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Logging Concessions, Certification & Protected Areas in the Peruvian Amazon: forest impacts from combinations of development rights & land-use restrictions*

Jimena Rico [a], Stephanie Panlasigui [b], Colby J. Loucks [c], Jennifer Swenson [d] and Alexander Pfaff [e]

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Abstract (222 words)

Economic activities (agriculture, logging, mining) drive tropical forest loss, so balancing development and conservation involves tradeoffs – as well as synergies. Conservation policies, such as protected areas (PAs), may save more forest when they include some development rights (Pfaff et al. 2014). There is less evidence about when development policies, such as logging concessions, include some conservation restrictions. The right to log creates an incentive for private firms to defend their forest assets, although firms could raise or reduce forest loss depending upon their capacities to defend, their motivations to log and public oversight. Reduced loss may be rewarded through voluntary certification or third-party oversight of logging practices, whose impact we hypothesize depends upon firms' logging motivations and their capacities to restrict loss. To shed empirical light, we examine forest impacts from rights and restrictions within the Peruvian Amazon during 2000-2013, removing biases using location and year effects. Compared to control forests outside of concessions and PAs, we find PAs reduce tree-cover loss − while those PAs that include development rights save more forest than strict PAs, for each region. Logging concessions reduce forest loss in Madre de Dios, yet they increase loss in Ucayali. Certification has an impact – 1% reduction in 2000-2013 forest loss − only in Madre de Dios, consistent with higher certification impacts if private firms choose to restrict loss.

[a] Lead author (jimena.rico@banxico.org.mx) & Economist, Directorate General of Economic Research, Banco de Mexico
[b] Master of Environmental Management, Nicholas School of the Environment, Duke University
[c] Deputy Goal Lead and Senior Director, Wildlife Conservation Program, World Wildlife Fund – United States
[d] Professor of the Practice of Geospatial Analysis, Nicholas School of the Environment, Duke University
[e] Corresponding author (alex.pfaff@duke.edu) & Professor, Sanford School of Public Policy, Duke University

1. Introduction

Loss of forest often follows human demand for forest products and outputs of cleared lands, raising questions about the best ways to balance economic development with conservation. The Food and Agriculture Organization (FAO 2015a) indicates that despite forest increases in temperate zones – including in plantations – there was net annual forest loss, globally, of 0.13% during 1990-2015 (in total 129 million ha over this period, the size of South Africa). Tropical loss is driven by legal and illegal logging and mining, infrastructure development, cattle ranching and expansion of industrialized agriculture (see, e.g., Laurance et al., 2001; Raschio, Contreras & Schlesinger 2014; DeFries, Rudel, Uriarte & Hansen 2010; Swenson, Carter, Domec & Delgado 2011; and Urrunaga, Johnson, Orbegozo, & Mulligan 2012).

Ecological impacts from such forest losses include erosion, degradation of water resources, species extinctions and around 15% of global carbon emissions (Laurance, Ferreira, Rankin de Merona & Laurance, 1998; Laurance, 1999; van der Werf et al., 2009; Wright & Muller-Landau, 2006). Linking those carbon emissions to economic development, climate change is expected to lower economic growth on average while raising poverty (Arent et al, 2014).

Policies long have attempted to conserve forested areas while allowing economic activities, yet there is still very limited understanding of how development and conservation interact. We study forest impacts in the Peruvian Amazon from combining development rights with land-use restrictions. We analyze protected areas (PAs) both without development rights in strict PAs and adding limited development rights in multiple-use PAs. We evaluate logging rights in concessions both with the typical state restrictions, in uncertified concessions, and with the additional restrictions implied by 'certifications of sustainable forest management'.

Globally, PAs are the leading policy to conserve forests by restricting economic activities. Yet limits often are not preferred by local communities or by market participants who seek forest products, crops, and other goods and services (Agrawal, Chhatre and Hardin, 2008). As a consequence, PAs may not limit economic activity in large and relatively inaccessible forests in Peru's Amazon region, including 'empty' PAs subject to illegal logging invasions (Urrunaga et al., 2012; interviewees 1 & 3, personal communication, 2015). But it has been found in settings of decentralized resource management that local stakeholders may act to lower invasions given their interest in forests (Agrawal et al., 2008). Conservation policies reflect this in PAs with varied restrictions and involvement for key local stakeholders. Most analyses find that PAs reduce deforestation but the impacts vary with PA type and location (see, e.g., Joppa & Pfaff, 2009, 2010; Pfaff, Amacher & Sills, 2013; Pfaff et al. 2015 a&b).

Logging concessions are a leading form of forest management. Governments grant logging rights to private firms, subject to regulatory requirements (FAO, 2015b). Yet limits on state monitoring and enforcement sometimes permit the loss of forest to exceed the agreed levels (Finer , Jenkins, Sky, & Pine, 2014; Sears & Pinedo-Vasquez, 2011; Urrunaga et al., 2012). On the other hand, extraction rights create incentive for firms to defend their forest asset by blocking other parties' illegal logging. That could reduce forest loss. Such reductions could be rewarded via third-party oversight, such as the Forest Stewardship Council (FSC) forest-management certification (more below in section 3.2). Audits intend to ensure that certified concessions comply with all applicable laws, at the least (FSC, 2015b). While compliance has costs for firms, certification may provide improvements in market access and prices (Auld, Gulbrandsen & McDermott, 2008) for firms that choose to restrict forest losses.

Given multiple public-private interactions, it is unclear which policies will have the largest forest impacts (see Section 2). Public and private actors affect PA siting and enforcement and how the relevant processes unfold can vary with PA sizes and types. For concessions, firms clearly want to block illegal extraction by others but their interactions with certifiers are less clear theoretically and empirically. We hypothesize that the impact of certification depends on firms' logging motivations and capacities to defend forests. We shed empirical light on whether certification complements public governance and firms' defense of forest.

We estimate policies' impacts on 2000-2013 tree-cover loss compared to a baseline in 2000. This is one of the first studies to address spatial and temporal sources of bias in estimates of impact for forest-management certification − which we do not expect to be sited randomly. We compare certified concessions to uncertified concessions. We also compare uncertified concessions as well as PAs to forest controls, outside of concessions and PAs. We study the Peruvian Amazon regions of Madre de Dios, Loreto and Ucayali (Figures 1 & 2), using all logging concessions and PAs established after 2000 (thus extending Miranda et al. 2016).

We find that the PAs lower tree-cover loss on average for our entire study area − while PAs that include limited development save more forest than do strict PAs, overall and by region. For conservation policies, then, our results supporting prior commentary about the potential for public-private interactions (in both PA siting and enforcement) to influence the rankings of conservation impact. Comparing this to private enforcement by firms, for the same years and regions, we find that relative to controls the uncertified concessions slightly reduce the tree-cover-loss rate in Madre de Dios yet slightly increase loss in Ucayali. This variation in impacts may reflect varied public governance as well as firms' motivations and capacities.

We find that it is only within Madre de Dios that FSC's certification lowers tree-cover loss (by about 1% in total during our entire study period) relative to the uncertified concessions. That FSC impact is found only in a region where uncertified concessions lower forest loss suggests that third-party certification efforts complement the enforcement choices by firms. Taken together, our results certainly highlight the importance of forest governance, as well as potential gains from policies that combine development rights with land-use restrictions.

The rest of the paper is organized as follows. Section 2 discusses the interactions between public and multiple private actors in both siting and enforcement. Section 3 describes our empirical case with background about both forestry and the FSC certification in Peru, as well as our data set. Section 4 considers descriptive statistics then presents our regression approaches − featuring panel analyses, utilizing fixed effects for concession or pixel units as well as year effects – after which Section 5 presents all our results. Finally, Section 6 summarizes and interprets our results and then suggests some future research directions.

2. Theoretical Insights on Impacts

2.1 Predicted Locations for Agriculture & Conservation

We consider 'canonical' locations for agriculture, which have implications for conservation locations, such as for PAs. Von Thünen (1826) highlighted the importance of transport cost in determining agriculture's net benefits, which fall as transport costs rise with distances to urban markets. Considering a city surrounded by forest land that could be used for farming, clearing for agriculture is predicted to extend outward, from the city, to where the profits in agriculture fall below those from forest. Given that baseline prediction for a landscape, we

ask where PAs will be located by the state. We expect greater private resistance where there is higher agricultural profit that would be lost due to the PA. Whether such costs of PAs are measured by land prices for state purchases or by political protest for state takings, costs are higher near the city. This theory appears to explain fairly well many big-picture patterns for location of PAs, often found 'on rock and ice' or 'high and far' (e.g., Joppa & Pfaff, 2009).

Yet different PA types can have different local benefits, which affect local net costs of PAs and, thereby, where PAs are politically feasible. For example, we see that multiple-use PAs, which allow smallholder resource extraction, are in locations with higher pressures (Nelson & Chomitz, 2011, Joppa & Pfaff, 2011, Pfaff et al., 2013). If such PAs are as well enforced as strict PAs (more on that just below), their locations imply the potential for higher impact.

2.2 Public & Private Conservation Monitoring

Monitoring and enforcement are key PA features distinct from siting. Public enforcement of PAs can vary by political unit (e.g., Pfaff et al. 2016 compare federal with state PAs in the Brazilian Amazon) and over time within a unit (e.g., Pfaff et al. 2017 show later impact from PAs in Mexico previously found to be 'paper parks'). For any regime, monitoring's intensity will be affected by costs, likely to be higher for larger PAs and further out on the agricultural frontier. Private actors may be willing to monitor multiple-use PAs that include provisions for their development benefits. With the resulting incentives, smallholders might well want to help the public actor to exclude other actors (Albers, 2010, Pfaff et al., 2013).

