Environmental Conservation 38 (4): 426–434 © Foundation for Environmental Conservation 2011 doi:10.1017/S037689291100052X

Evaluating the environmental impact of payments for ecosystem services in Coatepec (Mexico) using remote sensing and on-site interviews

THEMATIC SECTION
Payments for Ecosystem Services in Conservation: Performance and Prospects

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Date submitted: 30 October 2010; Date accepted: 30 August 2011

SUMMARY

Over the last decade, hundreds of payments for ecosystem services (PES) programmes have been initiated around the world, but evidence of their environmental benefits remains limited. In this study, two PES programmes operating in the municipality of Coatepec (Mexico) were evaluated to assess their effectiveness in protecting the region's endangered upland forests. Landsat satellite data were analysed to assess changes in forest cover before and after programme implementation using a difference-in-differences estimator. Additionally, surveys and interviews were conducted with local residents and a subset of PES programme participants to evaluate the programmes' social and environmental impacts, particularly the effect of the programmes on landowner behaviour. The remote-sensing data show that deforestation was substantially lower on properties receiving PES payments compared to properties not enrolled in the programmes, but the programmes did not prevent the net loss of forests within Coatepec. Moreover, the on-site interviews suggest that the payments may have had little impact on deforestation rates, and that other factors contributed to the conservation of forests in PES properties. These findings suggest that risk-targeted payments, robust monitoring and enforcement programmes, and additional conservation initiatives should be included in all PES schemes to ensure environmental effectiveness.

Keywords: conservation additionality, forest conservation, Mexico, mixed-methods research, payments for ecosystem services

INTRODUCTION

The conservation of Earth's ecosystems and the ecosystem services they generate has taken on greater urgency in recent years as ecosystems continue to decline (Dirzo & Raven 2003; MA [Millennium Ecosystem Assessment] 2005; SCBD [Secretariat of the Convention on Biological Diversity] 2010). While conservation science has matured in recent decades, its growth and influence has not matched entrenched patterns of resource degradation. Conservationists frequently understand the state of, and threats to, biodiversity, but often lack adequate resources and a complete understanding of the trade-offs inherent in different conservation approaches (Holling *et al.* 1998; Salafsky *et al.* 2002). To better understand the efficacy of payments for ecosystem services (PES) programmes, this article analyses the impacts of two PES programmes on PES participants and regional forest conservation in Coatepec (Mexico).

Coatepec (Mexico)

Like many governments throughout the world, the municipality of Coatepec (Mexico) (Fig. 1) has insufficient resources for conservation so optimizing conservation activities is particularly important. In contrast to most of Mexico's forested regions, Coatepec is unusual in that private individuals own the majority of forested lands rather than ejidos (communal lands shared by the community). In the uplands of Coatepec, two types of forest rich in biodiversity and the delivery of hydrological services exist, namely pine-oak and cloud forest. The pine-oak forests, which extend across Mexico, are part of the most diverse pine-oak forests anywhere in the world. The cloud forests represent the most biologically diverse land type in Mexico per unit area, with 30% of the species endemic to the country found in these forests (Flores-Villel & Gerez 1994; Rzedowski 1998). Cloud forests in general, including those of Coatepec, play a beneficial role in local hydrological processes, especially in terms of enhanced water quality (Martinez *et al.* 2009) and water supply (Bruijnzeel 2002; Holwerda *et al.* 2010).

Over the last 30 years, the expansion of agriculture in Coatepec and its adjacent municipalities has reduced the region's primary forests by 90% (Williams-Linera *et al.* 2002). In 2003, efforts to increase regional water security by protecting Coatepec's remaining forests culminated in the establishment of Mexico's first payments for hydrological

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Figure 1 Coatepec (Mexico) is located in the mountains of Veracruz State.

services programme, known as FIDECOAGUA, which is a trust fund managed by the municipal government of Coatepec. This programme has since been joined in Coatepec by Mexico's national payments for hydrological services programme, known by the acronym PSAH (*Pago por Servicios Ambientales Hidrológicos*). FIDECOAGUA receives some of its funds from a tax on municipal water users, and other funds from the national government.

