.05	B
Percent with forest management plan before 1996	38.0	49.03	17.81	38.39	0.003***	N
No. visits by govt env. agency in 10 yrs	15.78	18.52	1.57	4.05	0.000***	D
Percent of income from off-farm sources in 1996	68.7	37.30	57.2	37.25	0.127	N
Percent of finca with steep slope	38.4	31.48	25.2	24.73	0.003***	B
Percent forest logged in past 50 years	50.0	50.51	44.8	49.90	0.524	D
Distance to nearest forestry office (km)	29.15	14.39	25.07	13.98	0.092*	D
Finca size (ha)	165.11	338.02	70.66	112.25	0.003	D
Percent of finca with poor soil	27.1	30.87	19.6	25.38	0.100*	N

Notes: The *p*-values are from standard t-tests for difference in means.
Significance at 99% level indicated by *** = 99%, ** = 95%, * = 90%.

The landowners interviewed are characterized in Table 9.3. Landowners with PSA contracts are similar to the comparison sample of non-PSA landowners on many counts, including family structure, experience with plantation forestry and agriculture, environmental

beliefs, and in ownership, management, and basic biophysical characteristics of the *finca*. The last column in the table indicates which of three sub-samples of non-PSA landowners is most similar to the PSA sample. As expected, neighbors are most similar on the largest number of characteristics, including household socioeconomics and *finca* management. They may also be most similar in terms of unobservable market and biophysical factors that are spatially correlated, but the trade-off is that they are also most likely to be affected by any spill-overs or leakages.

The differences across the samples are also instructive. PSA participants are less likely to have been born in the region and less likely to have been resident on the *finca* in 1996. While education of the respondent does not differ across samples, there is more likely to be someone with university education in the family of a landowner with a PSA contract. Crops were less likely to have been grown (in 1996 and 2005) on *fincas* with PSA contracts. Perhaps because of this, the forest on these *fincas* is less likely to have been fenced. These *fincas* are also significantly larger on average, with more steep slopes and more native forest cover in 1996. Geographic pre-matching did not eliminate differences in these variables, suggesting that they are related to some self-selection or administrative targeting process for PSA. For example, an absentee landowner originally from the Central Valley (and perhaps living there again) may find it easier to access the PSA program and at the same time, may have less ability and need to use the *finca* for agricultural production.

Table 9.4: Native forest cover in Sarapiquí in 1992 and 2005

	PSA		*Non-PSA*	
	Mean	*St. dev.*	*Mean*	*St. dev.*
Native forest in 1992 (ha)	86.13	146.87	32.22	50.62
Native forest in 2005 (ha)	96.86	147.84	30.98	52.67
Sample size	50		87	
Finca size (ha)	102.75	148.82	64.74	89.49

Notes: As determined from aerial photographs

Source: Arriagada, 2008.

The goal of PSA clearly is to reduce deforestation and increase forest cover, but there are various ways to define and measure this outcome. FONAFIFO uses forest cover maps derived from satellite images for planning and monitoring. The *Atlas Digital de Costa Rica* also provides land cover maps developed from satellite images by National Meteorological Institute (*Instituto Meterológico Nacional*, IMN) and FUNDECOR/CATIE. All of these sources show that *fincas* with PSA contracts had significantly more primary forest than *fincas* without contracts and than the rest of the study cantons (Sarapiquí, Guacimo, and Pococí) both before and after the PSA program was instituted. However, inconsistencies in classification methods and the low resolution of these images do not allow us to assess the change in forest cover on individual *fincas* over time. Arriagada (2008) used aerial photographs of the PSA *fincas* and 87 of the non-PSA *fincas*. Because of cloud cover in 1996, photographs are only available for 1992 and 2005. The GIS lab at ITCR obtained, orthorectified, and interpreted photos to identify areas of native forest (including mature and regenerating forest but not plantations). On average, PSA *fincas*

gained 10.74 ha (or 6.5% of average PSA *finca* area) of forest between 1992 and 2005, while non-PSA *fincas* lost an average of 1.24 ha (or -1.7% of average non-PSA finca area) (Table 9.4).

Table 9.5: Change in land use in Sarapiquí, 1996-2005, as reported by landowners

(ha)

	PSA		*Non-PSA*	
	Mean	*St. Dev.*	*Mean*	*St. Dev.*
Total forest	2.12	11.57	-0.43	16.06
Mature forest (>20 yrs)	0.94	8.47	-3.12	19.13
Regenerating forest	0.76	6.44	1.05	12.67
Plantation	0.42	2.83	1.64	12.58
Crops	0.06	0.59	1.30	13.14
Pasture	-0.68	9.81	-0.13	13.18

Source: Authors' study.