Summarizing to this point, for PAs alone we can identify multiple forms of interactions in various decisions that affect conservation, which can invert the ranking of impacts by type.

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If political economy is especially responsive to local benefits − affecting siting of PAs − and if local forest users are capable of helping to exclude others, we might observe that the multiple-use PAs have more impact than strict PAs. Yet neither condition will always hold, as shown well by varied rankings of PA types across Amazonian states (Pfaff et al., 2015b).

2.3 Private Concession Enforcement & Interactions

Concessions, a leading development policy, create unambiguous incentives for the logging firms granted extraction rights (analogous to smallholders with rights in multiple-use PAs). Firms want to defend their exclusive access to the resources within concession boundaries, i.e., want to exclude others who harvest illegally. They may or may not be capable of that.

On the other hand, firms might extract more than agreed when the states granted the rights. Thus, even if others are excluded, the rate of extraction in a concession could be very high. In sum, while based upon rights to extract, concessions alone may raise or lower forest loss. Less loss is more likely if logging is selective, as has been typical in the Peruvian Amazon. Impact also can depend upon public enforcement of terms, for which sites and sizes matter.

Next we consider enforcement interactions between state agencies, private firms, and third parties involved in voluntary certifications of forest management. Such intervention could in principle substitute for and even go beyond the goals and means of the state, based upon market pressures: consumers may be less willing to buy outputs associated with forest loss. Thus, whatever we learn about public enforcement from PAs may not be relevant for FSC. We hypothesize that certification complements capacities and motivations to defend forest, one necessary condition for managing locally to please consumers. This is one of our foci.

3. Empirical Setting: three regions in the Peruvian Amazon

3.1 Forests & Forest Policies

Peru's tropical forests are the 2nd-largest in Latin America (Rainforest Alliance, 2014), and the 4th-largest globally, having over 70 million ha in 2011 (Ministerio del Ambiente, 2015). The government indicates that these forests protect: 97% of the freshwater supply; valuable timber species, such as cedar and mahogany; non-timber forest products; and biodiversity of ecological significance. Forests also are said to contribute to social development. Forests are home to over one thousand indigenous communities, including over fifty ethnic groups (Ministerio del Ambiente & Ministerio de Agricultura, 2011) described as "the poorest and most disenfranchised segment of the country's population" (Urrunaga et al., 2012).

Peru's Forestry and Wildlife Law No. 27308 categorizes around 70% of Peruvian forests as: i) production; ii) future management; iii) protected lands; iv) natural PAs; v) native and peasant communities; and vi) local forests (República del Perú, 2000). Within the areas for production, we compare certified with uncertified concessions. Uncertified concessions and varied PAs are compared with controls, i.e., forests outside of concessions and PAs. Other forms of management surely affect these forests but we lack data on them (see Discussion).

Peru's Protected Area Act (Law No. 26834) classifies PAs as national, regional, or private. National Indirect Use PAs are strictly protected, allowing only non-manipulative research, tourism and recreation in designated areas. They prohibit natural resource extraction and transformation of environments (República del Perú, 1997). National Direct Use PAs allow for resource management or extraction by local communities (República del Perú, 1997).

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National Reserved Zones are not even PAs yet. They have a temporary status in the process of obtaining PA status (Solano, 2010), which can take up to 15 years and also permits even more types of extractive activity including for oil (interviewee 15, personal communication, June 2015). Regional PAs are managed by the regional governments and by municipalities. We exclude all private conservation areas, which are much smaller and were created later. In sum, we build on Miranda et al.'s (2016) pre-2000-PA evaluation by focusing on the 17 post-2000 National or Regional PAs in Madre de Dios, Ucayali and Loreto (Appendix 1).

Concessions of 5,000 - 40,000 ha were granted to firms or individuals, in 40-year contracts (República del Perú, 2000) for timber production and economic development: 7.1 million ha (10% of Peru's forest) were designated for forestry in logging concessions in our study area (Madre de Dios, Loreto and Ucayali regions). The national total is about 8 million ha. Concessionaires must present a forest-management plan every five years and, annually, an operating plan indicating the subsections and volumes to be harvested for each key species (República del Perú, 2000). All wood extracted from the concessions is legally required to have a "Forest Transport Permit (GTF or *Guía*) which describes "the species and volume of the material and its place of origin" (Urrunaga et al., 2012). The regional forest authority is then supposed to check these official documents at different points in the transport system.

Yet evidence suggests illegal behaviors all along the production chains for logging outputs (Finer et al., 2014; Sears & Pinedo-Vasquez, 2011; Urrunaga et al., 2012). Concessionaires may fail to report extraction from outside concessions or may falsify approval documents (Urrunaga et al., 2012). While the GTF should have information about authorized volumes by species, the forest authority has no way to verify the origin of wood that it is inspecting
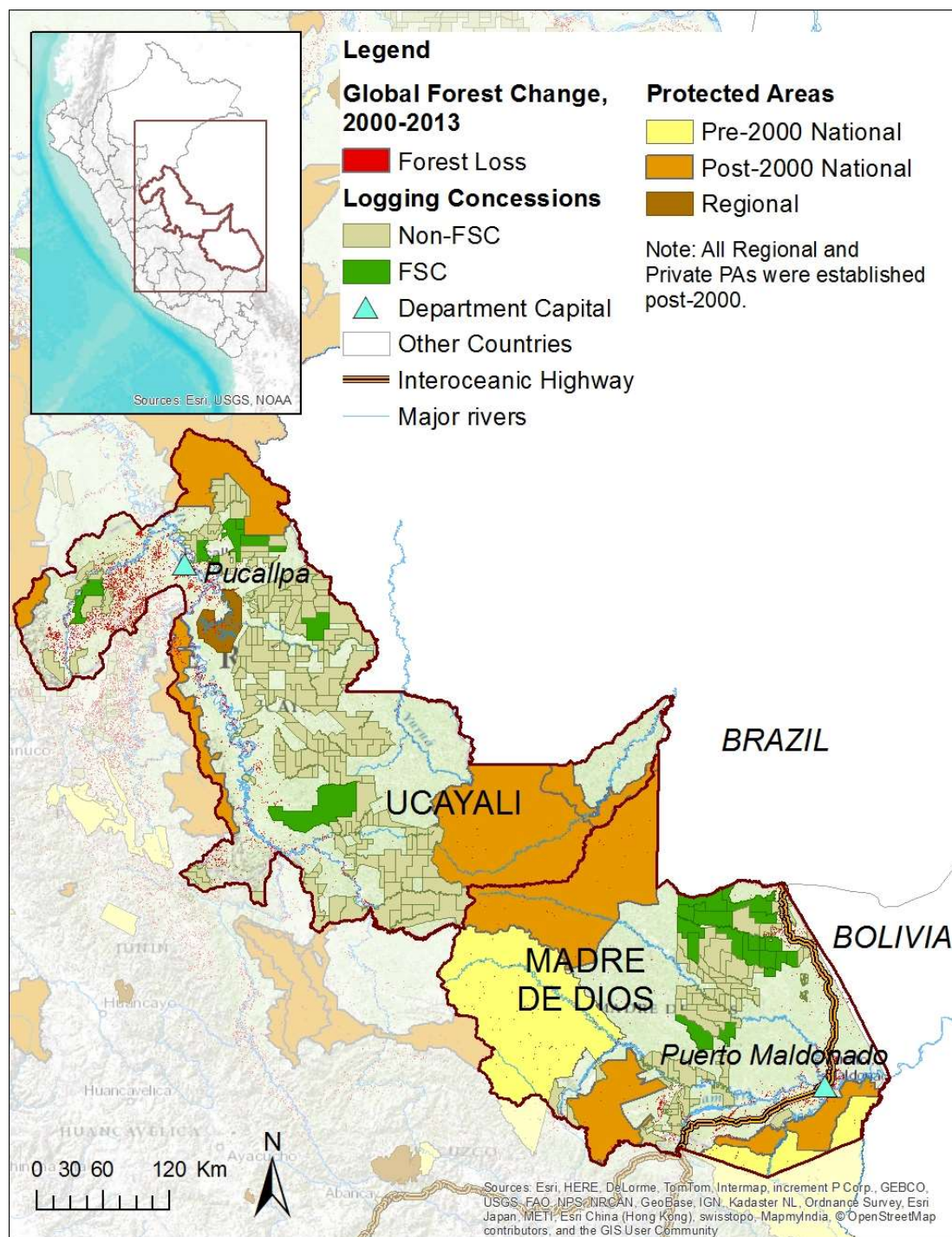
when in transport (Sears & Pinedo-Vasquez, 2011, Urrunaga et al., 2012). Thus, regulators are "monitoring the product, emphasizing species and volumes, rather than processes such as logging practices and negotiation of access to timber" (Sears & Pinedo-Vasquez, 2011).