In 2009, the two PES programmes included 51% of Coatepec's cloud forests and 70% of its pine-oak forests, which totalled 1992 and 363 hectares, respectively. The primary mission of the PSAH and FIDECOAGUA programmes is to conserve forests at risk of deforestation in order to protect ecosystem services, particularly watershed services (Muñoz-Piña *et al.* 2008; FIDECOAGUA staff, personal communication 2009). The FIDECOAGUA and PSAH programmes have been heralded as frontrunners for PES programmes worldwide; but, with the exception of a pilot study of the 2004 PSAH participant cohort (Alix-Garcia *et al.* 2010), neither scheme has undergone a quantitative assessment of their environmental impacts.

PES programmes and impact evaluation

PES programmes create markets in which landowners are able to sell a defined ecosystem service to one or more users of those services (Wunder 2007). Over the last decade, the PES concept has been embraced around the world resulting in the establishment of PES schemes for many ecosystem services, including carbon sequestration, hydrological services, biodiversity and scenic views (Wunder 2005). PES schemes are frequently cited as a promising conservation strategy for a variety of reasons, including their attractiveness relative to traditional command-and-control regulation (German 2009), potential conservation efficiency versus other conservation strategies (Landell-Mills & Porras 2002; Wunder *et al.* 2008), and perceived ability to address market failures, particularly undervalued ecosystem services (Engel *et al.* 2008). However, questions have arisen about the biophysical processes driving the provision of ecosystem services (Daily *et al.* 2009; Tallis *et al.* 2008, and the lack of empirical evidence demonstrating the effectiveness of PES schemes in conserving natural resources (Turner & Daily 2008; Wunder *et al.* 2008; Pattanayak *et al.* 2010). The immaturity of ecosystem service science may have put many PES projects ahead of the scientific underpinnings (Daily *et al.* 2009; Wunder *et al.* 2008). The lack of strong evidence documenting PES programme effectiveness might lead to diminished support for these programmes from taxpayers and governments (Wunder 2005), as well as damage the reputations of conservation groups touting PES as a conservation approach (Tallis *et al.* 2008).

Infrequent analysis of conservation additionality, or the difference in the amount of conservation achieved with a conservation programme compared to the amount of conservation without the programme, is not restricted to PES programmes; instead it mirrors a broad trend of infrequent impact evaluations of conservation initiatives in general (Kremen *et al.* 1994; Ferraro & Pattanayak 2006). Most empirical studies of PES impacts focus on social benefits and costs rather than conservation additionality. Studies documenting the conservation additionality of PES programmes remain limited with only eight known 'rigorous' impact evaluations (Pattanayak *et al.* 2010). Of these eight studies, five focused on Costa Rica's national PES scheme and most found that the programme had a small effect on reducing deforestation, with a <1%–10% reduction of deforestation (for example see Pfaff *et al.* 2008; Robalino *et al.* 2008).

Impact evaluations of PES programmes are generally split between qualitative case studies and empirical analyses using econometric approaches. Quantitative analyses of policy interventions, such as PES programmes, are often preferred for assessing the impact of policy changes because they can account for confounding factors (Pattanayak *et al.* 2010). Accounting for confounding factors is important because some factors may be correlated with the treatment intervention or selection bias may exist among treatment units, which can obscure the effects of the policy intervention (Ferraro 2009). Qualitative field research supplements quantitative research by examining the causal mechanisms linking a policy intervention with behavioural change, such as landowner conservation practices (Thomas & Koontz 2011). While relatively few PES programmes have been evaluated to assess their environmental impacts on ecosystem services, recent studies using different econometric approaches, such as propensity score matching, two-stage models, and difference-in-differences estimation, have advanced understanding of the additionality of a few PES schemes (see Pfaff *et al.* 2008; Alix-Garcia *et al.* 2010). This article adds to these efforts by combining a difference-in-differences estimator with field interviews to evaluate Coatepec's PES programmes.