An alternative way to measure forest cover is to ask landowners to report current and historical land use. Table 9.5 shows that while there is substantial variation, owners of PSA *fincas* on average report increases in mature forest[6] and total forest cover, while owners of non-PSA *fincas* report decreases. The obvious disadvantage of this approach is that landowners might not remember or might misreport land use. To the extent that landowners with PSA contracts are less likely to report clearing forest, this could result in an overestimate of the impact of PSA. However, there are also clear advantages of self-reported land use: it does not depend on accurate mapping of the sample *fincas*, it is not affected by mis-alignment of *finca* maps and remote sensing images, it is not subject to errors in interpretation of the images, it measures land use rather than land cover (for example, an area with scrubby land cover could be cattle pasture or regenerating forest), and it allows us to focus specifically on mature forest (at least 20 years old), which is most likely to provide the full suite of ecosystem services from aesthetics to biodiversity. In the remainder of this chapter, we analyze self-reported forest cover, which allows us to use the complete sample of landowners and to focus specifically on mature forest cover.

The characteristics that determine participation in the PSA program are also likely to determine land use, including forest cover. Because pre-matching did not eliminate differences in all of these variables, the average change in forest cover on non-PSA *fincas* does not provide an accurate picture of what would have happened on PSA *fincas* if the program had not existed. Thus, our next step is to estimate a propensity score equation of the probability of participating in the PSA program, as reported in Table 9.6. The first (simple) specification includes only a few key variables representing the major determinants of deforestation and PSA program participation identified in prior literature. The second (complete) specification adds more variables that represent other factors identified through the in-depth interviews. The estimation results show that PSA forest protection contracts are most likely on *fincas* with large areas of

[6] Most landowners report only small increases in mature forest cover, which is consistent with the constraints on creating "mature forest cover": the only possible source is regenerating forest that was at least 12 years old in 1996 and was allowed to continue growing until 2005.

forest, steep slopes, and absentee landowners originally from the Central Valley. As expected, the probability of participation (the propensity score) is generally much higher for PSA *fincas*. However, there is some overlap in propensity scores between PSA and non-PSA *fincas*, which allows us to find matches.

Table 9.6: Estimated marginal effects on the propensity of a *finca* to have a PSA contract

Dependent variable = 1 if *finca* has a PSA contract; *n* = 184

	Marginal Effect (standard deviation) [a]	
Characteristic[b]	*Simple*	*Complete*
Intercept	-1.950 (0.497)***	-1.052 (1.303)
Distance to forestry office	0.010 (0.013)	0.002 (0.016)
Parcel size	-0.011 (0.007)*	-0.006 (0.005)
Percent of parcel with steep slope	0.015 (0.007)**	0.016 (0.008)*
Self-reported 1996 native forest	0.020 (0.008)**	0.015 (0.007)**
Household labor force in 1996 [c]	-0.006 (0.086)	0.240 (0.177)
Percent of parcel with poor soil		0.000 (0.009)
D - Experience with forest plantations before 1996		-0.332 (0.482)
D - Forest management plan pre-1996		0.541 (0.534)
D - Previous participation in other forest programs		0.998 (0.563)*
D - Resident on parcel in 1996		-1.692 (0.957)*
Years of education of respondent		-0.117 (0.057)**
Age		-0.020 (0.019)
D - From Central Valley		1.961 (0.564)***
Intercept	-1.950 (0.497)***	-1.052 (1.303)
Observations	163	152
Pseudo R-square	0.132	0.280
Log-likelihood	-82.500	-64.481

Notes: [a] Significance at 99% level indicated by ***, ** = 95%, * = 90%
[b] D indicates "dummy" variables, coded as 1 = statement true for the respondent, and 0 = statement false for respondent.
[c] Labor in 1996 is proxied as current number of adults in families that were resident on *finca* in 1996.

Source: Authors' calculations.

