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Lack of association between deforestation and either sustainability commitments or fines in private concessions in the Peruvian Amazon

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ABSTRACT

A variety of policy interventions from public authorities and private companies attempt to reduce deforestation in private forest concessions. These include fines for illegal deforestation and market incentives for forest management practices that meet sustainability standards. While some studies have found significant differences in forest outcomes between concessions that participate in sustainability commitments and those that do not, others have found small or inconclusive differences. We contribute to this literature by examining all privately allocated concessions in the Peruvian Amazon to determine whether sustainability commitments correspond with lower deforestation rates. Conversely, we examine whether fines correspond with higher deforestation rates, a question for which fewer analyses have been published. Using matching methods, we do not find significantly different deforestation rates between control groups and logging concessions with third party environmental certification. We also do not see significant differences in deforestation rates in petroleum concessions managed by companies who have made sustainability commitments. Regarding punitive fines, we do not find significant differences in deforestation rates between control groups and logging concessions with fines levied. The same holds true for fines levied in brazil nut concessions. Potential explanations for these findings include insufficient monitoring or inadequate stringency for sustainability commitments, and insufficiently punitive fines or low enforcement levels.

1. Introduction

A growing body of research is examining the relationship between private sector companies and deforestation (Heilmayr and Lambin, 2016; Lambin et al., 2014, 2018). In part, this research seeks to understand what attributes of private sector companies influence forest outcomes on their lands and what mix of public and private policies lead to sustainable land use practices (Lambin et al., 2018). From the perspective of private governance, company attributes most frequently studied are whether and what kind of sustainability commitments such companies have made (Heilmayr and Lambin, 2016), while from the perspective of public governance, punitive fines levied against companies for illegal actions has been one of the subjects of study (Börner et al., 2015a, 2015b). Research in this area is of increasing relevance as a growing number of private sector companies are participating in private environmental governance: sustainability commitments including company pledges such as the New York Declaration on Forests (Climate Summit, 2014) and voluntary certification programs such as Forest Stewardship Council certification. In this context, it is especially important to understand the impacts of these new forms of private governance as well as traditional forms of public governance affecting companies' forest management practices.

1.1. Private governance

In the realm of private governance, sustainability commitments are one of the ways that companies choose to communicate environmental stewardship (Lambin et al., 2014). These commitments are a broad group of policies that may or may not specify practices (Lambin et al., 2018). Voluntary sustainability standards are one form of implementing sustainability commitments, and they can include third party certification (Auld et al., 2008; Lambin and Thorlakson, 2018). In this paper, instances of sustainability commitments are primarily observed as participation in third party certifications and sustainability standards

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that are developed by external organizations, such as NGOs, rather than by the company itself. Below, these are referred to in shorthand as external standards. In this research we examined sustainability commitments overall, including third party certifications, external sustainability standards, and internal company codes of conduct, because the occurrence of any kind of sustainability commitment in the Peruvian Amazon is low. Including all observed types of private environmental governance enables more nuanced analysis of trends.

1.2. Public governance

In the more traditional realm of public environmental governance based on a command-and-control approach, governments continue to deploy many practices to manage land use and deforestation. Fines and other sanctions on companies for infractions or illegal practices are one common component of command-and-control public environmental governance approaches (Börner et al., 2016; Börner et al., 2015a, 2015b). With adequate enforcement of high fines, fines are thought to decrease the occurrence of illegal practices. In other cases with low enforcement and low fines, such punitive measures may not inhibit illegal activity (Becker, 1974; Keane et al., 2008). In this research we examine fines ranging from ~$100–$500,000 for illegal deforestation to understand whether they are correlated with higher deforestation rates prior to a fine being levied.

1.3. Interactions between private and public governance

Researchers have also examined the interactions between private governance-based voluntary sustainability standards, and command-and-control public policy, such as fines (Lambin et al., 2014; Lambin and Thorlakson, 2018). In the case of voluntary sustainability standards and sanctions by public authorities (punitive fines), interactions vary widely; they are not always observable, and those that are can be either synergistic or antagonistic (Lambin et al., 2014, 2018; Lambin and Thorlakson, 2018). In this research we make the simplifying assumption that direct interactions between sustainability commitments and fines will be limited, but that the two would be complementary because sustainability commitments are designed to encourage the performance of good actors ('exemplary concessions') while fines are intended to punish the poor performance of bad actors ('law-breaking concessions'). That is, we expect sustainability commitments and fines to impact different types of private companies: the leaders in sustainability for the former and the laggards for the latter (Table 1).

