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How much deforestation do protected areas avoid in tropical Andean landscapes?

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ABSTRACT

For many decades, protected areas (PAs) have been considered by decision makers and conservation practitioners as one of the most common policies to promote biodiversity conservation. Diverse studies have assessed the impact of conservation policies at global and regional levels by comparing deforestation rates between PAs and unprotected areas. Most of these studies are based on conventional methods and could overestimate the avoided deforestation of PAs by omitting from their analyses the lack of randomness in the allocation of forest protection.

We demonstrate that estimates of effectiveness can be substantially improved by controlling for biases along dimensions that are observable and testing the sensitivity of estimates of potential hidden biases. We used matching methods to evaluate the impact on deforestation of Ecuador's tropical Andean forest protected-area system between 1990 and 2008. We found that protection reduced deforestation in approximately 6% of the protected forests. These would have been deforested had they not been protected. Conventional approaches to estimate conservation impact, which fail to control for observable covariates correlated with both protection and deforestation, substantially overestimate avoided deforestation. Our conclusions are robust to potential hidden bias, as well as to changes in modeling assumptions. In addition, it is assumed that this research will help decision-making in the framework of international climate change mitigation policies, such as REDD+.

1. Introduction

For many decades, protected areas (PAs) have been considered by decision makers and conservation practitioners as one of the most common policies to promote biodiversity conservation (Millennium Ecosystem Assessment, 2005; UNEP-WCMC, 2008). In recent years, the role of PAs has been extended to maintaining food security and water supply, and improving human health and the population's wellbeing (Dudley et al., 2014; Nigel, 2008). In addition, PAs have become the cornerstone for strengthening climate resilience (Gullison et al., 2007; Joppa and Pfaff, 2011; Juffe-Bignoli et al., 2014; Scharlemann et al., 2010) and mitigating the effects of climate change (Hannah, 2008; Soares-Filho et al., 2010). Due to the increasing importance of PAs in addressing not only their conservation impacts, but also the impacts on humans, PAs are now regarded as an important element of the landscape (Echeverria et al., 2008; Nagendra et al., 2009) and should be evaluated periodically in order to know if they actually protect their natural values and provide benefits to society (Nelson and Chomitz, 2011; Pfaff et al., 2009).

One way to assess the impact of conservation policies on forest ecosystems is by estimating their avoided deforestation (Bruner et al., 2001; Oliveira et al., 2007; Wendland et al., 2015). It is expected that PAs, as one of the most common conservation policies (Millennium Ecosystem Assessment, 2005), influence land use patterns that will avoid deforestation. There are several studies that assess the impact of conservation policies at the global and regional levels by comparing deforestation rates through time at a landscape scale (Bruner et al., 2001; Nagendra, 2008; Nelson and Chomitz, 2011). Most of these studies rely on indirect comparisons between PAs and unprotected areas (Bruner et al., 2001; Joppa et al., 2008). However, the results of these studies based on conventional methods could overestimate the avoided deforestation of PAs by omitting from their analyses the lack of randomness in the allocation of forest protection (Andam et al., 2008; Blackman et al., 2015; Pfaff et al., 2014).

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Error minimization in the estimation of avoided deforestation is of great interest within the framework of the REDD+ (Reducing Emissions from Deforestation and Forest Degradation) negotiations mechanism (Pfaff et al., 2014). To do this, it requires the combination of spatially explicit information on socioeconomic and biophysical factors (Echeverria et al., 2008; Soares-Filho et al., 2010) and the use of impact assessment methodologies (Gertler et al., 2011). The Propensity Score Analysis (PSA) is one of the most robust and widely used methods to assess the impact of policies on natural forest conservation (Andam et al., 2008; Gaveau et al., 2009). By using the PSA, it is possible to estimate the causal impact of PAs based on the estimation of counterfactual scenarios that estimate what would have occurred in the absence of PAs (Blackman et al., 2015; Joppa and Pfaff, 2009). Another advantage of using the PSA over conventional methods used in the conservation literature is its application in non-randomized policy designs, allowing the generation of similar comparison groups to PAs based on observable variables and using different econometric methodologies (Guo and Fraser, 2009; Rubin, 2006). This way, the PSA prevents that the non-randomness of the allocation of PAs can produce biased estimates of avoided deforestation (Andam et al., 2008; Arriagada et al., 2012, 2014; Blackman et al., 2015; Pfaff et al., 2009, 2014).