With the caveat that our sample size for this study is much smaller than typically used for matching analysis, Table 9.7 reports the impact of PSA contracts on the change in area of mature forest cover between 1996 and 2005. The second column simply compares the means of the PSA and non-PSA sample, while the next four columns report the results of matching PSA *fincas* to non-PSA *fincas* based on propensity scores from both the simple specification and the complete specification with multiple imputation to replace missing values. For both specifications, we report results using two matching methods: mature forest cover on PSA *fincas* is compared to (1) forest cover on the non-PSA *finca* with the closest propensity score, and (2) all non-PSA *fincas* with propensity scores within a radius of 2.5 standard deviations. Because of the small sample

size, it is appropriate to use a 15 percent confidence level to interpret these results. At this significance level, the simple comparison of means shows no significant difference, while all of the matching estimators suggest that the PSA program has a positive effect on forest cover. The matching estimators also suggest a slightly larger effect than the simple comparison. These results are consistent with targeting of contracts to *fincas* that are under relatively high threat of deforestation, as FUNDECOR has attempted in the study region. The counterfactual for these *fincas* would have been even higher deforestation than generally observed among the *fincas* not in the program, and this is reflected in the matching results. While statistically significant, the estimated effect of PSA on forest cover is very small: between 3 and 10 hectares, less than 13 percent of the average contract area and less than 7 percent of the average PSA *finca's* baseline forest cover.

Table 9.7: Estimated effect of PSA on mature and total forest cover in Sarapiquí

		Propensity score matching			
		Closest match		*All matches within a radius of 2.5 standard deviations*	
	Difference in means	*Simple participation model*	*Complete participation model*	*Simple participation model*	*Complete participation model*
Change in mature natural forest, 2005-1996 (ha)	4.06 (0.15)	8.4 (0.12)	7 (0.05)	3.1 (0.11)	10 (0.09)

Notes: Difference between PSA and non-PSA is reported in each cell. The probability that the difference is *not* significant (p-value) based on bootstrapped standard errors using 999 repetitions is reported in parentheses. Complete participation model uses multiple imputation by chained equations to replace missing values. See Arriagada (2008) for details.
With the simple (complete) participation model, two (three) of the PSA *fincas* are excluded from the comparison because there are no comparable non-PSA *fincas*.

Thus, our rigorous evaluation methods suggest a much smaller impact of PSA than simply comparing *fincas* with and without PSA contracts, or PSA *fincas* before and after the program. The most obvious explanation for this small impact is that landowners never intended to convert all the mature forest that they placed under PSA contract. Several studies, summarized in Table 9.8, asked PSA participants directly how they would have used land if it were not under PSA contract. In Sarapiquí, 32 percent said they would either conserve or not use the forest, while most of the others said they would use the area for production of cattle (34 percent) or timber (36 percent) (assuming that there were no restrictions on forest use). In a telephone survey of 100 PSA participants from all areas of Costa Rica, Ortiz and others (2003) report that 45 percent said they would have conserved their forest if the PSA program did not exist. Miranda and others (2003) conclude that most landowners in Heredia and San José provinces would protect their forest even without payments.

Table 9.8: Alternative land use if not under contract

(% of respondents)

Alternative use	*Nation-wide*[a]	*Sarapiquí*[b]
Crop cultivation	5	6
Pasture/Cattle ranching	17	34
Wood Production	8	36
Would not have used		26
Protection of the forest/conservation	45	6
Make fenceposts (*potreros*)		2
Ecotourism	2	2
Sell the property	12	
Nothing	5	
Don't know/no response	6	

Notes: Questions:
[a] If PSA did not currently exist, what would you decide to do with your finca? (Ortiz and others, 2003)
[b] If you were not in the PSA program and there were no laws restricting use of your forest, how do you believe you would be using your forest that is currently under PSA contract? - up to two responses accepted

A second possibility is that there are leakages to other areas of the *fincas*, which landowners convert or prevent from regenerating to compensate for the area now under PSA contract. The cash payments from FONAFIFO could even facilitate this. As shown in Table 9.9, Miranda and others (2003) and Ortiz and others (2003) do find some investment of PSA payments in the *finca*, consistent with displacement of productive activity to other parts of *finca*. Miranda and others (2003) argue that this does not actually result in leakage, because landowners are intensifying production in previously cleared areas. Furthermore, landowners generally use at least part of the payments for consumption.

Third, PSA contracts could have positive spill-overs to neighboring *fincas* that are not captured by our evaluation results. For example, landowners may learn about and plan to apply for PSA due to their neighbors' experience with PSA; 40 percent of survey respondents did say that they had discussed PSA with their neighbors. Neighbors of properties with PSA contracts may also be subject to greater monitoring. We found that the number of times a *finca* has been visited by an environmental agency in the past ten years increases with proximity to PSA properties: landowners in the district sample report an average of 0.6 visits, while the average number of visits is 1.2 in the buffer sample, 2.1 among neighbors, and 14.1 among PSA recipients. If there are positive spill-overs to non-participating *fincas*, the impact of PSA participation will appear smaller than it is.