1.4. Peruvian Amazon context

In the Peruvian Amazon, the study region for this research, both sustainability commitments and command-and-control policies, including fines, are used to address deforestation in privately held concessions. Private concessions are on lands that are publicly owned but are leased out in long-term concessions for extractive and other commercial uses. For the purposes of our study, because these are long-term concessions, we treat them as a type of privately held land. Few studies have examined deforestation trends in private concessions, principally because it is difficult to access spatial data for private concessions. Previous research in Peru that has examined deforestation rates by land use allocation has primarily focused on protected lands, indigenous lands, and limited forest concessions (Bruggeman et al., 2015; Oliveira et al., 2007). Oliveira et al. found that forest concession lands had, on average, lower deforestation rates than unallocated forest lands (Oliveira et al., 2007).

With data on private concessions, fines, and deforestation for the entire Peruvian Amazon, we ask: How do sustainability commitments made by private concession holders influence deforestation rates? And, how do punitive fines levied on private concession holders influence deforestation rates? We hypothesize that sustainability commitments that include provisions which impact deforestation would be associated with lower deforestation rates. Conversely, we hypothesize that punitive fines that are levied for illegal deforestation would be associated with higher deforestation rates prior to enforcement of a fine. In both cases, we compare concessions that have experienced the 'treatment' (sustainability commitment or fine) with those that have not been 'treated' (i.e., control concessions). Further, we focus on deforestation *after* participation in a sustainability commitment but *before* enforcement to examine the mechanism by which we expect each to work.

2. Methods

We examined privately allocated concessions in the Peruvian Amazon to determine whether private environmental governance through sustainability commitments is associated with lower deforestation rates as compared to concessions without sustainability commitments and, conversely, whether public environmental governance through fines influences higher deforestation rates as compared to concessions without fines. By measuring deforestation prior to the levy of a fine, we test whether fines are applied to companies who have caused more deforestation – i.e., what is the likelihood that a concession with high illegal deforestation actually receives a fine. We therefore evaluate the quality of enforcement of public policies against illegal deforestation. The study area is the entire Peruvian Amazon, including four different concession types allocated by the Government of Peru: petroleum, timber, rubber, and brazil nuts (Fig. 1). This research focuses on these four concession types as the concessions that occupy the greatest percentage of land in the Peruvian Amazon. This research does not examine soy, cattle or palm oil, three frequently studied commodities that impact tropical forest cover. These commodities are excluded because soy and cattle are not major commodities in the Peruvian Amazon as they are in other tropical forest countries. Palm oil is excluded because, although production is growing rapidly in the Peruvian Amazon, the extent of large-scale plantations is still modest. Timber, the fourth major commodity crop that has been a frequent subject of research, is included in this study, as it is a major product of the Peruvian Amazon.

For the purposes of this research, petroleum, timber, rubber, and brazil nut allocations are referred to as private concessions, meaning concessions that are held by non-state owners, who are usually individuals, private companies, or publicly traded companies. For each concession type, we assessed sustainability commitments that have been made and fines that have been levied for illegal deforestation. We then analyzed whether concession holders who have made sustainability commitments or who have received fines have any observed differences in deforestation rates from 2000 to 2011 as compared with concession holders who have not made such commitments or who have not been fined.

We created a database of private concession holders in the Peruvian Amazon that hold petroleum, timber, brazil nut or rubber concessions. Initial data are from the Peruvian Ministry of Environment (MINAM), which holds information on concession coordinates, size of concession, ownership, and type of contract. Additional data were collected from public records and field research including status of ownership, number of concessions owned, and, most importantly, participation in sustainability commitments including third party certification. For finding sustainability commitments, we assumed that companies in the Peruvian Amazon have incentive to declare commitments to improve their brand, image and profits. Therefore the search protocol assumed that certification information was publicly searchable. For fine data, reporting from Peru's Supervisory Body for Forest Resources and Wildlife (OSINFOR) were used. Fines were available for 2014, and only for logging and brazil nut concessions. They included detailed information on the amount of the fine levied and the specific illegal deforestation for which the fine was issued. A full list of characteristics collected is provided in Supplementary Materials.

Table 1
Framework of concession types and expected deforestation outcomes.* **

Concession Type	'Treatment'	Expected Outcome	Potential Motivations
Exemplary concession	Private governance: Sustainability commitment*	Lower deforestation ***after*** commitment (additional restrictions on logging)	A. Prove good actors (for reputation, income) B. Hide bad actors
Law-abiding concession	NA	Average deforestation	NA
Law-breaking concession	Public governance: Punitive fine**	Higher deforestation ***prior*** to fine (illegal deforestation is occurring, likely increasing total deforestation volume)	A. Fines lower than incentive to illegally deforest B. Low probability of getting caught

* Sustainability commitment includes provisions expected to decrease deforestation.
** Fine levied for illegal deforestation.