FIGURE 1

Loreto Region in Peru
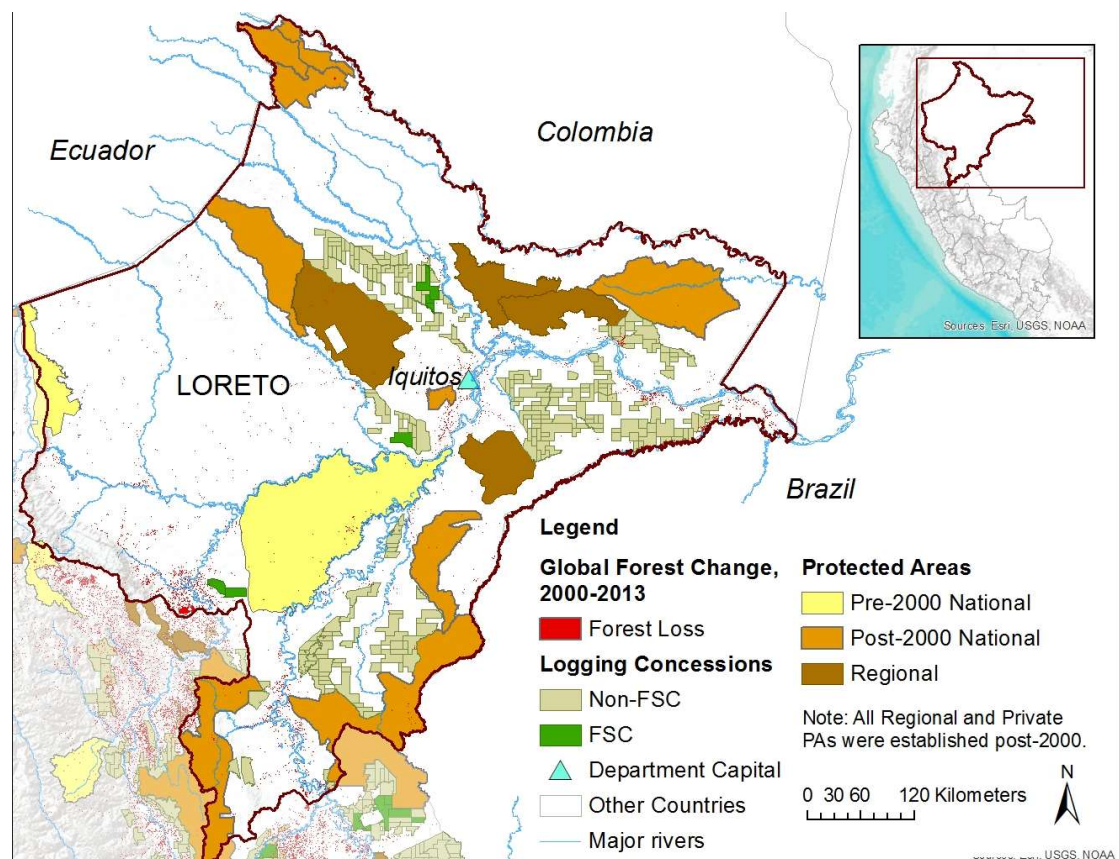
FIGURE 2

Peru's Ucayali and Madre de Dios Regions

Peru's Supervisory Body of Forest Resources & Wildlife (OSINFOR) monitors the logging activities in concessions, using field visits prior to verification (República del Perú, 2013a). Any supervisor could initiate an administrative process (PAU, in Spanish) to investigate a suspected irregularity, leading to a sanction and even to the cancellation of the concession (República del Perú, 2013b). Yet Finer et al. (2014) found that OSINFOR had never visited 36.3 percent of concessions, which is especially meaningful given that OSINFOR detected irregularities in the majority of the concessions where they had visited (Finer et al., 2014).

3.2 FSC Certification of Logging Concessions

We analyze private certification of sustainable forest management (SFM), in particular one of the most recognizable programs, certification by the Forest Stewardship Council (FSC). FSC started in 1993 for "environmentally appropriate, socially beneficial, and economically viable management of the world's forests" (FSC, 2015a). By March 2017, over 1,478 FSC certificates were active, covering 194.1 million ha of forest in 82 countries (FSC, 2017). FSC certification is said to be "rigorous, transparent and participatory certification" (Hale & Held, 2011), though its ability to produce forest benefit has been evaluated only rarely − and even less often rigorously so (see Counsell & Loraas, 2002; Nebel, Quevedo, Jacobsen & Helles, 2005; and more recently see Blackman, Goff & Rivera-Planter, 2015; Miteva, Loucks & Pattanayak, 2015; Nordén, Coria, & Villalobos, 2016; and Rana & Sills, 2016).

During 2006-2013, 34 logging concessions received a forest-management certification in Loreto, Madre de Dios or Ucayali (FSC Peru, 2017). By the beginning of August 2017, in total 899,430 ha were under FSC certification (FSC Peru, 2017) yet how this arose varies

by region and by firm. In Madre de Dios, technical and financial help from donors and NGOs supported FSC certifications (interviewee 6, personal communication, June 2014). This region has the largest area with FSC certification, with the majority of certificates in our area during our study period (20 of the 34 certificates). As external support, the Global Forest Trade Network (GFTN) of the World Wildlife Fund offered companies technical and strategic aid to help comply with − and, thus, raise ongoing achievement of – FSC's forest-management certification within logging concessions (World Wildlife Fund, 2015).

FSC compliance can raise labor costs, as employees should be on payroll and receive health benefits (interviewee 5, personal communication, August 2014). Companies do monitoring, including creating and auditing inventories. Consultants are hired. Overall, cost is incurred in order to obtain FSC certification (interviewee 1, personal communication, August 2014).

FSC certification may increase access to: i) markets that prohibit illegally sourced timber; ii) price premia; iii) government incentives; iv) operational efficiencies; and also v) NGO funding (Blackman, Raimondi, & Cubbage, 2014; Breukink, Levin, & Mo, 2015). Legal sources are critical, given the United States' Lacey Act's and European Union's FLEGT Action Plan's verification of legal origin (European Forest Institute, 2014; Urrunaga et al., 2012). Thus, if these initiatives were strictly enforced and certification was well audited, then, in principle, the export and, in turn, the sourcing of illegal timber could be reduced. More generally, certification and the laws that empower it could improve forest outcomes.

Yet with poor enforcement, FSC certification could have negative net impact, including via spillovers to other locations. Poor monitoring may allow firms enhanced access and scale

even without improving all practices (Finer et al., 2014; Sears & Pinedo-Vasquez, 2011; Urrunaga et al., 2012). A firm could, for example, log one concession sustainably but use the FSC label in addition for outputs from lands not managed according to FSC standards.

3.3 Data

3.3.1 Tree-Cover Loss

Our data for tree-cover loss at 30-meter resolution are from the *Global Forest Change* data (Hansen et al., 2013) for three Peruvian Amazon regions (Madre de Dios, Loreto, Ucayali) and annual during 2000 to 2013. We define 'forest' as a stand with at least 50% tree cover (when we use 30% it made no difference to analysis). Annual tree-cover maps were derived within ArcMap version 10.2 (ESRI, 2014). Subsequently, all the geospatial data referred to below were compiled, produced and harmonized by projection and resolution in ArcMap.

3.3.2 Concessions

We obtained data on logging concessions and FSC from WWF Peru in September 2014. They gathered, revised and updated data on concession boundaries from OSINFOR − plus concession characteristics from the Ministry of Environment (MINAM) and the Ministry of Agriculture (MINAG) including: contract number; concessionaire name; concession's legal status; date of creation; harvesting volume; logging cycle; description of harvesting system (the technology and the methods used); and annual planned investments. However, except for the first four variables, these variables were incomplete for most logging concessions. WWF Peru also gathered extra information about FSC from FSC Peru and MINAG, which

for any certified concession includes: FSC license; FSC code; type of FSC certificate; and certification status. Since FSC publishes information about all of these certificates online, we added the certificate start dates and, if applicable, the expiration and suspension dates.

3.3.3 Protected Areas

We also obtained from WWF Peru, in July 2015, data on all protected areas' boundaries and characteristics. That included name, category, type and start date. WWF Peru obtained the original information from the National Service of Natural Protected Areas (SERNANP).

3.3.4 Site Characteristics

We use characteristics (Appendix 2) that affect the probabilities of both tree-cover loss and our treatments (uncertified concessions, certification of concessions, and PAs). For market access, we use distances to cities, roads, and navigable rivers from MINAM (noting that we are not yet able to control for any key characteristics of the target markets). Oliveira et al. (2007) note: "75 percent of the total Peruvian Amazon forest damage [between 1999 and 2005], including 66 percent of disturbances and 83 percent of deforestation, was detected within a 20 km distance from the nearest roads". Distance to rivers is important in Ucayali and Loreto, as logs are transported by rivers when the roads are impassable during the rainy season (interviewees 8 and 12, personal communication, June 2014). Distance to roads can be the relevant indicator of market access for Madre de Dios, as logs are transported mainly by road there (interviewees 8 and 12, personal communication, June 2014). Our biophysical characteristics are elevation, slope and 1950-2000 average temperature and precipitation in the WorldClim (Hijmans, Cameron, Parra, Jones & Jarvis, 2005) and CGIAR-CSI (Jarvis,

Reuter, Nelson & Guevara, 2008) global data sets. All affect profits in agriculture, a land-use alternative to forest (as described in Section 2.1). Following extensive evidence within the related literature (e.g., Andam, Ferraro, Pfaff, Sanchez-Azofeifa & Robalino, 2008), we conjecture that the probability of deforestation rises with the profitability of agriculture.