Fourth, while the estimated impact of PSA on forest cover is small, it is possible that the program has a larger impact on forest quality, by encouraging better management and protection of forests. For example, participants in Sarapiquí report that they actively protect the forest: all

said that they maintain trails in the contract area, 48 percent that they guard the contract area, and 16 percent that they fenced the forest.

Table 9.9: Use of PSA payments, as reported by landowners

(% of respondents)

	Sarapiquí	*Heredia and San José provinces*	*Osa Peninsula*	*Nationwide*
Consumption (general household expenses, food)	32	13	100	14
Investment in farm	30	66	14	79
Other investment	24			
Education	8		91	
Savings	12	3	5	
Pay debts	2		14	

Sources: Sarapiquí from authors' study; Heredia and San José from Miranda and others (2003); Osa from Muñoz (2004); nationwide from Ortiz and others (2003).

Finally, it is also important to place the matching results in context of participants' overall evaluation of PSA. Both in our case study region of Sarapiquí and in other surveyed regions, participants report high levels of satisfaction with the program. For example, 73 percent of respondents interviewed by Ortiz and others (2003) and all respondents interviewed in the Osa peninsula by Muñoz (2004) reported that PSA had improved their quality of life. This is important for the long-term impact of the program, as it will influence decisions about whether to renew contracts. Ortiz and others (2003) found that 79 percent plan to renew their contracts.

9.5 Evidence on land use impacts at the regional level

The impacts of the PSA program can also be analyzed at a regional level. While the disadvantage of this approach is that the unit of analysis is no longer the decision-maker, it has the advantage of at least partially capturing any spill-overs and leakages. As compared to the *finca* level, administrative selection is likely to be more important at the regional level. For example, Ecomarkets introduced targeting of payments to high priority conservation areas.[7] Even in the absence of administrative selection, participation in the PSA program may depend on the characteristics of landowners and their land in the region.

There are various possible units of analysis at the regional level. Using a 10x10 kilometer grid, Sánchez-Azofeifa and others (2007) find no impact of PSA on deforestation rates. Similarly, using pixel-level analysis Pfaff and others (2008) find that PSA has a very small

[7] The effectiveness of targeting may vary substantially across regions. Ortiz and others (2003) find that overall 28 percent of PSA forest protection contracts have been established on land that was most apt for conservation, while 23 percent are on land that can support crops and/or pasture. In Huetar Norte, 29 percent of contracts are on land most appropriate for conservation, and 44 percent are on land that could also be used profitably for crops and/or pasture. In Amistad Caribe, on the other hand, 66 percent of contracts are on land that does not have any competing use and only 12 percent are on land suitable for crops and pasture.

impact (less than 1% of the enrolled land) on net deforestation. In contrast, Tattenbach and others, using administrative zones and different empirical methods, find that PSA contracting has a large negative effect on gross deforestation rates in the Central Volcanic Cordillera area (see Chapter 10).

In a preliminary analysis, we contrasted the 252 districts that had received PSA contracts in the period 1997-99 to the 254 districts that received no PSA contracts in the same period. The probability of having PSA contracts in a district was related to factors such as total forest area, extent of road network, and population densities. Matching analyses suggested that the initial phase of PSA contracting had a small impact on net change in forest cover between 1997 and 2000 at the district level.

For a more in-depth analysis, we used data from Arriagada (2008), who combined census data (INEC, 2007) with land cover maps derived from satellite images (ITCR, 2005) at the census tract level. This provides a rich database for propensity score matching to evaluate the impact of PSA on several forest cover outcomes. The second column of Table 9.10 shows that on average, tracts with at least one PSA contract (including all contracts signed by 2004) had more dynamic forest cover between 1997 and 2005. On average, all tracts gained forest cover between 1997 and 2005, but tracts with PSA contracts gained 50 ha more than tracts without contracts. This greater increase in forest cover reflects substantially more reforestation (96.5 ha more forest gain) but also more deforestation (46 ha more forest loss). As with the *finca* level analysis, these differences may be due to differences in the tracts that affect both the probability of PSA contracts and the change in forest cover. To control for these differences, we apply the same propensity score matching methods as for *fincas*. In matched samples of tracts, we find no difference in rates of forest loss: the gross deforestation rate is the same in both PSA and non-PSA tracts. However, PSA contracting in a tract did result in 24 to 34 ha more net forest gain, due to significantly higher rates of reforestation. This impact on net forest cover represents less than 2% of the average tract size. However, it represents 7-11% of the average area under contract.