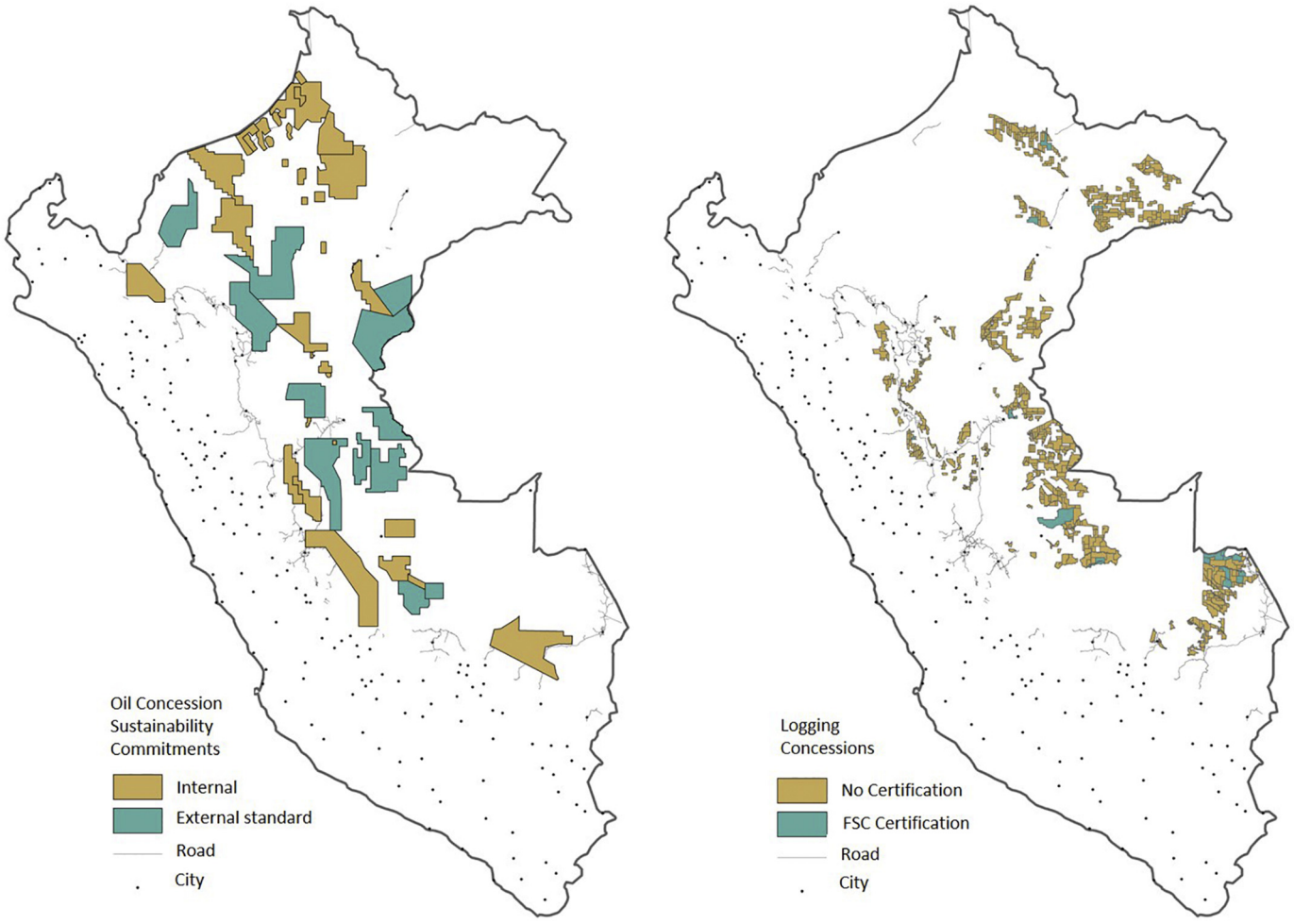

Fig. 1. Private Concessions in Peruvian Amazon. Note: Brazil nut and rubber concessions are too small to depict on a country-scale map.

The private concession data listed were analyzed together with deforestation data as an outcome variable. Deforestation data used for this study are from CLASlite (Asner et al., 2009) analysis derived from Landsat data, at 30-m resolution, and cover the years 2000–2011. Forest cover change that is only resolved at finer resolutions than 30-m is not included in this study. CLASlite uses spectral mixture analysis to create forest/non-forest classification maps which we compare across time periods to assess forest cover change (Further details in Supplementary Materials). The unit of analysis is the private concession polygon because the treatment of interest, either sustainability commitment or fine, occurs at the concession level. For each polygon, deforestation rates were calculated for 2000–2011, following the recommendations of Puyravaud, 2003, which accounts for change across multiple years (Puyravaud, 2003).

