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Impacts of certification, uncertified concessions, and protected areas on forest loss in Cameroon, 2000 to 2013

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ABSTRACT

Deforestation and forest fragmentation are leading drivers of biodiversity loss. Protected areas have been the leading conservation policy response, yet their scale and scope remain inadequate to meet biodiversity conservation targets. Managed forest concessions increasingly have been recognized as a complement to protected areas in meeting conservation targets. Similarly, programs for voluntary third-party certification of concession management aim to create incentives for logging companies to manage forests more sustainably. Rigorous evidence on the impacts from large-scale certification programs is thereby critical, yet detailed field observations are limited, temporally and spatially. Remotely-sensed data, in contrast, can provide repeated observations over time and at a fine spatial scale, albeit with less detail. Using the Global Forest Change dataset, we examine annual forest loss in Cameroon during 2000–2013 to assess the impact of Forest Stewardship Council certification, as well as uncertified logging concessions and national parks. We use panel regressions that control for the effects of unobserved factors that vary across space or time. We find low forest loss inside the boundaries of each management intervention, with < 1% lost over the study period. Yet those low levels of loss appear to be influenced more by a site's proximity to drivers of deforestation, such as distances to population centers or roads, than by national parks, uncertified concessions, or certification. The exception is that if a site faces high deforestation pressure, uncertified logging concessions appear to reduce forest loss. This may reflect private companies' incentives to protect rights to forest use. Such an influence of private logging companies could provide a foundation for future impacts from certification upon rates of forest loss, at least within areas that are facing elevated deforestation pressures.

1. Introduction

Habitat loss and fragmentation are the leading drivers of global biodiversity loss (Murphy and Romanuk, 2014; Tilman et al., 2017). Forests face increasing pressure as humans convert forested areas for infrastructure, mining, ranching, and industrialized agriculture (DeFries et al., 2010; Laurance et al., 2001; Swenson et al., 2011). The environmental consequences of forest loss are significant, including increases in erosion, the degradation of water resources, accelerated extinctions, and carbon dioxide emissions (Laurance, 2009; Laurance et al., 1998; Van der Werf et al., 2009; Wright and Muller-Landau, 2006).

Establishing protected areas has been the most common policy response to such pressures, with over 15% of the world's land and inland water area protected (Juffe-Bignoli et al., 2014). Recent studies indicate environmental benefits from protected areas, albeit lower than often is assumed and highly varied in magnitude (Andam et al., 2008; Joppa and Pfaff, 2011; Pfaff et al., 2015), due in part to variable capacities of governments to monitor and enforce rules (Pfaff et al., 2014). One motivation for our study is that an expansion of protected areas at the scale that is desired for conservation is unlikely in many countries. In fact, in recent years protected areas have experienced downgrading, downsizing and degazetting, often to allow extraction activities (Mascia and Pailler, 2011; Pack et al., 2016). With the total protected area falling far short of internationally agreed biodiversity conservation targets (Aichi Biodiversity Targets; (Aycrigg et al., 2013; Scott et al., 2001)), conservation management on private lands and public lands leased to private companies is increasingly proposed as a complement to protected areas (Kamal et al., 2015). Within that approach our focus is the recent trend toward third-party certifications of management

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practices deemed more ecologically, economically and culturally sustainable.

In forested regions, there has been a concerted effort to generate incentives for logging firms to curb their impacts on forest ecosystems and initiatives for sustainable forest management largely aim to slow deforestation (Marx and Cuypers, 2010). Globally, an increasing number of logging companies have adjusted management of forest concessions to respond to states and consumers. Third-party verification is required for timber sourcing to be legal under the United States' amendment of The Lacey Act of 2008, as well as European Union Timber Regulations of 2010 and the Australian Illegal Logging Prohibition Act of 2012. Verification of adjusted practices to reduce logging impact also is required for any certification of sustainable forest management.

Many forest concessions voluntarily applied for certification by the Forest Stewardship Council (FSC), which was founded in 1993 to promote “environmentally appropriate, socially beneficial, and economically viable management of the world's forests” (FSC, 2015). By 2018, a total of 1533 FSC certificates were active in 83 countries, covering over 198 million ha of forest (FSC, 2018a). However, beneficial and verifiable impacts from FSC remain a subject of active debate. Compliance outcomes, auditing and enforcement practices and, ultimately, forest outcomes vary widely under FSC (Burivalova et al., 2016; Counsell and Loraas, 2002; Nebel et al., 2005), while rigorous assessment of FSC impacts on forest ecosystems has been limited (Romero et al., 2017).