3.3.5 Data Units

We compiled a panel data set at the concession level. A concession's entire area is included in measuring its outcome: forest loss in a given year, as a fraction of the forest in 2000. Our data include one forest observation per year, for each of the concessions − and, thus, 6,825 concession-year observations to compare losses in certified versus uncertified concessions.

We also compiled a panel data set at a pixel level (30x30m), inside and outside concessions with 398,006 pixels over 55.4 million ha of forest. That implies a sample density of roughly 1 pixel for every 100 ha (1 km^2). With one observation for each of 13 years, for each pixel, we have 5.2 million pixel-year observations in total. Only within the pixel data do we have information about the forested lands outside of the concessions. Those data form the basis for analyses involving our control forests and PAs. We do not use them to test certification because, without a very high pixel density, we have few pixels within certified areas − thus, we are concerned that we would not appropriately represent them in inferences on impacts.

4. Methods: statistics & panel regressions

4.1 Descriptive Statistics

Table 1 compares interventions, overall and by region, using the number of pixels in forest in 2000 and the timing of interventions. Within the second and third rows for All Regions, it is clear that almost all of the forest in concessions is within those that started after 2000. That supports a panel analysis of post-2000 interventions using Global Forest Change data for tree-cover loss. In contrast, many PAs were established before 2000 – far below half on the whole but 58% of National Direct Use PAs in Loreto and 59% of National Indirect Use PAs in Madre de Dios. As the earlier PAs do not shift their PA status after 2000, we do not include them in our panel analyses. Yet we note they are the focus of Miranda et al., 2016.

TABLE 1

Number of forested (in 2000) pixels in our random sample, by region and treatment (type & timing).

	All Regions		Madre de Dios		Loreto		Ucayali	
	Treated < 2000	*Treated >= 2000*	*Treated < 2000*	*Treated ≥ 2000*	*Treated < 2000*	*Treated ≥ 2000*	*Treated < 2000*	*Treated ≥ 2000*
Controls	--------	238,529	------	23,417	------	179,466	------	35,646
Concession Uncertified	1,206	42,840	167	5,759	657	18,652	382	18,429
Concession Certified	341	6,720	------	3,452	341	582	------	2,686
National PA Indirect Use	13,011	25,222	13,010	9,051	0	6,512	1	9,659
National PA Direct Use	15,355	18,899	0	4,962	15,355	10,929	0	3,008
National PA Reserved	2,158	16,666	0	0	2,158	13,078	0	3,588
Regional PA	0	17,059	0	0	0	16,199	0	860
TOTALS	32,071	365,935	13,177	46,641	18,511	245,418	383	73,876

"Forest" = tree cover > 50%. Private PA points dropped. Both points hold for all tables below.

Clearly there exist regional differences. Madre de Dios has no Regional PAs or National Reserved Zones. Loreto has the smallest National Indirect Use area. Madre de Dios and Ucayali have higher fractions of ever-treated (about half) than Loreto (about a quarter), yet the latter has more treated points as it is larger. Madre de Dios has the highest certified area and highest share (20 of 91 concessions certified). Ucayali has the largest FSC concession, yet only 8 of 179 concessions certified, and Loreto has only 6 of 255 concessions certified.

4.1.1 Comparing Rates of Tree-Cover Loss

Table 2A has the simplest possible raw differences in rates of tree-cover loss between our control forests and the different forest areas that received each of our treatments – without any effort to control for other differences across either time or space. As we subtract loss in controls from loss in treated areas, negative values mean lower loss rates for the treatments. The top rows show concessions, certified or not, have lower tree-cover losses than controls. In a context of illegal timber production, it is of interest if enforcement by landowners, with incentives based upon development rights, sometimes 'fill in for' limited public monitoring.

Table 2A's final four rows consider PA types. They have lower tree-cover loss than controls and, on average, than concessions as well. Further, within each region, the National Direct Use PAs have greater or the same rates of tree-cover loss than the stricter Indirect Use PAs. Yet Table 2A's loss comparisons lack information. Forest is considered as treated (or not) throughout our period, while most concessions and many PAs were active in only some of those years. In addition, treated lands may differ in characteristics that affect the probability of tree-cover loss. For better comparisons, we will have to control for space and for time.

Simple Differences in Tree-Cover Loss Rates (2000-2013), by region and treatment type.

	All	*Madre de Dios*	*Loreto*	*Ucayali*
Uncertified Concessions minus Controls	-1.46% **	-2.44% **	-0.99% **	-4.39% **
Certified Concessions minus Controls	-1.42% **	-3.01% **	-0.60%	-3.95% **
National Indirect Use PA minus Controls	-1.93% **	-2.90% **	-1.15% **	-5.31% **
National Direct Use PA minus Controls	-1.68% **	-2.88% **	-0.96% **	-4.20% **
National Reserved PA minus Controls	-2.04% **	----	-1.28% **	-5.22% **
Regional PA minus Controls	-1.95% **	----	-1.31% **	-2.57% **

*$p<0.05$; ** $p<0.01$

4.1.2 Treatment Timing & Tree-Cover Loss

Table 2B adds information based on the year within which these interventions were active.

It aggregates the PA types and provides total loss rates before and while they were active.

Seemingly potentially in contradiction to the spatial comparisons above, the tree-cover-loss

rates in ever-PA areas are higher when the PAs were active than before they were active.

That highlights the need to control for time, as pressures upon forests could rise over time.

Similarly, we distinguish when any given concession or any FSC certificate were active.

For the non-FSC concessions, tree-cover loss when the concession is active is greater than

before the concession starts. Further, tree-cover loss after the concession ends also is higher than before it is active. A concession's status or operation − e.g., creating logging roads − may raise later loss. Alternatively, loss rates may be trending up over time across the area.

TABLE 2B

Absolute Tree-Cover Loss Rates (2000-2013), by region and timing relative to different treatment types.

	Controls	*Ever In A PA*		*In Concession, Not FSC*			*In A Concession That Is FSC At Some Point*			
Madre de Dios	3.19%	0.00%	0.28%	0.03%	0.59%	0.12%	0.00%	0.06%	0.12%	0.00%
Loreto	1.36%	0.02%	0.20%	0.04%	0.24%	0.10%	0.00%	0.43%	0.33%	0.00%
Ucayali	5.36%	0.10%	0.30%	0.03%	0.86%	0.14%	0.04%	0.56%	0.74%	0.07%
All Regions	2.14%	0.03%	0.24%	0.03%	0.54%	0.12%	0.01%	0.30%	0.38%	0.03%

4.1.3 Treated-Site Characteristics

Tables 3A - 3D show that regions and interventions differ in forest-relevant characteristics. Table 3A provides averages for seven characteristics for all of the pixels in each treatment. Tables 3B – 3D provide road, river and city distances for subsets of each treatment's pixels.

Consistent with prior analyses (Joppa & Pfaff, 2009; Pfaff et al., 2013), Table 3A's top row shows that the National Direct Use PAs ("Direct"), which are one form of multiple-use PA, are closer to roads than are the stricter PAs ("Indirect") – and in fact are as close to roads as concessions and controls. Its third row shows that concessions are closer to the capital than are National PAs. Biophysical characteristics vary less (so are not a focus in Tables 3B-D).

TABLE 3A

Averages for all observed characteristics relevant for rates of deforestation, by treatment.

	Controls	*Non-FSCC*	*FSCC*	*Indirect*	*Direct*	*Reserved*	*Regional*
Distance to road (km)	47	55	41	86	46	86	59
Distance to river (km)	19	22	25	17	22	23	34
Distance to capital (km)	192	169	157	235	211	192	127
Elevation (m)	1,460	1,462	1,450	1,455	1,451	1,448	1,468
Slope (degrees)	9.72	9.75	9.80	9.69	9.70	9.63	9.73
Temperature (°C)	19.20	19.21	19.25	19.24	19.25	19.24	19.14
Precipitation (mm)	1,562	1,566	1,560	1,569	1,568	1,566	1,555

Tables 3B, 3C and 3D show mean distances to roads, rivers and capital, respectively, of the certified and uncertified concessions and all PA types − by region and before or after 2000. Table 3B's top two rows show the few pre-2000 concessions − all in Loreto − are closer to roads than post-2000 concessions. Its third row shows Indirect Use PAs − all in Madre de Dios and Ucayali − follow this pattern, though Direct Use PAs do not follow this pattern. Table 3C suggests that there are fewer such differences in terms of the distances to rivers. Table 3D, however, echoes the time patterns within Table 3B for distances to the capital.

TABLE 3B

Average road distance (km), by region and timing of national policy treatments

	All Regions		*Madre de Dios*		*Loreto*		*Ucayali*	
	Treated < 2000	*Treated ≥ 2000*	*Treated < 2000*	*Treated ≥ 2000*	*Treated < 2000*	*Treated ≥ 2000*	*Treated < 2000*	*Treated ≥ 2000*
NonFSCC	32.6	55.7	9.9	50.0	38.5	73.3	32.4	39.7
FSCC	22.0	41.6	-----	48.3	22.0	39.4	------	33.4
NatPA Indirect Use	62.9	97.2	62.9	122.0	------	33.9	80.2	116.7
NatPA Direct Use	47.5	38.6	------	25.7	54.1	41.6	------	48.6
NatPA Reserved	53.6	90.7	------	------	53.6	104.3	------	41.3
Regional PA	------	58.6	------	------	------	60.8	------	17.6

Average river distance (km), by region and timing of national policy treatments.