The social and environmental impacts of the programmes were analysed using a mixed-methods approach that combined

https://doi.org/10.1017/S037689291100052X Published online by Cambridge University Press

a time-series analysis of remotely-sensed forest cover change with surveys and field interviews of PES programme participants and informed community members. A variety of studies have combined remote sensing and interview data to assess landscape change and conservation programmes (for example Schweik & Thomas 2002; Klooster 2003; Ostrom & Nagendra 2006; Codjoe 2007; Turner *et al.* 2007), but ours is one of the first to combine field interviews with remote sensing to evaluate the efficacy of PES programmes (see Arriagada *et al.* 2009).

METHODS

Image processing and classification

To analyse changes in forest cover, images acquired by NASA's Landsat satellite sensors in the years 1997 (TM), 2003 (ETM+) and 2009 (ETM+) were assembled to form a time-series change-analysis dataset. For 2009, two Landsat scenes were combined digitally using NASA's ETM+ gap-filling software to correct for data errors generated by a scan line correction failure on Landsat 7. To ensure consistency of cloud cover and seasonality of vegetation across the scenes, all images had < 10% cloud cover and were acquired between the months of March and April. Atmospheric and radiometric calibrations were also used to convert the original radiance of the scenes, which is the terrestrial reflectance signatures captured by the satellites, to reflectance values to ensure comparability across platforms and image acquisition periods. Topographic correction, using a Lambertian topographic correction model and a 20 m digital elevation map (DEM) was applied to all scenes to correct for differences across images relating to the sun's elevation and azimuth at the time of acquisition.

Two data sources were used to classify the Landsat scenes. The first was a set of six digital orthophotos produced by Mexico's Institute of Geography and Statistics (INEGI [*Instituto Nacional de Estadistica e Geografia*] 1995). The second source was a set of 200 reference points acquired with a global positioning system (GPS) unit during the summer of 2009. In addition to the reference points collected in the field, 200 supplementary reference points were developed based on the INEGI digital orthophotos, spatially referenced field notes, and Jason Scullion's familiarity with the region. All user-generated reference points were selected based on a minimum distance rule of 90 m from points previously collected in the field.

Classification was completed using a supervised classification approach based on a random selection of reference points. Spectral classes were aggregated using the software RuleGen, which applies a semi-automated decision tree model to create landscape classes based on the statistical similarities of spectra found in a given satellite scene (Jengo 2005). Accuracy assessments of the image classification, which compares known ground reference points to the classified image, were completed using the points remaining after the supervised classification. Confusion matrices (i.e. data tables used to assess the accuracy of an image classification) were constructed to compare the class identified within each sample point to its known reference point. Overall accuracy scores for each classified Landsat scene were: 1997 (82%), 2003 (83%) and 2009 (85%).

Deforestation and pattern analysis

The remote sensing component of this study was designed to derive data products that portray the patterns of forest change across Coatepec during the period 1997–2009. These products support the primary goal of the landscape analysis to assess Coatepec's upland forest cover change between two time periods: 1997–2003 (before the PES programmes began) and 2003–2009 (during the operation of the PES programmes). To establish what would have happened without the PES intervention, we compared forest cover change between all properties under PES payment contracts in 2009 with PSAH and FIDECOAGUA to the counterfactual of all properties not under PES contracts. All properties receiving PES payments in Coatepec were identified using geographic information system (GIS) polygons supplied by FIDECOAGUA and PSAH (CONAFOR [*Comisión Nacional Forestal*] 2009; FIDECOAGUA 2009). To better understand historical changes in forest cover, forest fragmentation was estimated using the contagion index of the spatial analysis software FRAGSTATS version 3.3, which measures the 'clumpiness' of landscape patches using a scale of 0–100 (McGarigal *et al.* 2002).