Table 9.10: Estimated effect of PSA on forest cover in census tracts

		Propensity score matching	
	Simple comparison	*Closest match*	*All matches within a radius of 2.5 standard deviations*
Forest gain, 2005-1997 (ha)	96.6 (0.00)	19.11 (0.05)	31.53 (0.00)
Forest loss, 2005-1997 (ha)	46.27 (0.00)	Not significant	Not significant
Net change in forest cover, 2005-1997 (ha)	50.33 (0.00)	34.08 (0.13)	24.32 (0.03)

Notes: Difference between PSA and non-PSA is reported in each cell. The probability that the difference is *not* significant (p-value) is reported in parentheses, based on Abadie-Imbens bias corrected standard errors for closest match, and bootstrap standard errors using 999 repetitions for radius matching.
Simple comparison is difference in means for 1065 tracts with PSA contracts compared to 7,138 tracts without PSA contracts. Matching is based on 1019 tracts with PSA contracts that are on-support, compared to 519 matching tracts without PSA contracts.

Source: Arriagada, 2008.

9.6 Conclusions

The deforestation rate has declined and forest cover has increased in Costa Rica since the launch of the PSA program. However, these trends cannot be attributed automatically to the PSA program, because of many other contemporaneous policy changes such as the elimination of government subsidies, and economic changes such as reduced profitability of cattle ranching. To disentangle these effects, it is critical to consider *changes* in forest cover over time in areas with and without PSA contracts. However, this still leaves the question of why some landowners chose (or were chosen) to participate while others did not. Propensity score matching can eliminate this selection bias by controlling for characteristics that jointly affect the probability of deforestation and land use decisions. By applying propensity score matching to changes in forest cover, we obtain methodologically rigorous estimates of the impact of PSA on land use.

Specifically, we apply these methods to evaluate the impact of the PSA forest protection contract, as implemented in its initial years of 1997-1998, on the mature forest cover of *fincas* in Sarapiquí. There are many reasons to expect that the PSA program would not have a significant effect: FONAFIFO sought to minimize transactions costs and program delays in the early phase of the program by not differentiating or targeting payments, and economic logic leads us to believe that landowners would respond by enrolling forest that they would not have converted in any case (whether due to low returns to alternative uses, legal restrictions, or environmental preferences). In fact, we do find that regions with less productive land, fewer roads, and lower population density are more likely to have PSA contracts. In Sarapiquí, absentee landowners with larger *fincas* that have more steep slopes are more likely to have enrolled in the PSA program, as compared to other landowners who were also eligible but did not enroll.

Nevertheless, using the most rigorous evaluation methods, we find that the initial phase of the PSA program did have a statistically significant positive effect on mature forest cover in Sarapiquí. While different matching methods produce slightly different estimates, it is reasonable to conclude that *PSA contracts reduced deforestation by about 10% of the area enrolled on fincas in Sarapiquí.* This might reflect FUNDECOR's efforts at targeting areas under deforestation threat in this region. In comparison, in a nation-wide analysis of all PSA contracting through 2004 at the census tract level, we find that PSA has resulted in greater gains in net forest cover but has not affected deforestation rates (forest loss). This suggests the importance of spill-over effects, whether through increased enforcement, education and awareness of conservation values, or simply by demonstrating the option value of obtaining a future PSA contract. Again, the precise estimates depend on the matching method, but it is reasonable to conclude that *PSA contracts increased the net gain in forest cover by about 10% of the area enrolled at the census tract level nation-wide.*

In this chapter, we have focused exclusively on the impact of PSA on forest cover. Having shown that PSA increases forest cover, the next question is whether that additional forest generates increases in ecosystem services or environmental quality. This is addressed in Chapter 13 and in the literature on targeting PES (for example, Wünscher and others, 2006; Ferraro 2008). As FONAFIFO considers options for differentiating and targeting payments, we strongly recommend that they identify and collect data on appropriate comparison regions and *fincas* that can serve as controls in future impact evaluations. We also recommend collection of data on the *quality* of forest under PSA contracts and in comparison areas, as this is likely to be critical for

understanding program impacts on ecosystem services. Finally, we support efforts to upgrade the database of PSA contracts, including maintenance of current contact information for participants and higher resolution forest cover maps, as this will facilitate future evaluation and continual improvement of the program.

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