	All Regions		Madre de Dios		Loreto		Ucayali	
	Treated < 2000	Treated ≥ 2000	Treated < 2000	Treated ≥ 2000	Treated < 2000	Treated ≥ 2000	Treated < 2000	Treated ≥ 2000
Non-FSCC	20.0	22.1	14.6	17.7	23.9	24.4	15.7	21.1
FSCC	24.2	25.2	-----	29.1	24.2	15.9	------	22.1
NatPA Indirect Use	14.6	19.0	14.6	21.2	-----	16.7	13.9	18.4
NatPA Direct Use	20.8	23.5	-----	17.3	20.8	28.2	-----	16.5
NatPA Reserved	23.2	23.3	-----	-----	23.2	18.9	-----	39.5
Regional PA	------	34.2	------	------	------	35.9	------	3.3

TABLE 3D

Average capital city distance (km), by region and timing of national policy treatments.

	All Regions		Madre de Dios		Loreto		Ucayali	
	Treated < 2000	Treated ≥ 2000	Treated < 2000	Treated ≥ 2000	Treated < 2000	Treated ≥ 2000	Treated < 2000	Treated ≥ 2000
NonFSCC	122.9	170.5	64.0	137.7	154.9	167.2	93.4	184.2
FSCC	139.7	157.7	-----	160.2	139.7	107.5	-----	165.3
NatPA Indirect Use	159.0	274.0	159.0	268.3	-----	222.4	242.2	314.1
NatPA Direct Use	196.3	222.9	-----	102.9	196.3	274.7	-----	233.0
NatPA Reserved	259.1	183.6	-----	-----	259.1	209.0	-----	91.1
Regional PA	------	127.0	------	------	------	130.3	------	64.8

4.2 Panel Regression: concessions units

As treatments are not randomly assigned, we control for spatial and temporal influences to reduce bias in impact estimates. To do so, we use spatiotemporal data within panel analysis. Concerning temporal influences, this methodology subtracts out an average time trend, thus the impacts of shifts in policies across time are not confounded by any other factors' trends. Concerning spatial influences, this compares each site in later years to itself in earlier years.

Thus, every single fixed characteristic of every single site is held the same in comparisons. That includes characteristics we do not measure. Thus, spatial differences will not matter. Panel impact estimates reflect how treated sites' changes − after versus before treatment − compare to the time changes for untreated sites, within each site, for the same time periods.

For each treated concession, we compare the tree-cover loss rate for certified years with the loss rate for uncertified years. If certification starts in 2006, we subtract annual tree-cover loss after 2006 from before. Here, as certifications start after 2005 and mostly remain active (few terminations or expirations), the certified years are the later years of our study period. Since forest pressure was higher in later years, temporal correlation of certification and loss can make it look like certification causes loss. That is fixed by subtracting an average trend.

Following the above logic, Equation 1 is our panel specification with fixed and year effects − which we estimate for the whole study area, as well as separately for each of the regions:

$$L_{it} = \beta_0 + \beta_1 F_{it} + \beta_2 C_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \qquad\qquad (1)$$

where L_{it} = percent tree-cover loss in concession i in year t; C_{it} = 1 if concession i active in year t; F_{it} = 1 if concession i had active certification in year t; α_i = concession fixed effects; λ_t = year effects; and ε_{it} a random error. We cluster standard errors at the concession level.

Concessions vary in size, so results for 'the average concession' (same weight on each unit) could differ from results for the average hectare within any concession (weighting by area). Our default panel weights each concession equally, as we wanted to focus on results for the average across the decision units. In robustness checks, weighting did not shift conclusions.

4.3 Panel Regression: pixels units, with matching by treatment for greater similarity

As the points above apply also to pixel data units (though weighting by area is irrelevant), equation 2 is our pixel-units panel specification, with pixel fixed effects plus year effects:

$$L_{it} = \beta_0 + \beta_1 I_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \tag{2}$$

similar to (1) except now i refers to a pixel, so $L_{it} = 1$ if the forested pixel was deforested in year t but 0 if it was not[1] (and missing after deforestation); $I_{it} = 1$ if the intervention for site i (a concession or a PA) was active in the year t. We cluster standard errors at a pixel level.

We emphasize that the panel regression is a form of 'difference-in-difference estimation': the difference post-treatment versus pre-treatment for the treated units (the first difference) and the same difference computed for the control units (second difference) are compared (difference in differences). That second difference is the empirical guess about what would have occurred in treated areas without treatment. Treatment impact is identified if the time changes in treated units would have been the same, without treatment, as in control units.

Numerous pixels allow improved panel analyses. To increase the validity of assuming that without treatments the treated and control pixels would have had the same trends over time, we endeavor to find the controls that have the most similar observable characteristics to the treated units (see Section 3.3 and Appendix 2 for the data that we use for making similarity judgments, as well as the Discussion section for some data that we do and will not have). After matching, we run our panel specification using treated units and matched controls.

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[1] For this binary outcome, we explored conditional fixed effects logistic regression but we could not use this model because deforestation is too rare: $L_{it} = 1$ in less than 1% of the cases (pixel-year observations). To the best of our knowledge, there are no commands for rare binary events using panel data allowing fixed effects.

Appendix 3 shows the gains in similarity from different types of matching: propensity score matching (PSM), with and without replacement, and covariate matching (final 3 columns). Biophysical characteristics vary so little in the Peruvian Amazon that we did not use them to select the most similar controls. We rely on the final column, nearest neighbor covariate matching with replacement, always doing the matching within the same region, because it yielded the best covariate balance − as seen across the rows for each treatment and variable.

PSM starts with a treatment regression then matches pixels on the basis of their predicted probabilities of treatment. Comparing PSM columns shows some gain from 'replacement': even if a control pixel is chosen as the best fit for one treated pixel, it is replaced in the pool to find the best fit for other treated pixels. Thus, we also used replacement for the covariate matching. For each treated pixel, covariate matching computes the Mahalanobis distance − within the space of the observed characteristics − to each control pixel. We matched to the single control pixel closest to each treated pixel (for more information see StataCorp 2013).

5. Results

5.1 Protected Areas vs. Control Forests

Table 4's upper half summarizes our panel impact estimates for all of our PA interventions. There is significant variation in impact across the intervention regions and the types of PAs.

5.1.1 National Indirect Use PAs (strict)

Strikingly, for Madre de Dios, strict PAs have more tree-cover loss than the control forests. That is consistent with a concern that 'empty' PAs could be susceptible to illegal invasions. However, that does not hold for Ucayali, where there is no significant effect of these PAs.

Loreto displays the opposite impact, lower tree-cover loss. It is not statistically significant for the region, given a larger standard error, yet it drives a statistically significant average loss reduction from Indirect Use PAs for the whole study area. That impact is quite small: a loss reduction of one quarter of one percent for the entire period (half a percent for Loreto).

5.1.2 National Direct Use PAs (multiple-use)

Multiple-use PAs significantly lower tree-cover loss in each region. Average loss reduction for the whole study area is over 1 percent (over the entire period). Loreto's effect is smaller and applies to two-thirds of the observations in our study area, while the impacts in Madre de Dios and Ucayali are far larger, at about 6 percent lower tree-cover loss for the period.

5.1.3 National Reserved Zones (still in the process of becoming PAs)

Reserved Zones have low average impact, reducing tree-cover loss by one third of a percent for the whole period. The small average impact is driven by one region whose impact is not actually statistically significant − Ucayali, given fewer observations and a higher standard error. Ucayali's impact coefficient is close to 2 percent lower tree-cover loss for the period.

5.1.4 Regional PAs (managed by lower levels of government)

Regional PAs lower tree-cover loss rates by around 2 percent, on average, over the entire period. Most of these conservation interventions are located in Loreto, where they reduce loss by 1 percent relative to the control forests. However, the very few Regional PAs in Ucayali are quite another story, appearing to reduce tree-cover loss, on average, by 3 percent per year.

TABLE 4 pixel-level data panel examining deforestation during 2001-2013 for post-2000 interventions