To evaluate the relative impact of the PES policy intervention on upland forest conservation in Coatepec, a difference-in-differences (DiD) estimator was used, which is an econometric approach for estimating the relative influence of a policy intervention (Buckley & Shang 2003). DiD is a measure of the difference in outcome before and after treatment for the control and treatment group. In other words, DiD uses the control group to subtract any changes that may have occurred at the same time. A DiD estimator assumes that both the treatment and control will respond to external factors in similar ways. For the two PES programme interventions in Coatepec (2003–2009), the control group was the upland forest area not receiving PES payments and the treatment was the properties receiving PES payments. The outcome variable measured was the change in hectares of forest cover between time periods. The DiD estimator was specified using the OLS linear regression model:

$$\widehat{\delta} DD = \overline{Y}_1^T - \overline{Y}_0^T(\overline{Y}_1^C - \overline{Y}_1^C)$$

Where $\overline{Y}_1^T$ = treatment in 2009, $\overline{Y}_0^T$ = treatment in 2003, $\overline{Y}_1^C$ = treatment effect and $\overline{Y}_0^C$ = no treatment effect.

Social dynamics research methods

Field interviews using an exploratory research framework were conducted to understand the effect of the programmes

https://doi.org/10.1017/S037689291100052X Published online by Cambridge University Press

Table 1 Forest cover change for both PES payment areas and non-PES payment areas.

Cover type	*1997–2003*		*2003–2009*	
	Cover change since 1997 inside PES areas	*Cover change since 1997 outside PES areas*	*Cover change since 2003 inside PES areas*	*Cover change since 2003 outside PES areas*
Cloud forest	−24 ha (−2.1%)	−112 ha (−7.7%)	−98 ha (−8.8%)	−362 ha (−27.1%)
Pine-oak forest	+101 ha (+63.9%)	+82 ha (+96.4%)	−3 ha (−1.1%)	−60 ha (−35.9%)

on landowner behaviour. Interview questions focused on: (1) the land-use activities landowners would undertake if they did not receive PES payments, (2) the impact of the PES payments on participants' personal income and (3) individual perceptions of the social impacts of Coatepec's PES programmes. Field interviews with programme participants were conducted in the homes of 14 of the 38 participants receiving joint PES payments from FIDECOAGUA and PSAH through a cooperative agreement known as *Fondos Concurrentes* (Concurrent Funds). Participants were randomly selected for interviews based on a participant list provided by FIDECOAGUA. A field assistant administered the participant interviews over a period of one week. Jason Scullion also surveyed 19 local residents who did not receive PES payments, but had knowledge of the programmes. Local residents were identified using the snowball sampling method. Snowball sampling works by asking an initial group of survey participants to recommend additional survey participants based on their familiarity with the research topic (Biernacki & Waldorf 1981). Local residents in the sample included local researchers, PES managers and members of conservation-oriented non-governmental organizations (NGOs). The survey of the non-participants was designed to build on the PES participant interviews with respect to the perceived social impacts of the PES programmes. The non-participant surveys were conducted over the internet using a uniform survey instrument. After the non-participants completed the internet survey, eight non-participants were contacted and interviewed to elucidate the causal mechanisms underlying their survey responses. Overall, there was a 60% overlap in questions between the PES participant interviews and non-participating residents' internet survey. Survey questions for each respective group did not match 100%, as the non-participants did not have direct experience of receiving PES payments.

RESULTS

Forest change

Coatepec experienced a high degree of land-use change between 1997 and 2009. During this period, the municipality had a net loss of 595 ha of cloud forest (from an original 1997 estimate of 2586 ha) and a net gain of 120 ha of pine-oak forest (243 ha in 1997). The annual average forest change over the study period shows that Coatepec's cloud forests declined by 1.9% per year and its pine-oak forests increased by 4.1% per year. During the same period, the FRAGSTAT's contagion index showed the municipality's landscape became more disaggregated and fragmented: 1997 (56.2), 2003 (49.8), and 2009 (38.2).