Analysis was conducted using a quasi-experimental design, which approximates an experimental design by making use of a statistically derived quasi-control group (Ferraro, 2009; Heilmayr and Lambin, 2016; Nolte et al., 2013). For this analysis we used propensity score matched difference-in-differences (Andam et al., 2008; Blackman, 2013; Miranda et al., 2014; Nolte et al., 2013). Propensity score matching matches treatment points (in this case, concessions with a sustainability commitment in the first case or a fine in the second case) with 'control' points that have a similar propensity score but have not made a sustainability commitment or received a fine for illegal deforestation. Difference-in-differences was then used to estimate the average treatment effect on the treated (ATT) as a measure of the impact of sustainability commitments or fines on concessions that experienced either sustainability commitments or fines. Matching was selected for analysis to enable comparison of different 'treatments' (sustainability commitment or fine) on concessions with a control group (neither sustainability commitment nor fine) while controlling for potential confounding factors.

Propensity scores are calculated as an index of the covariates that are likely to influence both treatment (sustainability commitment or fine) and treatment outcome (deforestation). The covariates for this study include, elevation, distance to the nearest road, distance to the nearest city, distance to the nearest river, geopolitical state in which the concession is located, concession size, and concession ownership type.

Elevation data were derived from NASA Shuttle Radar Topography Mission data (Jarvis et al., 2008). Road, city, and river data are from the Peruvian Ministry of Environment (MINAM). Forest cover in 2000, the starting year of the study period, are from Hansen et al. global forest cover and forest loss dataset (Hansen et al., 2013).

Each of the four concession types was analyzed individually as the full group is heterogeneous. There are only 41 petroleum concessions. Each concession is large, with an average concession size of > 400,000 ha. In contrast there are 884 Brazil nut concessions, with an average size of only 874 ha. Summary statistics for each of the four concession types are provided in the results section (Table 2).

3. Results

3.1. Sustainability commitments

Among 552 logging concessions in the Peruvian Amazon, the only kind of sustainability commitment found was third party certification via Forest Stewardship Council (FSC). FSC certification in Peru requires compliance with all national laws regarding forests, and also includes a number of provisions that are expected to limit forest loss (detailed in discussion). Fourteen concessions had some record of current or past FSC certification (Table 2). Certification for forests is generally done by FSC, SFI, PEFC, and Tree Farm System (US only). At the time of data collection (June 2016) there were no SFI Chain of Custody Certificates in Peru, nor were there PEFC forest management certificate holders nor SmartLogging certificate holders. There were 11 PEFC Chain of Custody certificate holders; these certificate holders are not logging concession holders but rather companies that use tree products, such as paper companies that agree to source sustainably. Regarding fines, 119 logging concessions had received punitive government fines.

Among brazil nut concessions, no sustainability commitments were found, but 158 of the 884 brazil nut concessions had received punitive government fines. Among rubber concessions, neither sustainability commitments nor fines were observed.

Finally, 41 petroleum concessions had some kind of stated commitment to sustainability, so types of commitments were sorted into two groups for analysis, based on whether they followed external or internal standards (further details on commitments below). Many petroleum concessions are held by multiple companies, for which the percent share of holding was known. For a concession to qualify as having an external standard, the majority shareholder must follow an external standard, or both of the two largest shareholders that combined make up a majority share of the concession must have external standards.

3.2. Logging concessions

3.2.1. FSC certification

Of the 14 logging concessions that had FSC certification, 13 were owned by firms, and only one was held by an individual. In addition to FSC certification, we assessed public versus private and individual versus firm ownership as relevant factors. Of the 13 firms, 2 were publicly held, 2 were unknown, and the remaining 9 were privately held. Across all 552 logging concessions (not only those with FSC certification), ownership was roughly evenly split: 291 concessions were held by firms, and 261 were held by individuals. Among the 291 concessions held by firms, 41 were of unknown holding type, only 21 were publicly held, and the remaining 229 were privately held.

In a naïve analysis, without accounting for any covariates, FSC-certified logging concessions had a much lower average rate of deforestation (−0.012%/yr) than non-certified concessions (−0.099%/yr). In a matching analysis, results were not significant ($p = 0.17$) with an ATT estimate of 0.112, which would be interpreted as a 0.112% lower annual deforestation rate in FSC-certified concessions as compared to non-certified concessions that are matched to account for relevant deforestation attributes including size of concession, region, ownership structure, distance to city, distance to river, distance to road, and elevation. Although we refer to 'lower' and 'higher' deforestation throughout this section in reference to matching results for clarity of interpretation, it is important to note that no matching results were significant, so whether results are actually 'lower' or 'higher' when

Table 2
Private concession types in the Peruvian Amazon.