	All	*Madre de Dios*	*Loreto*	*Ucayali*
NatPA Indirect Use (fixed & year effects)	-0.0002 (0.0001)***	0.0001 (0.0000)***	-0.0004 (0.0004)	-0.0001 (0.0001)
N	391,395	127,796	121,391	142,208
NatPA Direct Use (fixed & year effects)	-0.0012 (0.0001)***	-0.0050 (0.0014)**	-0.0003 (0.0001)**	-0.0049 (0.0006)***
N	294,903	45,351	199,169	50,383
NatPA Reserved (fixed & year effects)	-0.0003 (0.0001)***		-0.0000 (0.0001)	-0.0013 (0.0008)
N	279,317		207,215	51,372
Regional PA (fixed & year effects)	-0.0016 (0.0003)***		-0.0007 (0.0002)***	-0.0301 (0.0066)***
N	244,575		227,833	13,728
Uncertified Concession	0.0001 (0.0001)	-0.0007 (0.0004)*	-0.0001 (0.0001)	0.0008 (0.0002)***
Year 2002	0.0002 (0.0001)***	0.0004 (0.0002)*	0.0001 (0.0001)**	0.0000 (0.0002)
Year 2003	0.0003 (0.0001)***	0.0011 (0.0004)**	0.0001 (0.0001)**	-0.0001 (0.0002)
Year 2004	0.0005 (0.0001)***	0.0014 (0.0005)***	0.0004 (0.0001)***	0.0001 (0.0002)
Year 2005	0.0007 (0.0001)***	0.0016 (0.0005)***	0.0005 (0.0001)***	0.0005 (0.0003)*
Year 2006	0.0006 (0.0001)***	0.0011 (0.0004)***	0.0005 (0.0001)***	0.0002 (0.0002)
Year 2007	0.0007 (0.0001)***	0.0016 (0.0004)***	0.0004 (0.0001)***	0.0003 (0.0002)
Year 2008	0.0012 (0.0001)***	0.0019 (0.0005)***	0.0007 (0.0002)***	0.0013 (0.0003)***
Year 2009	0.0013 (0.0001)***	0.0017 (0.0005)***	0.0009 (0.0002)***	0.0016 (0.0002)***
Year 2010	0.0013 (0.0001)***	0.0026 (0.0006)***	0.0007 (0.0001)***	0.0016 (0.0002)***
Year 2011	0.0014 (0.0001)***	0.0026 (0.0005)***	0.0007 (0.0001)***	0.0019 (0.0002)***
Year 2012	0.0021 (0.0002)***	0.0038 (0.0006)***	0.0010 (0.0002)***	0.0027 (0.0003)***
Year 2013	0.0025 (0.0002)***	0.0034 (0.0006)***	0.0016 (0.0002)***	0.0031 (0.0003)***
constant	-0.0004 (0.0001)***	-0.0005 (0.0002)***	-0.0002 (0.0001)***	-0.0006 (0.0001)***
Fixed Effects (for pixels)	Yes	Yes	Yes	Yes
N	744,632	93,531	352,607	298,494

* $p<0.1$; ** $p<0.05$; *** $p<0.01$. Standard errors in parentheses. Standard errors clustered by pixel ID. This table summarizes the panel regressions for each of the five interventions. To save space, we omit year effects for PA regressions (all are similar to those above).

5.2 Uncertified Concessions vs. Control Forests

Table 4's panel analysis of pixels found no impact of uncertified concessions, on average. Yet results for regions show that the average impact masks differences in regions' impacts. In Madre de Dios, uncertified concessions reduce tree-cover loss relative to control forests by ~1 percent for 2000-2013. This effect of concessions, versus control forests, is the same magnitude as the impact of certifications relative to the uncertified concessions (see below). At least in this governance context, private enforcement perhaps functions to reduce losses.

However, the opposite impact is found for Ucayali. Table 4's result suggests that the private rights raised tree-cover loss. Of the same magnitude as the loss reduction in Madre de Dios, within Ucayali the uncertified concessions have more tree-cover loss than control forests. This result is supported by Table 5, in which the panel analysis is done using concessions.

5.3 FSC-certified vs. Uncertified Concessions

Table 5's concession-unit panel shows no significant impact from certification, on average, relative to uncertified concessions. The lack of statistically significant impact also describes Loreto and Ucayali. Yet there is a significant effect in Madre de Dios: a 0.07 percent fall in tree-cover loss, annually, implying a ~ 1 percent reduction in tree-cover loss for 2000-2013.

Year effects are critical. Without them, certification is erroneously found to increase losses given that later years have significantly higher losses (Table 5). These controls, then, avoid mistakenly assigning 'perverse' impact to certification. We arrive at an empirical suggestion that FSC certification is complementary to private governance in these logging concessions. In Madre de Dios, where the latter alone lowers tree-cover loss, FSC certification does too.

TABLE 5

Concession Panel, All Annual Tree-Cover Losses Inside Logging Concessions During 2001-2013

	All	*Madre de Dios*	*Loreto*	*Ucayali*
Active FSC (any impact additional to concession's)	0.0000 (0.0006)	-0.0007 (0.0003)**	0.0000 (0.0003)	0.0015 (0.0027)
Active Concession (versus when inactive)	0.0001 (0.0001)	-0.0004 (0.0005)	0.0001 (0.0001)	0.0006 (0.0002)**
Year 2002 (1,0)	-0.0000 (0.0000)	0.0003 (0.0003)	-0.0000 (0.0000)	-0.0004 (0.0001)**
Year 2003 (1,0)	-0.0000 (0.0001)	0.0006 (0.0005)	-0.0001 (0.0000)**	-0.0006 (0.0002)***
Year 2004 (1,0)	0.0001 (0.0001)	0.0007 (0.0005)	0.0000 (0.0001)	-0.0005 (0.0002)**
Year 2005 (1,0)	0.0001 (0.0001)	0.0005 (0.0005)	0.0000 (0.0001)	-0.0004 (0.0002)*
Year 2006 (1,0)	0.0000 (0.0001)	0.0006 (0.0005)	-0.0001 (0.0001)	-0.0006 (0.0002)**
Year 2007 (1,0)	0.0001 (0.0001)	0.0008 (0.0005)	-0.0000 (0.0001)	-0.0005 (0.0002)**
Year 2008 (1,0)	0.0003 (0.0001)***	0.0011 (0.0006)*	0.0002 (0.0001)	-0.0001 (0.0002)
Year 2009 (1,0)	0.0006 (0.0001)***	0.0008 (0.0006)	0.0004 (0.0001)***	0.0007 (0.0003)***
Year 2010 (1,0)	0.0005 (0.0001)***	0.0014 (0.0006)**	0.0002 (0.0001)***	0.0004 (0.0002)*
Year 2011 (1,0)	0.0006 (0.0001)***	0.0014 (0.0006)**	0.0001 (0.0000)**	0.0007 (0.0002)***
Year 2012 (1,0)	0.0010 (0.0002)***	0.0021 (0.0008)***	0.0005 (0.0001)***	0.0011 (0.0003)***
Year 2013 (1,0)	0.0013 (0.0002)***	0.0015 (0.0006)**	0.0005 (0.0001)***	0.0022 (0.0005)***
constant	0.0002 (0.0001)**	0.0002 (0.0002)	0.0001 (0.0001)*	0.0003 (0.0002)
Fixed Effects (for concessions)	Yes	Yes	Yes	Yes
R²	0.05	0.07	0.04	0.09
N	6,825	1,183	3,315	2,327

Notes: Standard errors in parentheses. * p<0.1; ** p<0.05; *** p<0.01. We used a panel of 525 concessions for the period 2001-2013. Therefore, we had a total of 6,825 observations. We clustered the standard errors by concession.

6. Discussion

To shed empirical light on development and conservation policies, and their combinations, we estimated the 2000-2013 forest impacts of many interventions in the Peruvian Amazon (specifically in the Madre de Dios, Loreto and Ucayali regions). We examined uncertified logging concessions, FSC certification of logging concessions, PAs for strict conservation, and four types of multiple-use PAs. For the entire study area, PAs lowered tree-cover loss, in contrast to the lack of average impacts for uncertified logging concessions and for FSC.

However, we found many interesting points within the variation in these policies' impacts. Uncertified concessions lowered tree-cover loss in Madre de Dios, suggesting that firms do sometimes successfully defend forest given their extraction rights, e.g., by excluding others. In contrast, the uncertified concessions alone led to increased loss of tree-cover in Ucayali, where the private firms appeared to either fail to exclude other actors— who log or deforest— or to log more based upon their own motivations. This striking variation across regions in concessions' impacts may be due to differences in access to Lima, lower timber production costs in Ucayali and, overall, different markets as the concessions in Madre de Dios export valuable species while Ucayali sells less valuable timber into local markets (interviewee 12, personal communication, February, 2016). Therefore, our uncertified concessions' results suggest roles in forest conservation of both forest governance and private logging drivers.

Uncertified concessions' varied impacts, indicating varied private or public willingness and capacity to lower loss, may explain why FSC had impacts only in Madre de Dios (reducing

2000-2013 forest loss by around 1%). The result is also consistent with claims of greater effort in FSC implementation there, including by international actors. That could result from species of interest, e.g., or from their perceptions of stronger governance and private forest defense. Either way, different FSC impacts across regions suggest other critical governance inputs.

Even though all types of PAs, on average, reduced tree-cover loss in the entire study area, forest impacts from conservation policies also included loss, as strict PAs in Madre de Dios slightly raised rates of tree-cover loss. That highlights potentially limited public monitoring and enforcement, raising questions about private actors' possible roles in local governance, e.g., in multiple-use PAs. For the entire study area and each region, we found multiple-use PAs had greater forest gains (more reduction in tree-cover loss rates), relative to strict PAs. In sum, our results highlight the importance of forest governance and suggest the feasibility of forest-conservation benefits from policies that facilitate selective development needs. Of course, in comparing interventions we also would like to consider costs, and thus net gains, across policy options. Unfortunately, costs for these policies are not available at this time.

Turning to methods and data, given spatially precise yet broad forest coverage, over time, we consider our impact estimates to have helped to advance the impact evaluation of forest policies by applying panel approaches − to remove the influences of fixed differences over space and time − when most past forest policy evaluations rely on cross-sectional methods. We stress that this did not address unmeasured differences between units that vary in time. However, given numerous sets of influences on forests that vary across either space or time − including many for which reliable metrics are not available − there is great value in data

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over time, for subtracting all fixed effects. Without such effort, estimates can change sign.