During the period of PES programme operations in the municipality (2003–2009), both pine-oak forests and cloud forests had a net loss of forest area (63 ha and 551 ha, respectively). However, forest area change varied substantially depending on whether the properties were under PES payment contracts. During the PES programme period, cloud forests on properties receiving PES payments had an 8.8% reduction in forest cover, while those not receiving payments lost 27.1% of their forest cover. Similarly, pine-oak forests in the PES payment areas had a 1.1% decrease in forest cover in contrast to non-payment areas that experienced a 35.9% reduction (Table 1).

The DiD estimate, which compares the amount of forest conservation that occurred on PES to non-PES properties, indicates that landowners who received PES payments had a higher level of conservation than landowners who did not receive payments. The DiD analysis shows that the relative policy influence of Coatepec's two PES programmes was +34.8% for the conservation of pine-oak forests and +18.3% effect for cloud forests (Tables 2 and 3).

Perceptions of PES programme participants and non-participants

Of the 14 PES participants we interviewed, representing 40% of the landowners paid jointly by FIDECOAGUA and PSAH in 2009, all claimed the PES payments were <3% of their total personal income. Further, all but one claimed the payments were <1% of their income. However, despite this low marginal benefit, only two participants said they would not re-enrol in the PES programme if given the opportunity, which suggests the cost of foregone uses of the land is similarly low. The participants were accordingly asked how they would use their forests if they had not received PES payments. Four of the 14 interviewed participants (29%) stated they would not cut their forests in the absence of PES payments, while four other participants said they would convert most or all of their forests to pasture or agriculture. An additional five participants (36%) said they would keep their land forested through a combination of conservation and forestry. One landowner was unsure how he would use his forests in the absence of PES payments. In sum, these results show that nearly one-third of the interviewed participants did not conserve their forests because of receiving PES payments, but had already intended

https://doi.org/10.1017/S037689291100052X Published online by Cambridge University Press

Table 2 Difference-in-differences estimation of the influence of Coatepec's PES programmes on its pine-oak forests during the period of the programme operations (2003–2009). Difference-in-differences estimated influence of PES programmes = + 34.8% deforestation reduction.

Type of area	*Before PES programme (2003)*	*After PES programme (2009)*	*Difference in forest cover*
PES properties (treatment)	259 ha	256 ha	−3 ha or −1.1%
Non- PES properties (control)	167 ha	107 ha	−60 ha or −35.9%

Table 3 Difference-in-differences estimation of the influence of Coatepec's PES programmes on its cloud forests during the period of the programme operations (2003–2009). Difference-in-differences estimated influence of PES programmes = + 18.3% deforestation reduction.

Type of area	*Before PES programme (2003)*	*After PES programme (2009)*	*Difference in forest cover*
PES properties (treatment)	1115 ha	1017 ha	−98 ha or −8.8%
Non- PES properties (control)	1337 ha	975 ha	−362 ha or −27.1%

Table 4 Responses of 14 participants in the PES programme and 19 non-participants in the programme regarding their perceptions of the socioenvironmental impacts of Coatepec's PES programmes.

Perspective of PES impact on	*Agree*	*Disagree*	*Unsure*
Increased environmental awareness of forest/water linkages	19	8	6
Improved economic well being of participants	6	22	5
Improved trust between citizens and government	9	14	10
Improved cooperation between citizens and government	7	19	7
Positive social benefits for non PES participants	3	30	0
Positive for forest conservation in Coatepec	15	5	4

to follow this strategy. Concurrently, nearly one-third of the interviewed programme participants said they would convert at least some of their land from forest cover if they did not receive the PES payment.