Concession types	Total area (ha)	# Concessions	Ave Concession size (ha)	# Concessions with Commitment or fine
Logging concessions	7,886,553 ha	552	12,497 ha	14 FSC certified 119 fined
Brazil nut concessions	879,934 ha	884	874 ha	158 fined
Rubber concessions	16,156 ha	24	673 ha	No data found
Petroleum concessions	16,577,980 ha	41	404,340 ha	12 external standards 29 internal standards

Table 3
Matching results for sustainability commitments and fines. No significant results were found.

Concession	Timber			Brazil Nut		Petroleum
Treatment	Certification	Fine	Public company	Sustainability commitment	Fine	External Standard
[n]	14	119	21	NA	158	12
Control	No certification	No fine	Private company	—	No fine	Internal Standard
[n]	538	433	230	—	726	29
Estimate	0.112	−0.0038	−0.014	—	0.0083	0.0047
p-value	0.17	0.92	0.67	—	0.83	0.98

Note: In this table, estimate values that are negative indicate higher deforestation, while estimate values that are positive indicate lower deforestation compared to the control group. This is because deforestation rates were calculated using the method from Puyravaud, and are all expressed as negative values (Puyravaud, 2003).

using a matching method cannot be assessed. See Table 3 for a summary of results.

3.2.2. Logging concession fines

Of the 119 logging concessions that received fines in 2014, 49 were owned by firms, and 70 were individually owned. Of the 49 firms, 1 was publicly held, 8 were unknown, and the remaining 40 were privately held. As discussed above, ownership type among all logging concessions was relatively evenly split between firm and individual ownership, and the majority of firm-held concessions were held privately rather than publicly.

In a naïve analysis, without accounting for any covariates, concessions that received fines actually had a slightly lower rate of deforestation (−0.071%/yr) than concessions that had not been fined (−0.105%/yr). This result is counterintuitive. When concessions with 0 values for deforestation rate were excluded, eliminating concessions that might be inactive, results followed the same counter-intuitive pattern: fined concessions had a lower rate of deforestation (−0.134) than concessions that had not been fined (−0.196). Matching results were not significant ($p = 0.92$) with an ATT estimate of −0.0038, or − 0.0038% higher deforestation rate in fined concessions as compared to matched, non-fined concessions.

3.2.3. Publicly owned logging concessions

Of the 291 logging concessions held by firms rather than individuals, 21 were publicly held, and 229 were privately held. (For 41 concessions ownership type was unknown.) In a naïve analysis, without accounting for covariates, concessions that are publicly held had a lower rate of deforestation (−0.042) compared to concessions that were privately owned by firms (−0.085). Matching results were not significant ($p = 0.67$) and showed the opposite trend as observed in naïve analysis, with an ATT estimate of −0.014.

3.3. Brazil nut concessions

3.3.1. Brazil nut concession fines

Of the 884 brazil nut concessions, 158 received fines in 2014. All brazil nut concessions were held by individuals. In a naïve analysis, without accounting for any covariates, concessions that received fines had a higher rate of deforestation (−0.129%/yr) compared to concessions that did not receive fines (−0.109%/yr), following expected trends. Matching results were not significant ($p = .83$), with an ATT estimate of 0.0083, or 0.0083% lower deforestation rate in fined concessions as compared to non-fined concessions that are matched to account for relevant deforestation attributes including size of concession, distance to city, distance to river, distance to road, and elevation. (Region and ownership structure are not used as covariates in analysis for brazil nut concessions because they do not change across concessions; all are owned by individuals and located in Madre de Dios.) This finding is counter-intuitive, as one would expect deforestation to be higher in fined concessions. When deforestation rates of 0 are removed to account for inactive concessions, matching results remain similar and are still not significant ($p = 0.49$).

3.4. Petroleum concessions

3.4.1. Petroleum concession internal and external standards

Petroleum concessions that stated commitment to following an external standard followed ISO 14001, the Global Reporting Initiative (GRI) method or were part of the Dow Jones North America Sustainability Index. ISO 14001 sets criteria for environmental management systems. GRI is an independent organization that maintains standards for sustainability reporting. The Dow Jones North America Sustainability Index is a Dow Jones index in which companies are selected for inclusion based on being 'the most sustainable companies.' 12 petroleum concession holders followed one of these two external standards. The remaining 29 companies followed an internal company-based standard, which included environmental management systems, environmental impact assessments, and 'maintaining high environmental standards.'