Moving forward, we believe it is critical to improve the data. One useful addition would be information about the settings for FSC certification − including some characteristics of the firms involved, given that it is quite possible different companies employ FSC differently. For example, multinational corporations constrained by trade rules and aware monitoring is imperfect, in principle, could employ the FSC label from one concession to 'green wash' the exports from others land not managed to FSC standards. Primarily domestic small firms do not get such gains. Thus, firm size could affect use of and impacts of FSC certification, since firms' motivations and constraints differ. To better understand this, FSC could collect firm characteristics − plus all the information ideally contained in forest management plans (e.g., techniques, volumes and species). Data on costs of FSC also would aid in evaluating the net benefits or costs of certification. Unfortunately, these data are currently incomplete.

Turning to our control group, geospatial data on institutions that influence forests outside of PAs and concessions also are incomplete. We followed the literature in using as controls all forest outside policies of interest. While formal and informal institutions exist in our study area, as they do globally, useful spatial data were not available at the time of this analysis. Another refinement of interventions data concerns when interventions effectively end − if that differs from when they officially end. If a concession or a PA has become inactive but officially has not been terminated, then treating an area as active biases impact evaluations.

In terms of outcomes metrics, the data we used on tree-cover loss has some limits including interpretations of some plantations as forest (Tropek et al., 2014). Improved forest data also

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may help identify more subtle differences between treatment and control forests, as well as help us to focus spatially, e.g., upon selective logging areas inside concessions. The latter is important because forest impacts of improved management might be near logging roads. However, more precise data, with higher definition, are only available for smaller areas. Investments in data ideally will improve all future analyses − yet consistent mapping and monitoring of very detailed forest-cover changes for large regions will remain a challenge.

To build upon our assessments, future studies could use other indicators of forest impacts. Certainly, there are measures of forest fires, which could indicate impacts of management. Selective logging's and, thus, certification's impacts may be changes in forest degradation, i.e., subtler changes in forest quality that yet are critical for providing ecosystem services. Degradation may be detected using remote-sensing data techniques with field investigations (though, like deforestation, its definition can vary). Yet high-resolution and well tested data were not available for this study and processing such data is outside the scope of this study. Still, we strongly expect a trend of improvement in evaluations as data improve many ways.

References

Agrawal, A., Chhatre, A. & Hardin, R. (2008). Changing governance of the world's forests. Science 320: 1460-1462.

Albers, H.J. (2010). Spatial modeling of extraction and enforcement in developing country protected areas. *Resource and Energy Economics* 32, 165–179.

Andam, K. S., Ferraro, P. J., Pfaff, A., Sanchez-Azofeifa, G. A., & Robalino, J. A. (2008). Measuring the effectiveness of protected area networks in reducing deforestation. *Proceedings of the National Academy of Sciences*, *105*(42), 16089-16094.

Arent, D.J., R.S.J. Tol, E. Faust, J.P. Hella, S. Kumar, K.M. Strzepek, F.L. Tóth, and D. Yan (2014). Key economic sectors and services. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, & L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 659-708.

Auld, G., Gulbrandsen, L.H. & McDermott, C.L. (2008). Certification schemes and the impacts on forests and forestry. Annual Rev. of Envir. and Resources 33, 187-211

Blackman, A., Goff, L. T., & Rivera-Planter, M. (2015). Does Eco-certification Stem Tropical Deforestation? Forest Stewardship Council Certification in Mexico. *Forest Stewardship Council Certification in Mexico (August 6, 2015). Resources for the Future Discussion Paper*, 15-36.

Blackman, A., Raimondi, A., & Cubbage, F. (2014). Does Forest Certification in Developing Countries Have Environmental Benefits? Insights from Mexican Corrective Action Requests, Resources for the Future Discussion Paper No. 14-06.

Breukink, G., Levin, J., & Mo, K. (2015). Profitability and Sustainability in Responsible Forestry. Economic impacts of FSC certification on forest operators. Retrieved from http://d2ouvy59p0dg6k.cloudfront.net/downloads/profitability_and_sustainability_i n_responsible_forestry_main_report_final.pdf

Counsell, S., & Loraas, K. T. (2002). Trading in credibility: the myth and reality of the Forest Stewardship Council. (Retrieved from http://globalforestcoalition.org/wp-content/uploads/2010/12/Trading-in-Credibility1.pdf)

DeFries, R.S., Rudel, T., Uriarte, M., & Hansen, M. (2010). Deforestation driven by urban population growth and agricultural trade in the twenty-first century. Nature Geoscience 3: 178-181.

European Forest Institute (2014). What is the EU FLEGT Action Plan? EU FLEGT Facility. Retrieved from http://www.euflegt.efi.int/43

ESRI. (2014). ArcGIS 10.2.2 for Desktop. Redlands, CA: Envir. Systems Research Institute.

Food and Agriculture Organization of the United Nations (FAO). (2015a). Global Forests Resources Assessment 2015. Rome (http://www.fao.org/3/a-i4793e.pdf).

Food and Agriculture Organization of the United Nations (FAO). (2015b). Making forest concessions work to sustain forests, economies and livelihoods in tropical timber producing countries. Retrieved from http://www.fao.org/forestry/44075-08960f20f3f0a4e82224fa19b65812a22.pdf

Finer, M., Jenkins, C. N., Sky, M. A. B., & Pine, J. (2014). Logging Concessions Enable Illegal Logging Crisis in the Peruvian Amazon. Scientific Reports, 4719(4), 1-6.

Forest Stewardship Council (FSC). (2017). Facts & Figures March 2017. Retrieved from https://ic.fsc.org/en/facts-and-figures

Forest Stewardship Council (FSC). (2015a). Our vision and mission. Retrieved from https://ic.fsc.org/vision-mission.12.htm.

Forest Stewardship Council (FSC). (2015b). Internally generated data. Retrieved from https://ic.fsc.org/internally-generated-data.183.htm.

Forest Stewardship Council (FSC) Peru. (2017). Iniciativas Certificadas en el Perú Retrieved from https://pe.fsc.org/es-pe/nuestro-impacto/datos-y-cifras

Hale, T. & Held, D. (2011) *Handbook of Transnational Governance.* Cambridge: Polity Press

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, R., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., & Townshend, J.R.G. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science, 342* (6160): 850–53. Data at: http://earthenginepartners.appspot.com/science-2013-global-forest.

Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G., & Jarvis, A. (2005). Very high resolution interpolated climate surfaces for global land areas. *International journal of climatology*, *25*(15), 1965-1978.

Jarvis, A., Reuter, H. I., Nelson, A., & Guevara, E. (2008). Hole-filled SRTM for the globe Version 4. *available from the CGIAR-CSI SRTM 90m Database (http://srtm. csi. cgiar. org)*.

Joppa, L. N., & Pfaff, A. (2011). Global protected area impacts. Proceedings. Biological Sciences / The Royal Society, 278(1712), 1633–8.

Joppa, L. & Pfaff, A. (2010). Reassessing the forest impacts of protection: the challenge of nonrandom location and a corrective method. *Annals of the New York Academy of Sciences*, *1185*, 135-149.

Joppa, L. N., & Pfaff, A. (2009). High and far: biases in the location of protected areas. *PloS one*, *4*(12), e8273.

Laurance, W. F. (1999). Reflections on the tropical deforestation crisis. *Biological Conservation*, *91*(2), 109-117.

Laurance, W. F., Cochrane, M. A., Bergen, S., Fearnside, P. M., Delamônica, P., Barber, C., ... & Fernandes, T. (2001). The future of the Brazilian Amazon. *Science*, *291*(5503), 438-439.

Laurance, W. F., Ferreira, L. V., Rankin-de Merona, J. M., & Laurance, S. G. (1998). Rain forest fragmentation and the dynamics of Amazonian tree communities. *Ecology*, *79*(6), 2032-2040.

Ministerio del Ambiente. (2015). Los Bosques en cifras. Retrieved August 13, 2015, from http://www.minam.gob.pe/bosques/los-bosques-en-cifras/

Ministerio del Ambiente, & Ministerio de Agricultura. (2011). El Perú de los Bosques. Lima, Perú.

Miranda, J. J., Corral, L., Blackman, A., Asner, G., & Lima, E. (2016). Effects of Protected Areas on Forest Cover Change and Local Communities: Evidence from the Peruvian Amazon. *World Development*, *78*, 288–307. doi:10.1016/j.worlddev.2015.10.026

Miteva, D. A., Loucks, C. J., & Pattanayak, S. K. (2015). Social and environmental impacts of forest management certification in Indonesia. *PloS one*, *10*(7), e0129675.

Nebel, G., Quevedo, L., Jacobsen, J.B., & Helles, F. (2005). Development and economic significance of forest certification: the case of FSC in Bolivia. *Forest Policy and Economics*, 7(2), 175-186.

Nelson, A., & Chomitz, K. M. (2011). Effectiveness of strict vs. multiple use protected areas in reducing tropical forest fires: a global analysis using matching methods. *PLoS One*, *6*(8), e22722.

Nordén, A., Coria, J., & Villalobos, L. (2016). Evaluation of the Impact of Forest Certification on Environmental Outcomes in Sweden (No. 657). University of Gothenburg, Department of Economics.

Oliveira, P. J. C., Asner, G. P., Knapp, D. E., Almeyda, A., Galván-Gildemeister, R., Keene, S., …Smith, R. C. (2007). Land-use allocation protects the Peruvian Amazon. *Science* (New York, N.Y.), *317*(5842), 1233–6. doi:10.1126/science.1146324

Pfaff, A., F. Santiago-Avila and L. Joppa (2017). "Evolving Protected-Area Impacts in Mexico: political shifts as suggested by impact evaluations". *Forests* 8(17) doi:10.3390/f8010017.

