Ecological Economics 143 (2018) 64–73

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Beneath the Canopy: Tropical Forests Enrolled in Conservation Payments Reveal Evidence of Less Degradation

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ARTICLE INFO

Article history:
Received 7 December 2016
Received in revised form 25 June 2017
Accepted 29 June 2017
Available online xxxx

Keywords:
Tropical forest conservation
Programa Socio Bosque
Additionality
Deforestation
Forest degradation
Impact Evaluation

ABSTRACT

Assessments of programs offering payments for forest conservation have largely focused on their contribution to avoiding deforestation but have overlooked degradation. We integrated remotely-sensed forest cover images, georeferenced landscape information, field-level forest inventories and face-to-face landowner surveys to quantify avoided deforestation and degradation within the context of Ecuador's Socio Bosque Program (PSB). We found the PSB prevented 9% of enrolled forest area in Ecuador's Amazon Basin from being deforested over the 2008–2014 period. This value is higher than previous assessments conducted in other Latin American nations. Inventory data suggest that forests within PSB-enrolled areas exhibited less evidence of degradation although statistical differences were only marginally significant. On average, PSB-enrolled forests had between one and two more tree species per hectare than non-enrolled forests. These additional tree species were twice as likely to be of commercial timber value and at greater threat of extinction.

1. Introduction

The net loss and degradation of forest ecosystems is an impending threat to human well-being (Millennium Ecosystem Assessment – MEA, 2005). Deterioration of the biological richness of tropical forests have major implications at multiple scales ranging from impacts to global carbon cycles to imperiling forest-dependent livelihoods (Houghton, 2012; Wunder, 2001). Despite the importance of conserving forest biodiversity, destruction of tropical primary forests prevails; from 1995 to 2015 some 70 million ha of tropical primary forests have been lost (Food and Agriculture Organization of the United Nations - FAO, 2015; Gibson et al., 2011).

Policy makers have relied on the adoption of command-and-control and voluntary instruments to slow down tropical deforestation and degradation. The creation of designated protected areas, that currently extent over 375 million ha of tropical forests, impose legal harvest restrictions with violations penalized through fines (Baland et al., 2010; Miteva et al., 2012). However, the enactment of protected forest areas can be met with a lack of local community support and compliance with delineated restrictions (Shyamsundar and Kramer, 1996) which have triggered the emergence of voluntary financially-compensated conservation programs. Payments for forest conservation (PFC), among the plethora of Payment for Ecosystem Service (PES) schemes, aim to motivate a change in forest owner behavior by internalizing non-market benefits that forests provide through conditional financial compensation (Engel et al., 2008; Jack et al., 2008; Wunder, 2005, 2015).

The effectiveness of PFC programs in avoiding deforestation, although not negligible, is reportedly limited and associated effects on preventing degradation are largely unknown. Numerous studies (Table 1) have applied cross sectional samples of satellite imagery to determine changes in forest canopy across a landscape covering PFC and non-PFC enrolled forests using quasi-experimental research designs (Miteva et al., 2012; Vincent, 2016). Assessment of Costa Rica's Payment for Environmental Services program (Span.: Pagos por Servicios Ambientales) has found little to no evidence the program has prevented large areas from being deforested (Sánchez-Azofeifa et al., 2007; Pfaff et al., 2008). Similar results extend to evaluations of Mexico's national Payments for Hydrological Services program (Span.: Pago por Servicios Ambientales Hidrológico; Alix-Garcia et al., 2012; Honey-Rosés et al., 2011). Studies reporting a more sizable PFC impact in preventing deforestation have been implemented on a subnational scale, and evaluate a region of the program where non-enrolled forested areas experience notably high rates of deforestation (Arriagada et al., 2012; Sills et al., 2008).

Evaluation of PFC programs solely based on avoided deforestation may underestimate their full range of benefits – inclusive of prevented degradation. Forest degradation, defined as a temporary or permanent deterioration in the density or structure of a forest's vegetation cover or species composition (Grainger, 1993), remains largely unmonitored. Whereas trends in tropical deforestation have decreased in recent years, forest degradation is an unremitting and serious threat to the sustainability of tropical forests (Food and Agriculture Organization of the

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http://dx.doi.org/10.1016/j.ecolecon.2017.06.038
0921-8009/

Table 1
Additionality of PFC programs estimated through quasi-experimental study design approaches in Latin America.

Authors (publication year)	Country	Scale	Unit	Duration (years)	Avoided deforestation (percent)
Jones et al. (2016)	Ecuador	Sub-national	Parcels	3	<1
Mohebalian and Aguilar (2015)	Ecuador	Sub-national	Pixels	8	<1
Jones and Lewis (2015)	Ecuador	Sub-national	Parcels	2	< 1
Robalino and Pfaff (2013)	Costa Rica	National	Pixels	3	< 1
Arriagada et al. (2012)	Costa Rica	Sub-national	Parcels	8	11–17
Alix-Garcia et al. (2012)	Mexico	National	Parcels	4	3.2
Honey-Rosés et al. (2011)	Mexico	Sub-national	Parcels	6	2.6
Arriagada (2008)	Costa Rica	National	Parcels	9	2.24–4.07
Pfaff et al. (2008)	Costa Rica	National	Pixels	4	<1
Robalino et al. (2008)	Costa Rica	National	Pixels	6	<1
Sills et al. (2008)	Costa Rica	Sub-national/National	Parcels	10/9	10/<1
Sánchez-Azofeifa et al. (2007)	Costa Rica	National	Pixels	3	< 1