In a naïve analysis, without accounting for any covariates, petroleum concessions following external standards had almost the same rate of deforestation (−0.2095%/yr) as those following internal standards (−0.2094%/yr). Matching results were not significant ($p = 0.98$) with an ATT estimate of 0.0047, or 0.0047% lower deforestation in concessions following external standards as compared concessions that are following only internal standards and are matched to account for relevant deforestation attributes including size of concession, region, exploration permission, distance to city, distance to road, and elevation (Table 3).

4. Discussion

We found no significant effect of sustainability commitments or concession fines on deforestation in the Peruvian Amazon. These findings were consistent across FSC certification in logging concessions, external sustainability commitments in petroleum concessions, and fines levied on logging and brazil nut concessions. Some concessions types did not participate in sustainability commitments at all (rubber, brazil nut) while for others all concessionaires participated either with internal or external standards (petroleum).

4.1. Likelihood of participating in sustainability commitments

In our data set, concessions that participated in sustainability commitments were frequently either international (petroleum concessions) or oriented toward export of products (logging concessions). Because of additional international scrutiny for products from these concessions, it is not surprising that sustainability commitments were found here and not elsewhere (Thorlakson et al., 2018). In addition, these concession types are more frequently held by large companies, and sometimes by large publicly-held companies that are responsible to shareholders, which may also increase the likelihood of participation in a sustainability commitment (Thorlakson et al., 2018). Though logging

concessions had more sustainability commitments than other concession types, the fraction of certified logging concessions in Peru is still quite small. Thorlakson et al. (2018) found that when large companies do participate in sustainable sourcing practices, they rarely extend the sustainable sourcing protocol through to the raw material producers, such as forest concession holders, which may inform the relatively small number of FSC certifications in our study area in spite of the general popularity of FSC certification and of sustainable sourcing practices for wood and paper products.

In contrast to logging and petroleum concessions, brazil nut and rubber concessions, though they also may export product through intermediaries, are much smaller, always held by individuals rather than firms, and are not internationally owned. Because of these characteristics, it is not surprising that no sustainability commitments were found for brazil nut or rubber concessions (Lambin and Thorlakson, 2018; Thorlakson et al., 2018). In addition, prior research has shown that companies that directly interact with consumers or retailers are more likely to participate in voluntary sustainability standards than others, and none of the concession types in our study are directly consumer facing, meaning that a small number of commitments would be expected (Lambin and Thorlakson, 2018; Thorlakson et al., 2018).

Finally, overlapping land use allocations, or the occurrence of one parcel of land being allocated for multiple uses either formally or informally, may also influence both participation in sustainability agreements and effectiveness of fines. The Peruvian Amazon has many overlapping land use allocations. Prior research has indicated that overlapping allocations are associated with lower deforestation (Anderson et al., 2018) but, it is not known how they interact with sustainability commitments or fines.

4.2. Sustainability commitments and deforestation for logging concessions and petroleum concessions

A number of researchers have examined the relationship between certification and deforestation, with mixed results. In Peru, FSC is the only certification type observed in logging concessions. FSC Peru commitments require not only that certificate holders comply with all Peruvian forest laws, but also that they meet a number of additional environmental and social standards (Forest Stewardship Council, 2001). Several of these environmental standards would be expected to reduce deforestation rates as compared to non-certified concessions. For example, FSC-certified concessions must ensure that no illegal logging by outsiders is taking place on their concession, including carrying out protection and monitoring activities. They are also required to limit forest loss due to harvesting activities; limit harvest to a permanently sustainable rate; plan and map out separate areas for forest production and protection; plan felling to avoid leaving forest clearings; maintain high conservation value areas; and provide full chain of custody documentation (Forest Stewardship Council, 2001).

FSC is one among several third-party certifications in the forest sector and is seen as more stringent than other certifications such as SFI or PEFC (Nordén et al., 2016; Smith and Fischlein, 2010). However, other forest certifications have also become more stringent over time through competition among certifiers (Overdevest, 2010). Nordén et al. (2016) found no difference between FSC and PEFC certification outcomes in Sweden. More importantly, they found that certification did not improve environmental outcomes in terms of number of trees and high stumps left after harvest (Nordén et al., 2016). Blackman and Rivera (2011) similarly found limited evidence (4 of 11 studies) of environmental benefits from certification (both FSC and coffee certification). And, in a second study of FSC certification in Mexico, Blackman et al. (2015) found no impact of certification on deforestation. Finally, in a recent working paper, Panlasigui et al. (2015) found minimal impact of FSC certification on deforestation in Cameroon and in Peru. In Peru, a small effect for certification was found only in the state of Madre de Dios, but no average effect was found in the study area. It should be noted that most of these studies focus on deforestation as the outcome result; other unmeasured forest management outcomes may also be important in certified forests. Beyond empirical evidence on FSC impacts on deforestation, questions have arisen about the ability of FSC to ensure that certified products are meeting FSC criteria (Kröger, 2018) and the ability of forest managers to comply with FSC certification standards (Rafael et al., 2018).