Pfaff, A., Robalino, J. & Herrera, D. (2016). Decentralization given environment-development tradeoffs: Federal versus state conservation and impacts on Amazon deforestation. Mimeo, Duke University

Pfaff, A., Robalino, J., Herrera, D., & Sandoval, C. (2015a). Protected Areas' Impacts on Brazilian Amazon Deforestation : Examining Conservation – Development Interactions to Inform Planning. *PLoS ONE*, 1–17. http://doi.org/10.1371/journal.pone.0129460

Pfaff, A., Robalino, J., Sandoval, C., & Herrera, D. (2015b). Protected Area Types, Strategies, and Impacts in Brazil's Amazon: public protected area strategies do not yield a consistent ranking of PA types by impact. *Phil. Trans. R. Soc. B*, *370*(1681), 20140273.

Pfaff, A., Rica, C., Rica, C., & Herrera, L. D. (2014). Governance, Location and Avoided Deforestation from Protected Areas : Greater Restrictions Can Have Lower Impact, Due to Differences in Location. *World Development*, *55*, 7–20.

Pfaff, A., Amacher, G. S., & Sills, E. O. (2013). Realistic REDD : Improving the Forest Impacts of Domestic Policies in Different Settings. *Review of Environmental Economics and Policy*, *7*(1), 114–135. http://doi.org/10.1093/reep/res023

Rainforest Alliance. (2014). Community Forestry in Peru. Retrieved May 28, 2014, from http://www.rainforest-alliance.org/work/community-forestry/regions/peru

Rana, P. & Sills, E.O. (2016). Does certification change the trajectory of tree cover in working forests in the tropics? An application of the synthetic control method. Working Paper. NCSU (forthcoming CIFOR).

Raschio, G., Contreras, C., & Schlesinguer, (2014). Análisis de agentes y causas de la deforestación y degradación forestal para la región de Madre de Dios, Perú. Report to World Wildlife Fund/Peru. April 2014.

República del Perú. Ley de Áreas Naturales Protegidas (Ley No. 26834) (1997).

República del Perú. Ley Forestal y Fauna Silvestre (Ley No. 27308) (2000).

República del Perú. Resolución Presidencial N.006-2013-OSINFOR (2013a).

República del Perú. Resolución Presidencial N.007-2013-OSINFOR (2013b).

Sears, R. R., & Pinedo-Vasquez, M. (2011). Forest Policy Reform and the Organization of Logging in Peruvian Amazonia. *Development and Change, 42*(2), 609-631.

Solano, P. (2010). *Legal Framework for Protected Areas: Peru*. Gland, Switzerland. IUC

StataCorp. (2013). Stata: Release 13. Statistical Software. Retrieved from
    http://www.stata.com/manuals13/te.pdf

Swenson, JJ., Carter, C.E., Domec, J.C., & Delgado, C.I. (2011). Gold Mining in the
    Peruvian Amazon: Global Prices, Deforestation, and Mercury Imports. *PloSONE*.
    doi:10.1371/journal.pone.0018875

Thünen, J. V. (1826). Der isolierte Staat. *Beziehung auf Landwirtschaft und
    Nationalökonomie.*

Tropek, R., Sedláček, O., Beck, J., Keil, P., Musilová, Z., Šímová, I., & Storch, D. (2014).
    Comment on "High-resolution global maps of 21st-century forest cover change".
    Science 344(6187) 6187: 981.

Urrunaga, J.M., Johnson, A., Orbegozo, I.D., & Mulligan, F. (2012). The Laundering
    Machine: How Fraud and Corruption in Peru's Concession System are Destroying
    the Future of its Forests. Washington, DC: Environmental Investigation Agency
    Retrieved from http://eia-global.org/news-media/the-laundering-machine

Van der Werf, G. R., Morton, D. C., DeFries, R. S., Olivier, J. G., Kasibhatla, P. S.,
    Jackson, R. B., Collatz, G.J. & Randerson, J. T. (2009). CO2 emissions from forest
    loss. *Nature geoscience*, *2*(11), 737-738.von Thunen, Johann H. (1826). "Der
    isolierte Staat in Beziehung der Landwirtschaft und Nationalo¨konomie" (1996,
    Transl.). In *von Thu¨nen's The Isolated State,* ed. Peter Hall. Oxford, UK:
    Pergamon Press.

Wright, S.J. & Muller-Landau, H.C. (2006). The Future of Tropical Forest Species.
    Biotropica 38(3): 287-301.

World Wildlife Fund. (2015). GFTN-Peru. Retrieved from
    http://gftn.panda.org/gftn_worldwide/latin_america/peru/

Appendix 1. Protected Areas *(our impacts are estimated for the seventeen post-2000 PAs)*

Protected Area	Type	Year	Affected In Our Area
Pacaya Samiria	National, Direct Use	1972	Loreto
del Manu	National, Indirect Use	1973	Madre de Dios
Bahuaja Sonene	National, Indirect Use	1996	Madre de Dios
Santiago Comaina	National, Reserved Zone	1999	Loreto
Tambopata	National, Direct Use	2000	Madre de Dios
El Sira	National, Direct Use	2001	Ucayali
Cordillera Azul	National, Indirect Use	2001	Loreto & Ucayali
Amarakaeri	National, Direct Use	2002	Madre de Dios
Purus	National, Direct Use	2004	Ucayali & Madre de Dios
Alto Purus	National, Indirect Use	2004	Ucayali & Madre de Dios
Allpahuayo Mishana	National, Direct Use	2004	Loreto
Sierra del Divisor	National, Reserved Zone	2006	Loreto & Ucayali
Matsés	National, Direct Use	2009	Loreto
Comunal Tamshiyacu Tahuayo	Regional	2009	Loreto
Pucacuro	National, Direct Use	2010	Loreto
Imiria	Regional	2010	Ucayali
Ampiyacu Apayacu	Regional	2010	Loreto
Yaguas	National, Reserved Zone	2011	Loreto
Alto Nanay- Pintuyacu Chambira	Regional	2011	Loreto
Güeppi-Sekime	National, Indirect Use	2012	Loreto
Huimeki	National, Direct Use	2012	Loreto
Airo Pai	National, Direct Use	2012	Loreto

N.B. We have excluded from our analyses a Regional PA that was created in 2015, i.e., after the end of our study period.

Appendix 2. Fixed Covariates *(for matching, noting panel analyses add fixed & year effects)*

Type	Variable	Justification
Market access	Distance to roads (km)	Forests closer to roads are more accessible and, thus, face more of many pressures that generate forest loss.
	Distance to major cities (km)	The forests closer to markets also face more pressures.
	Distance to rivers (km)	In Ucayali and Loreto, logs are transported via rivers: closer to rivers has a higher probability of forest loss.
	Elevation (m) Slope (degrees) Precipitation (mm) Temperature (°C)	

Appendix 3. Covariate Balances Resulting from Different Approaches to Pixel Matching

UNCERTIFIED CONCESSIONS	Treated	All Controls (no match)	Matched Controls (PSM, without replacement)	Matched Controls (PSM, with replacement)	Matched (Covariate, replacement & by region)
Distance to Capital	170.52	191.60***	172.75***	171.52*	169.93
Distance to River	22.06	18.63***	21.41***	21.39***	21.89*
Distance to Road	55.69	47.49***	58.46***	57.81***	55.26*
Loreto	0.44	0.75***	0.43	0.40	0.44
Ucayali	0.43	0.15***	0.41***	0.41***	0.43
mean bias		*41.3*	*3.9*	*3.3*	*0.7*
INDIRECT USE					
Distance to Capital	273.97	191.60***	248.74***	241.62***	255.45***
Distance to River	18.98	18.63***	14.76***	13.95***	17.17***
Distance to Road	97.23	47.49***	109.49***	84.47***	93.65***
Loreto	0.26	0.75***	0.23***	0.34***	0.26
Ucayali	0.38	0.15***	0.48***	0.38	0.38
mean bias		*78.6*	*23.9*	*24.9*	*10.0*
DIRECT USE					
Distance to Capital	243.60	191.60***	240.11***	240.09***	242.39
Distance to River	24.78	18.63***	26.38***	26.27***	24.45**
Distance to Road	40.50	47.49***	39.79**	39.64**	39.76**
Loreto	0.65	0.75***	0.65	0.65	0.65
Ucayali	0.18	0.15***	0.19*	0.19**	0.18
mean bias		*29.9*	*4.0*	*3.9*	*1.4*
RESERVED					
Distance to Capital	183.63	191.60***	186.35***	186.38***	183.03
Distance to River	23.30	18.63***	24.01***	24.20***	23.02
Distance to Road	90.74	47.49***	91.68**	91.56*	89.18***
Ucayali	0.22	0.15***	0.19***	0.19***	0.22
mean bias		*41.1*	*4.0*	*4.2*	*1.5*
REGIONAL					
Distance to Capital	129.58	191.60***	121.38***	122.10***	129.31
Distance to River	36.05	18.63***	34.15***	33.47***	35.49**
Distance to Road	67.01	47.49***	64.42***	65.14***	66.24**
Loreto	0.94	0.75***	0.94	0.94	0.94
mean bias		*77.3*	*8.0*	*8.1*	*1.8*

* = p < 0.1, ** = p < 0.05, *** = p < 0.01