The scale of FSC certification creates a challenge for assessment, one made even more daunting by the diversity of contexts involved across the globe. Though the world has learned a great deal from fieldwork in a number of settings (Cerutti et al., 2014; Cerutti and Tacconi, 2006; Medjibe et al., 2013), it is not currently feasible to collect fine-scale field data (e.g., biodiversity, carbon density, watersheds, adherence to management plans for concession sub-units) at sufficient time intervals across FSC-certified concessions, uncertified concessions, and in control forests to permit comparisons to assess environmental impacts of FSC. The collection of field data is expensive and time consuming, particularly in remote locations of developing countries. To address part of such assessments, we now have widely available and cost-efficient remotely sensed data and derived data products being produced regularly with global coverage over many years. The most straightforward remotely sensed outcomes measure to consider the effects of different land-use interventions is the rate of forest loss. The recent creation of global forest loss products such as Hansen et al. (2013; featured in GlobalForestWatch.org) or Sexton et al. (2013) provide consistently mapped remotely sensed estimates of forest loss, across the globe, at a fine spatial scale. Three recent studies demonstrate the feasibility of using remotely sensed measures of forest loss for inferences concerning FSC impacts (Blackman et al., 2015; Heilmayr and Lambin, 2016; Miteva et al., 2015). Overall, these studies suggest small if any reductions of deforestation by FSC certification, while also conveying that forest impacts can vary greatly across settings.

Another primary concern in terms of forest management is the need to also monitor degradation. However, this has proven more challenging to do across large tropical areas and often requires ancillary data to complement the satellite imagery available as early as 2000. Specifically, there is no “wall to wall” mapped data of degradation across Cameroon – currently or for years past (although see Zhuravleva et al. (2013) for one detailed degradation study about the DRC).

Forest regulation in Cameroon was established through a series of policy changes that began in the 1990s and stretched into the 2000s. The bulk of Cameroon's forestry policy was set by the 1994 Forestry Law No. 94-01 (Cerutti et al., 2016a) that established two zones, the permanent forest estate and the non-permanent forest estate, the latter being the default status of unclassified forests (WRI, 2012). The permanent forest estate requires that natural ecosystems be maintained in perpetuity and encompasses protected areas. Forest parcels within the state-owned permanent forest estate can become logging concessions. First the boundaries of such concessions must be defined by the state, then they are leased on a three-year contract to a private logging company, which must design and gain approval for a management plan before obtaining a 15-year contract, which is renewable once, for a total tenure of 30 years (Cerutti et al., 2016b). Logging companies often take measures to prevent other actors from entering their concessions to extract timber or non-timber forest products. In fact, the FSC-certified logging concessions are required to take such measures (FSC, 2018b). However, staffing challenges at Cameroon's Ministry of Forests and Fauna's have, in some instances, led to companies harvesting before the boundary negotiations have been completed or the full legal contract is established (Cerutti et al., 2016a).

The European Union has had a large influence on Cameroon's forest management policy since 2006, when discussions progressed toward a FLEGT Voluntary Partnership Agreement between the European Union and Cameroon (Cerutti et al., 2016a). Timber exports from Cameroon have been on the rise since 2004 (Karsenty and Ferron, 2017). Much could be improved, as a recent study found that 40% of forest loss in Cameroon is located outside of the permanent and non-permanent forest estates, indicating that illegal logging may be a major source of deforestation (Verhegghen et al., 2016). Legality and sustainability of timber sourced from Cameroon might be improved if NGOs could collaborate with governments and companies to improve auditing and monitoring. Plans for such changes continue to be under discussion (Central African Forest Initiative, 2015; European Forest Institute, 2014; Global Witness, 2005). As Asian markets adapt to import a majority of the increased production from these areas (Cerutti et al., 2016a) it is likely to affect the future of Cameroon's forests, as logging companies respond directly to requirements for legality and sustainability from their consumers (Karsenty and Ferron, 2017).

We present a rigorous assessment of forest loss in Cameroon from 2000 to 2013 for various types of land-use management: concessions that have been certified by FSC; concessions that were never certified; and national parks. We focus on FSC's Forest Management certificate, although two other certificates, Chain of Custody and Controlled Wood, have also been applied for post-harvest timber processing (FSC, 2018a). In 2013, Cameroon had > 1 million ha of FSC's Forest Management certificates (Cerutti et al., 2016a). Given the total forest area involved, certification could have significant environmental and social impact in Cameroon and more generally across central Africa. Previous studies of FSC in central Africa found positive social impacts (Cerutti et al., 2014; Cerutti and Tacconi, 2006) and less damage from logging roads (Medjibe et al., 2013).