Programme participants and the 19 local non-participants were both asked about the social impacts of Coatepec's PES programmes, specifically how the programmes affected programme participants and the community at large. Most respondents stated that the programmes had not improved the economic well-being of participants (Table 4). Also, most participants and non-participants doubted that the PES programmes had built trust and cooperation between local citizens and the government, and a strong majority of respondents disagreed that the PES programmes had a positive social impact on people outside the programme. Yet, most respondents stated that Coatepec's PES programmes were important for conserving the region's upland forests, and that in the absence of the PES programmes the rate of deforestation would have been higher.

DISCUSSION

This research indicates that evaluations of the impacts and effectiveness of conservation initiatives can be strengthened through mixed-methods research. For example, looking only at the remote-sensing results of this study would suggest that the PES programmes increased conservation because less deforestation occurred on enrolled lands. Yet, all the PES participants stated that their PES payments had a low net impact on their personal income, which is consistent with the statement by most respondents that they would have kept their land forested in the absence of payments. The interviews thus moderate the conclusion one might draw from the remote-sensing analysis by suggesting that the PES payments had a relatively small effect on landowner behaviour, which is the purpose of PES programmes.

During the study period, a number of landscape drivers influenced the efficacy of the PES programmes, thus illustrating how PES programmes are only one of many forces affecting landowners' land-use decisions and subsequent forest cover changes. For example, the relatively large increase in pine-oak forest coverage during 1997–2003 was likely due in part to recently established timber plantations. Also, the increase in deforestation that occurred from 2003–2009 was largely due to the expansion of agricultural activities, namely pasturelands, coffee plantations, mixed agriculture and sugar cane plantations.

Two important questions related to the efficacy of Coatepec's PES programmes that our research design could not test are the existence of programme leakage (the movement of deforestation from PES properties to non-PES properties) and the level of contract compliance. Leakage may be an issue in Coatepec since higher deforestation rates were recorded outside of the PES areas, but our research was not designed to examine leakage. The prevalence of deforestation inside of PES lands also raises questions about programme enforcement and the level of illegal logging that may be occurring inside PES lands. Because our analysis relied on GIS layers of

PES coverage from 2009, and as much as 25% of the properties were added to the programmes during 2003–2008, we are unable to evaluate contract compliance. However, other evidence indicates that forest cutting did occur on PES lands in Coatepec. For example, an interview-based study of 24 regional PES participants in and around Coatepec, found 25% of the PES participants interviewed had signs of visible tree cutting on their properties under PES contracts, although the property owners in each case attributed the cutting to timber theft rather than personal contract violations (Fuentes-Pangtay 2008). Additionally, interviewees in our study reported that during the history of the PES programmes in Coatepec and the surrounding region, only two PES participants had been sanctioned for violating their contracts. Our detection of potential logging in PES areas also raises questions about the effectiveness of enforcement in local PES programmes. Concerns over programme enforcement were echoed by Muñoz-Piña *et al.* (2008) when commenting on Mexico's PSAH programme report that suggested all participants were 100% compliant with their contracts. They commented that this level of compliance is unlikely given the chequered history of landowners abiding by Mexico's forestry regulations.