The impact assessment of PAs using the PSA has been widely tested in the tropical forests of Costa Rica, Indonesia, Thailand and Mexico (Andam et al., 2010; Blackman et al., 2015; Gaveau et al., 2009; Pfaff et al., 2009). However, there are no previous studies on tropical Andean forests, which are recognized worldwide for their high biological diversity (Young and León, 2000). Knowing how effective PAs have been in the protection of these ecosystems would permit improvements in the design of conservation policies applied to these ecosystems and advancements in measures to mitigate the effect of climate change.

In this study, we estimated the avoided deforestation attributable to PAs in Ecuador. Ecuador was selected because its tropical Andean forests are classified as one of the most megadiverse worldwide per surface unit, with 1250 species of plants belonging to 136 different families registered in 1 km^2 (Léon-Yánez, 2011; Valencia et al., 1994). Myers (2000) and Pimm et al. (2014) suggest that these forests are a "hotspot" of biodiversity and that they are disappearing due to the rapid change in land use to meet, among other things, the demand for wood and non-wood forest products.

In this context, the aim of this study was to estimate PAs' avoided deforestation for Ecuador's tropical Andean forest between 1990 and 2000 and between 2000 and 2008. Measurement of avoided deforestation was based on an estimated counterfactual scenario allowing us to answer the following research question: how much more tropical Andean forest would have been lost in the absence of the assigned protection? Results of this study can also be instrumental in improving the management of PAs in countries that have the objective of reducing deforestation and conserving their natural resources, as is the case in Ecuador. In addition, it is assumed that this research will help decision-making in the framework of international climate change mitigation policies, such as REDD+.

2. Materials and methods

2.1. Study area and data

The research considered all Ecuadorian tropical Andean forests, which cover about 14 million hectares. In the mid-20th century, some of the country's native forest was cleared, especially as a result of migration and land reform. This policy required (one of its main objectives) the landowner to change the forest cover to other uses to confirm ownership (Holland et al., 2013). Between 1990 and 2008, approximately two million hectares of native forest was lost in Ecuador. Forest cover fell dramatically from 69.6% of the country's potential forest area in 1990 to 63.5% in 2000, and 60.7% in 2008 (Sierra, 2013).

2.2. Variables

2.2.1. Treatment variables

Only PAs created between 1990 and 2008 were included in the analysis. PAs created after 2008 or which had no remaining forest cover in 1990 (i.e., no baseline forest cover) were excluded from the analysis. Out of Ecuador's existing 45 PAs, three national parks and eight reserves were analyzed (Table 1). The binary variable, protected forest/unprotected forest, allowed us to construct treatment (i.e., protected cells) and control (i.e., unprotected cells)

Table 1
Selected protected areas.

Protected areas	Category	Year of creation	Area (ha)	Forests type
El Angel	Ecological reserve	1992	16,541	Montane humid forests montane very humid forests subalpine rainforests
Antisana	Ecological reserve	1993	120,000	Montane very humid forests lower montane very humid forests premontane very humid forests montane rainforests premontane rainforests subalpine rainforests
Sumaco Napo-Galeras	National park	1994	205,751	Lower montane humid forests lower montane very humid forests premontane very humid forests lower montane rainforests premontane rainforests
Manglares Cayapas Mataje	Ecological reserve	1995	51,300	Tropical humid forests tropical dry forests
Los Illinizas	Ecological reserve	1996	149,900	Montane humid forests lower montane humid forests montane very humid forests lower montane very humid forests premontane very humid forests subalpine very humid forests subalpine rainforests
Mache Chindul	Ecological reserve	1996	119,172	Premontane humid forests tropical humid forests premontane very humid forests tropical dry forests
Llanganates	National park	1996	219,931	Montane humid forests lower montane humid forests montane very humid forests lower montane very humid forests premontane very humid forests montane rainforests lower montane rainforests premontane rainforests subalpine rainforets
Arenillas	Ecological reserve	2001	13,170	Tropical dry forest tropical thorn forest
Cofan Bermejo	Ecological reserve	2002	55,451	Premontane very humid forests premontane rainforests
Yacuri	National park	2009	43,090	Lower montane humid forests premontane humid forests montane very humid forests
Cerro Plateado	Biological reserve	2010	26,114	Montane very humid forests

Source: Ministry of Environment of Ecuador.