2. Methods

2.1. Data

We use the annual forest loss information from the Global Forest Change dataset (Hansen et al., 2013), derived from Landsat 7 ETM+, at 30-m pixel resolution, from the year 2000 to 2013. While the government of Cameroon uses the Food and Agriculture Organization (FAO) definition of forests, which is 10% or more tree cover, we used the threshold of 30% tree cover detection for each year within a pixel as an indicator of forest (Margono et al., 2014). This agrees with the United Nations Framework Convention on Climate Change's (UNFCC) definition of forests, as well as with official definitions within other tropical forest countries such as Peru and Brazil. As most of the tropical forests within our study area are primary forest, we felt that the UNFCC's definition forest cover would be more appropriate for our analysis of forest impacts.

From the Forest Atlas of Cameroon (WRI, 2012), we acquired data for protected areas and for the sites and companies associated to all the forest management units, of which there were 114 within the forest-dominated southern half of the country. We examine the following

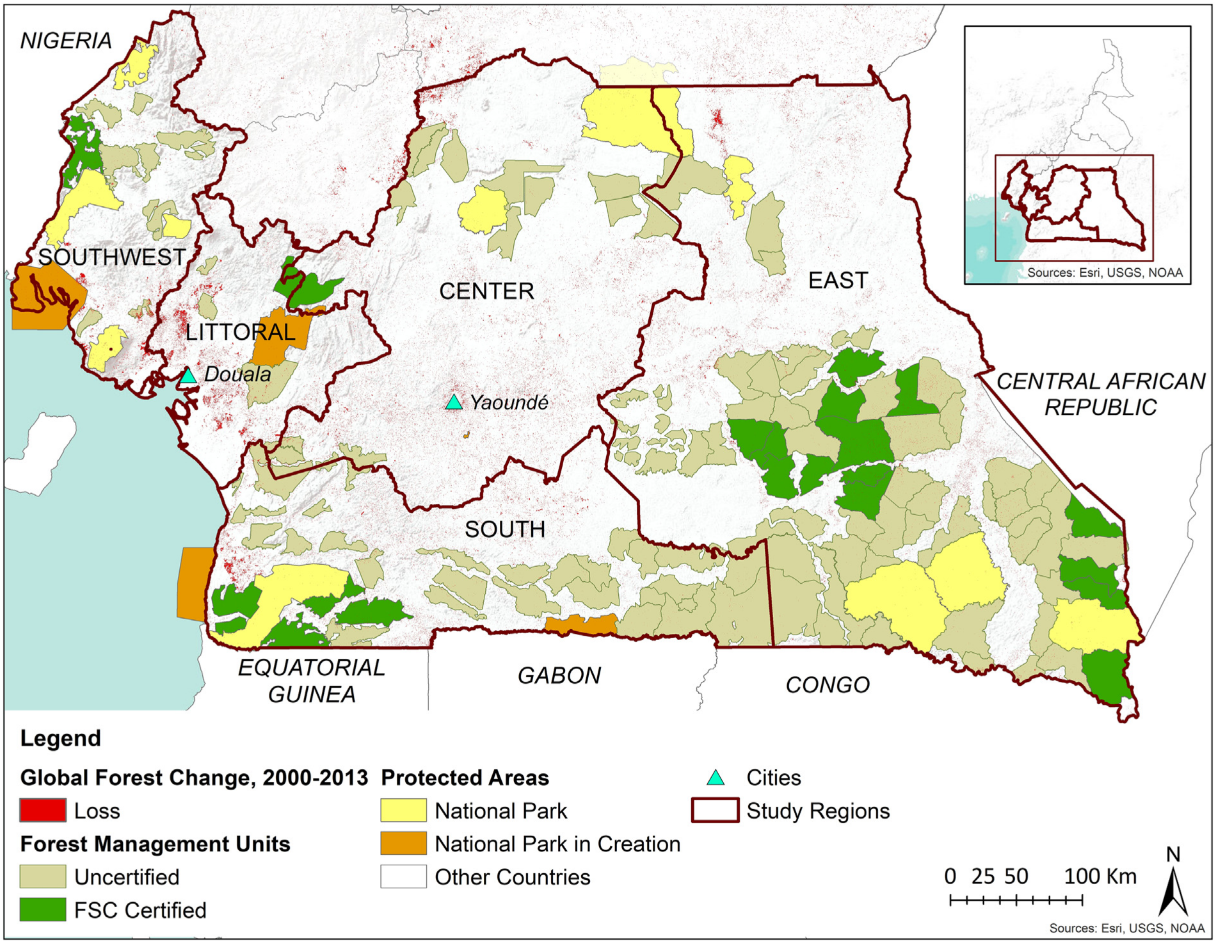

Fig. 1. Map of the study area. The study area is in the southern half of Cameroon and includes five regions: Southwest, Littoral, Center, South and East. For forest management units, the label "FSC certified" indicates those logging concessions that had an active FSC certificate at any time during our study period from 2000 to 2013.