While the above studies do not find a connection between certification and deforestation, a number of studies in other geographic locations have found significant links. Research by Heilmayr and Lambin (2016) in Chile showed that certification regimes, including FSC, reduced deforestation rates by 2–23% on participating lands. More recent research in Chile confirms this finding (Tricallotis et al., 2018). Medjibe et al. (2013) also found that certified forests had better environmental outcomes than uncertified forests in Cameroon. In Indonesia, Miteva et al. (2015) found that FSC-certified concessions had 5% lower deforestation rates compared to non-certified concessions.

Nordén et al. (2016), who did not find that certification improved the number of trees left after harvest in Sweden, conclude that certification standards should be strengthened along with monitoring and enforcement of those standards. We similarly conclude that no evidence of FSC certification impacting deforestation rates may indicate that either certification standards are not significantly stronger than legal standards in Peru, or that monitoring of certification practices in Peru is limited. Panlasigui et al. (2015) suggest that certification is at an early stage in Peru, and changes in deforestation may be more evident as more concessionaires participate for longer periods of time. We find this a less convincing explanation; there are few FSC-certified concessions Peru, but the commitment period is five years, and some extend back to multiple certification renewals.

Far fewer researchers have examined petroleum concessions with sustainability commitments related to deforestation. It is not known whether each concession has selected provisions of their chosen sustainability commitments that include commitments specific to deforestation, but as this is one of the primary metrics for sustainability practices in the Amazon, we make the assumption that lower deforestation may be correlated with participation in an external sustainability commitment. Compared to the FSC-certified forest concessions, petroleum concessions following external standards are following several different standards that are much more heterogeneous, and they were compared to petroleum concessions that also have made sustainability commitments, albeit internal commitments, which are thought to be weaker (Lambin and Thorlakson, 2018). For petroleum concessions as a group, the available data make it difficult to distinguish between concessionaires who wish to show that they are good actors either to increase revenue or maintain reputation, and concessionaires who may be engaging in ‘greenwashing’ (Lambin et al., 2018; Thorlakson et al., 2018). Further, companies may be purposefully setting very easy to achieve or vague standards if their main objective is to maintain or improve their reputation through sustainability commitments (Lambin et al., 2018). Finally, these concessions are very large, and petroleum-related activity would be expected to be observed on only a very small fraction of the concession at one time, thus potentially making differences in deforestation difficult to observe.

4.3. Fines and deforestation for logging concessions and Brazil nut concessions

For logging and brazil nut concessions, fine data are from 2014, and deforestation rates are measured in 2011. Because of this sequencing, we hypothesized that high deforestation rates in the 2011 data may indicate poor concession governance in that period, which was then later fined in 2014. In this sequencing, concessions with fines would be associated with higher deforestation rates, yet we did not find any statistically significant differences in deforestation rates in fined concessions and those that were not fined.

Fines for brazil nut concessions range from $118–$12,484 with an average fine of $1068. Fines for timber concessions range from $118 to $532,850 with an average fine of $36,788. $118 fines are quite low for concessions with average size of 900 ha (brazil nut) or 12,000 ha (logging), and may not encourage compliance. To assess fine data in greater details, we disaggregated data into two groups: small fines that may not be impactful, and large fines that are more likely to encourage compliance. Because brazil nut concessions are quite small and always held individually, the fine threshold for large fines in these concessions was set at ~$1100. For logging concessions, the threshold for large fines was set at ~$11,000. Examination of only 'large fines' also yielded non-significant results for deforestation rates.

Law enforcement literature, both broadly and for conservation specifically, suggests that for a fine to be an effective deterrent (in this case a deterrent to deforestation), both the size of the fine and the likelihood of enforcement of the fine are key factors (Becker, 1974; Börner et al., 2015a, 2015b; Keane et al., 2008; Robinson et al., 2010). Likelihood of enforcement is not known for the data analyzed here, but the geographic distribution of fines does not appear to have a bias, so we do not assume uneven likelihood of enforcement across regions. Full enforcement of fines requires clear land use allocation and identification of a party to be fined. Enforcement across the Peruvian Amazon may thus be hindered if concessions experience either overlapping allocations, as addressed above, or incongruencies between *de jure* and de facto land use allocations (Kröger and Lalander, 2016).