United Nations - FAO, 2015; Convention on Biological Diversity - CBD, 2016). Forest degradation has been estimated at about 100 million ha per year globally with subtstantial detrimenal impacts to forest ecosystem functions and services (Basurco et al., 2006; Chazdon, 2008; Foley et al., 2007). PFC programs often assume a mutual contribution between reduced carbon emissions through sequestration and benefits to biological diversity but the strength of that linkage remains contested (Waldon et al., 2011). Houghton (2005) suggest that the percent of carbon emissions linked with forest degradation -as compared with deforestation - has been estimated to range from 5% in humid forests to as high as 132% in Tropical Africa. In addition to disruption to carbon cycles, forest degradation has been linked to a reduction in soil and water quality (Celentano et al., 2016), below-canopy stunted vegetation structure and reduced species composition (Mehta et al., 2008), directly affecting human wellbeing (Heltberg et al., 2000; Shanley and Luz, 2003). Improvements in remote-sensing techniques allow exploration of forest degradation (Dons et al., 2015; Ryan et al., 2012) but satellite imagery offers only coarse results based on the forests' canopy instead of providing data on forest structure or composition. Remote-sensing techniques are apposite for frequently applied large-scale regional- or landscape-level assessments, such as the global mapping of forest carbon stocks (Baccini et al., 2012; Saatchi et al., 2011) but are less suited for fine-scale impact evaluation. Noteworthy to PFC impact assessments, a degraded forest may appear to be indistinct from a non-degraded one when canopy densities are compared, challenging its detection using a standard remote-sensed approach (Geist and Lambin, 2001).

The United Nations' Initiative on Reducing Emissions from Deforestation and Forest Degradation, plus, conservation, sustainable management of forests and enhancement of forest carbon stocks (UN-REDD+) program aims to reduce carbon emissions alongside complementary objectives such as biodiversity conservation (United Nations Reduced Emittions from Deforestation and Forest Degradation – UNREDD, 2016). Many of the extant PFC programs across the world have been devised as national-level instruments to implement UN-REDD+ efforts. But there has been a lack of examination of avoided degradation that points to a neglected dimension among programs under the umbrella of UN-REDD+ (Vincent, 2016). A greater focus on biodiversity beyond land use changes has been an urgent call for the next generation of conservation impact evaluation (IE) research (e.g. “Conservation 2.0”) which seeks to measure how impacts for conservation interventions vary based on the socio-political and bio-physical context in which they are implemented (Miteva et al., 2012). Without integrated assessments of deforestation and degradation the full range of potential PFC program benefits to forest ecosystem structure and functions will continue to go unsubstantiated (Harrison et al., 2012). The proposed analytical framework presented here helps to answer that call.

In this manuscript we report on a comprehensive evaluation of avoided tropical deforestation and degradation of a PFC program that encompassed the use of remotely-sensed forest cover images, georeferenced landscape information, field-level forest inventories and face-to-face landowner surveys. Our aim was to generate information to the growing body of work regarding additionality in prevented deforestation and to determine whether there is any evidence of lesser degree of forest ecosystem degradation among lands enrolled in a PFC program. Empirically, our assessment was conducted within the context of Ecuador's Socio Bosque Program (Span.: Programa Socio Bosque - PSB). We found the PSB to be an ideal case study because its design and surrounding context is similar to many PFC programs in Latin America and beyond (Mosandl et al., 2008). In the next section, we provide additional context to the PSB, describe our data collection methods, detail the application of propensity score matching (PSM) to reduce non-random bias and outline our econometric approach to detect differences between enrolled and non-enrolled forests. We then present our results regarding association between the PSB and evidence of lesser deforestation and degradation along insights regarding IE and how our findings fit within forest conservation policies.

2. Methods

Our evaluation was based on two analytical models of forest cover and tree species composition to elucidate evidence of avoided deforestation and differences in indicators of ecosystem degradation. The first model applied the conventional approach to estimate avoided deforestation from satellite imagery and controlled for enrollment bias using remote-sensed landscape scale covariates. The second model incorporated ground-level forest biometric information from inventory plots to landscape-scale covariates and controlled for enrollment bias based on face-to-face household surveys.

Empirical evidence for the impacts of a PFC program was gathered in Ecuador's Amazon Basin. Ecuador is one of the most ecologically diverse countries in the world (Mittermeier et al., 2004) yet has experienced one of the highest rates of deforestation in South America in recent decades (Mosandl et al., 2008). Ecuador's forest also incurs a high rate of degradation due to unsustainable harvesting practices (Sierra and Stallings, 1998). To prevent deforestation and forest degradation, Ecuador's government has registered 67% of its forests as protected areas, and implemented regulations prohibiting the harvest of timber from native forests, even if they are privately owned (Blaser et al., 2011). Yet, despite these regulations, an estimated 70% of forest owners in Ecuador's Amazon Basin illegally harvest and sell timber (Mejía and Pacheco, 2014). In 2008, Ecuador's Ministry of Environment (Span.: Ministerio de Ambiente del Ecuador - MAE) instituted the PSB program to provide financial incentives to private forest owners and communities in exchange for the conservation of their forests (Ministry of the Environment of Ecuador – MAE, 2010). While the program has grown to include the conservation of many different ecosystems, it originally targeted primary forests- which is the focus of this study. The PSB is based on 20-year conservation commitments which are formalized via legally-binding contracts (Ministry of the Environment or Ecuador – MAE, 2008). Forest owners are provided biannual payments as partial compensation for restrictions from altering their forest's natural cover or from commercially harvesting timber or hunting. For a more detailed