The effectiveness of Coatepec's PES programmes

The main findings of this study are that (1) Coatepec's forest cover decreased at a higher rate during the operation of the PES programmes than the previous six years, (2) the PES properties experienced relatively low levels of deforestation in contrast to areas outside the PES properties, and (3) the PES programmes partially contributed to this lower level of deforestation. Further, the difference-in-differences estimation shows that Coatepec's local PES programme, FIDECOAGUA, and Mexico's national PSAH programme had positive effects on the conservation of Coatepec's upland forests. However, the DiD estimates are likely to over-report or under-report the influence of the PES payments due to excluded variables such as the heterogeneity of landscape conditions and the variable opportunity costs of landowners. Still, given the high level of avoided deforestation reported by the DiD estimate, we conclude that the PES programmes likely conserved some of Coatepec's upland forests. However, our interviews with PES participants indicate that the effects of the programmes were modest; 29% of the interviewed participants claimed they would conserve their forests even without the PES payments, 36% said they would use their forestland more intensely but preserve the forest cover without payments, and all of the participants interviewed said the payments had only a small impact on their income. Fuentes-Pangtay (2008) reported that 41% of the PES participants he interviewed in and around Coatepec said that in the absence of payments they would conserve their forests or plant shade coffee. In Mexico more generally, the challenge of including only forests with high deforestation risk has proven challenging, as demonstrated by a recent analysis of national PSAH payments that found only 32% of Mexico's PSAH payments in 2008 went to forests at 'high' to 'very high' risk of deforestation (C. Muñoz Piña, personal communication 2010). While Mexico's PSAH programme now includes deforestation risk as a participant enrolment criterion, Coatepec's FIDECOAGUA programme does not. In sum, the question of whether Coatepec's PES payments influenced landowners' decisions requires further exploration, given that our landowner interviews indicate that at least some landowners who participated in these PES programmes were driven in part by factors other than the PES payments, such as cultural factors or the suitability of their properties for alternative land uses. The question of conservation additionality in Coatepec's programmes is difficult to answer with our research design. The difference-in-differences approach and field interviews had an advantage in that they are relatively simple, but their weakness is accounting for confounding factors that are necessary for the precise measurement of conservation additionality (see for example Pfaff *et al.* 2008; Andam *et al.* 2008).

Market failures and Coatepec's PES programmes

Our experience in Coatepec supports the claim by Engel *et al.* (2008) that when PES programmes operate in areas characterized by several simultaneous market failures, PES payments should be used in combination with other conservation strategies. In Coatepec, it is likely that several market failures exist, such as free-riding and undervalued ecosystem services. Currently, the main response of the government to address these market failures is the PES programmes, but this approach may not suffice, as evidenced by landowner opportunity costs of foregone land uses relative to the level of PES payments at the time of this study. In 2009, PES payments paid by FIDECOAGUA were US$ 78 ha yr^{-1} for cloud forest and US$ 69 ha yr^{-1} for pine-oak forests, and the payments made by the PSAH programme were US$ 28 ha yr^{-1} for pine-oak forests and US$ 37 ha yr^{-1} for cloud forests (FIDECOAGUA 2010; C. Muñoz Piña, personal communication 2010). By comparing these payments to the average opportunity costs of forest landowners at a number of PES sites across Mexico (US$ 30–US$ 150 ha yr^{-1}; GEF [Global Environment Facility] 2006), it is reasonable to assume that in most locations PES payments would be competitive. Nevertheless, landowners owning forestlands may have other land use options to pursue, especially those who have available economic capital, lands with high agricultural productivity and access to agricultural markets. In these cases, the PES programmes may not be sufficient to outweigh some alternative land-uses. For example, in 2004, a forestland owner in Coatepec could have earned an average US$ 384 ha yr^{-1} from owning coffee plantations and US$ 2088 ha yr^{-1} for for sugar cane plantations (Martinez *et al.* 2009), which is much greater than the highest possible PES payment of US$ 78 ha yr^{-1}.

https://doi.org/10.1017/S037689291100052X Published online by Cambridge University Press

Perceptions of the impacts of Coatepc's PES payments on the local community

One of the more surprising results of the social impacts assessment based on the interviews and internet survey was the sizable number of respondents who answered 'don't know' to various survey and interview questions. This uncertainty is hard to interpret, but it suggests that Coatepec's PES programmes are inadequately educating local residents and programme participants about the programmes in a way that influences landowner decisions. The lack of information about the PES programmes among PES participants is further supported by the findings that 62% of the regional PES participants interviewed were unable to name the programme they received PES funds from, while 75% did not think there was any particular characteristic about their land that made them eligible to receive PES payments (Fuentes-Pangtay 2008).