As noted above, the size of the fine is sometimes quite low, which would make a fine a less likely deterrent of bad behavior. Le Polain de Waroux et al. note that low fines do not encourage compliance with forest laws in the Gran Chaco region of South America (le Polain de Waroux et al., 2016, 2017). Even in Brazil, a country with relatively high enforcement of forest governance, Börner et al., 2015a find: "…field-based enforcement operations have not been universally effective in deterring deforestation during our observation period." Borner et al. do find that field-based enforcement was most effective in reducing large-scale deforestation, and less effective in reducing small scale deforestation (< 20 ha patches). These field-based enforcement operations can lead to fines for bad actors, but they can also include seizure of assets and/or restriction of access to credit (Börner et al., 2015a, 2015b). Therefore the comparison with Peru is not exact. However, their findings are congruent with our findings in Peru. Fines that are very low may not be impactful, but large fines for illegal deforestation would be expected to be levied for, and therefore correspond with, higher deforestation in the period prior to the fine. That we do not find these results indicates that fines may still be too low overall, or that the overall level of enforcement is not adequate to insure compliance.

In contrast to Borner's findings, Cisneros et al. (2015) in Brazil find that blacklisting of districts with high deforestation rates is associated with reducing deforestation in those districts. This is somewhat similar to a fine, but at a broader (district-wide) scale and fines are presumably not as public. The Cisneros study also explicitly differentiates between blacklisting effects and 'field-based enforcement.'

In a second study, Börner et al., 2015bcompare use of a punitive measure (fines) with use of an incentive (PES) to reduce deforestation in Brazil. They find that there is a trade-off between the two approaches. Punitive measures are more cost-effective for government, but incentives result in higher welfare for forest owners and managers. This comparison is different from the Peru case in that both measures are government sponsored, whereas in Peru the punitive measure is governmental while the incentive is voluntary; therefore one would not expect the two measures we assess for Peru to have direct tradeoffs as they do in Brazil.

4.4. Interaction between sustainability commitments and fines

Interactions between voluntary sustainability standards (such as FSC certification) and command and control measures (such as fines) can occur in a variety of ways (Lambin et al., 2014). Lambin and Thorlakson (2018) investigate how private voluntary sustainability standards interact with public policy and governance. In the case of voluntary sustainability standards as certification and public policy as punitive fines, the interactions appear to be limited because voluntary standards operate in the realm of meeting or exceeding general or high standards, where punitive fines operate where minimum standards (legal operation) are not being met (Table 1).

However, there are a number ways in which certification and fines may interact indirectly, and may be complementary (Lambin et al., 2018). For example, research in Eastern Europe has indicated that implementation of FSC was differentially successful, dependent on government engagement and support (Niedziałkowski and Shkaruba, 2018). Because certification generally requires compliance with all applicable laws, it can be seen as supporting legal compliance and making the state's enforcement process for fines easier (Meidinger, 2006). Further, because certification efforts focus on raising standards, governments can focus on enforcement for under-performers (Lambin and Thorlakson, 2018; Lambin et al., 2018). In one study that examined the agricultural sector in Indonesia, this type of interaction occurred and certification led to better enforcement of laws (Wijaya and Glasbergen, 2016). However, this example was in a case of wide adoption of a certification standard, and FSC has not been widely adopted in Peru. If enforcement were more stringent, it could be the case that certification and fines could be weakly complementary in Peru, reinforcing each other in nudging good actors (i.e., leaders in sustainability) to improve via certification and poor actors (i.e., laggards in sustainability) to improve via fines.

4.5. Limitations and future directions

Though we use a long period data set for deforestation, have access to all concession data for the Peruvian Amazon, and deploy rigorous statistical methods with matching, it is possible that sustainability commitments and fines are not found to significantly influence deforestation rates because data remain insufficient. Concession areas are large, and a method for identifying active areas of each concession would be beneficial. Further, the overall rate of deforestation is low, so differences among concessions may go unobserved. Panlasigui et al. (2015), who examined deforestation and certification in Peru, similarly indicate that more comprehensive data may yield more illuminating results.

5. Conclusions

We found no statistically significant results linking either sustainability commitments or fines to changes in deforestation rates for the Peruvian Amazon. In the case of sustainability commitments, this may be due to FSC certification not being sufficiently stringent or not adequately monitored. In the case of fines, this may result from fines that are too small and not adequately enforced to compel legal compliance. There may also be some limited complementary interaction between sustainability commitments and fines. Improved data, including more spatially and temporally explicit information, may improve results in future analyses.

Declarations of interest

none.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.forpol.2019.03.010.

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