Another striking finding of this study was that a majority of respondents believed the PES programmes had not improved trust and cooperation between the government and the citizens of Coatepec, which may limit enrolment in the programmes. A deeper look at the history of the PES programmes in Coatepec reveals why such beliefs may be widely held: occurrences of not receiving promised PES payments, late payments, sporadic payments, and concerns over programme transparency relating to why some applicants receive PES payments and others do not (J. Scullion, unpublished data 2009). Mistrust is problematic because trust facilitates cooperation among public and private stakeholders (Thomas 1998), and is an essential condition of collective action in general (Seabright 1993; Armitage 2007; Ishihara & Pascual 2008) and cooperation in environmental policy in particular (Weber 1998; Schneider *et al*. 2003). Moreover, trust and cooperation may enhance the economic efficiency of PES schemes by lowering monitoring and enforcement costs (Jack *et al*. 2008). Alternatively, the absence of trust in the government can contribute to the failure of PES programmes, such as in the case of the West African Wildlife Project, which collapsed due to a host of factors including participants' lack of trust in the local government (Tallis *et al*. 2008). Also, if landowners become distrustful of the PES schemes they will be less likely to re-enrol; a few participants in Coatepec cited this as the reason why they or others would not re-enrol when their contracts expired. Given that a leading cause of PES programme failure is poor governance (Tallis *et al.* 2008), developing trust and cooperation among PES stakeholders should be an important priority for all PES schemes.

PES enrolment and Coatepec's PES programmes

All PES participants interviewed said the PES payments had a relatively small impact on their overall income; yet, all but two said they would re-enrol in the programme if given the opportunity. Understanding rationales for why participants enrol in PES programmes is an important question given that the inherent self-selection process of PES enrolment filters out individuals based on a number of reasons that may include, but are not limited to, the amount of the conservation payment (Chen *et al*. 2009). While most participants are likely to enrol in PES schemes based on some form of a cost/benefit analysis of the opportunity costs of conserving their forests versus forest conversion, some participants may enrol (or re-enrol) for a host of other reasons, such as access to economic markets or other government programmes (Rosa *et al*. 2004; CONAFOR staff, personal communication 2009) or community norms, such as a neighbour's re-enrolment behaviour (Chen *et al.* 2009). Alternatively, some PES participants may enrol in the PES programmes simply because they face low opportunity costs to conserve their forests. Others may enrol because of a conservation ethic. For example, several landowners in Coatepec said they enrolled in the PES programme because it was 'the right thing to do' or because 'forest conservation is important'.

CONCLUSIONS

Mixed-methods research capitalizes on the advantages and synergies of each research approach. This research has shown that Coatepec's PES programmes had a positive impact on the conservation of some upland forests, but the region still experienced a net loss in upland forests. This finding should bring caution to those who view other PES schemes, such as REDD+ (the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries, http://www.un-redd.org/), as the solution to halting deforestation. PES initiatives may advance forest conservation, but they also have limitations, especially in regions with weak governance and/or high land conversion potential.

This case study indicates the need for: (1) risk-targeting as a criterion for PES participant enrolment, (2) a robust monitoring and enforcement programme to reduce inefficiencies and ensure contract compliance, (3) education and trust building within the community, (4) consistency in PES disbursements, (5) transparency in PES administrative decisions, and (6) complementary conservation programmes and policies to correct concurrent market failures and address the root causes of ecosystem loss. It is our hope that conservation scientists and managers of conservation programmes, like the PES programmes in Coatepec, will build on our efforts by conducting mixed-methods research to evaluate and improve conservation additionality.

ACKNOWLEDGEMENTS

We are grateful to Heidi Asbjornsen, FIDECOAGUA, CONAFOR, Robert Manson, Kitzia Fuentes, Michael Peralta, Vanessa Lopez, Lysette Munoz-Villers, Friso Holwerda and two anonymous reviewers.

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