administrative regions: East, Littoral, Center, Southwest, and South (Fig. 1). We collated the information about logging concessions from FSC's online public database, the literature, and expert assistance (Cerutti et al., 2014). We wanted to include several other variables relevant for forest management decisions – such as the annual allowable cut as detailed within management plans including for sub-units of concessions, or operating budgets – in order to provide additional useful controls. However, such records are either incomplete or do not exist at this time, so those factors could not be included.

We used variables for biophysical characteristics and for accessibility that are typical of recent deforestation analyses (Andam et al., 2008). Biophysical characteristics included elevation from the NASA Shuttle Radar Topographic Mission (Jarvis et al., 2008), slope derived from elevation, and average annual precipitation and temperature provided by the WorldClim dataset (Hijmans et al., 2005). We derived accessibility indicators – distances to nearest road, timber processing plant, and population centers – from 2014 version of the Forest Atlas of Cameroon (WRI, 2012).

All of the geospatial data were managed using ArcMap 10.2.2 (ESRI, 2014) with the Spatial Analyst tools. Statistical analyses were conducted in Stata (StataCorp, 2015).

2.2. Analysis

Our analysis includes 20 concessions that received FSC forest management certificates between 2005 and 2010 and cover 14,842 km^2, 94 uncertified forest concessions that cover 56,289 km^2, and 11 national parks that cover 19,174 km^2.

To assess the impact of FSC certification, we compare the rates of forest loss in certified versus in uncertified logging concessions, controlling for spatial differences and the pressure on forests over time. We also compare the rates of forest loss in uncertified concessions and national parks with loss rates in control forests – i.e., forest outside the boundaries of the policies we examine – over time and space. We control for spatial differences and the increase in deforestation pressure over time, in order to assess the impacts of both public enforcement and private management.

We constructed a pixel-level panel dataset from a random sample of 30-m pixels that covers both inside of each intervention and all of the control forests – which we defined as all forests outside of logging concessions, national parks and hunting zones. We used the pixel-level panel dataset to generate descriptive statistics within each intervention and for the control forests, calculating the average values of the biophysical and accessibility characteristics that affect forest loss as well as the overall percent forest loss for the study period. We also then evaluate the forest loss over time for FSC certified, uncertified concessions and national parks (see Tables 1 and 2).

For the pixel-level analyses, we increase the similarity for pixel comparisons by matching each of the treated pixels (i.e. uncertified concessions, national parks, FSC certified concessions) with control pixels on the basis of observed biophysical and accessibility characteristics. We did both covariate and propensity-score matching for each of the treatments, then selected the method that gave us the most similarity (Supplementary material, Tables A1–A3). Thus, we selected

Table 1
A random sample of pixels was distributed across five administrative regions: Southwest, Littoral, South, Center and East. We study interventions initiated from 2000 through 2013 and compare them with controls (before and after matching). We observe the percent of forest loss in control pixels by region.

	Post-2000 interventions & controls observations (number of pixels, by region)				
	Southwest region	Littoral region	South region	Center region	East region
Logging concession	2088	1049	3780	941	14,441
Uncertified	1510	843	2837	451	10,816
Certified	578	206	943	490	3625
National park	1030	–	–	528	4835
Controls (pixels that are in forests & outside interventions)	11,297	10,381	18,561	34,167	31,524
Total observations (by region)	14,415	11,430	23,715	38,392	54,527
Forest loss in controls (2000–2013)	2.21%	4.47%	2.60%	2.15%	1.71%

Table 2
For each intervention and for the full set of unmatched controls, we calculate the averages for observed characteristics that are relevant for rates of forest loss. We use post-2000 interventions, eliminating observations in concessions created after 2013.

	Uncertified concession	Certified concession	National park	Control forests
Forest Loss (2000–2013)	0.44%	0.21%	0.09%	2.3%
Distance to roads (km)	5.4	2.5	15.3	3.4
Distance to cities (km)	10.7	12.4	25.9	5.2
Distance to plants (km)	35.9	39.2	44.3	45.2
Elevation (m)	567	587	635	594
Slope (degrees)	4.7	4.9	6.0	4.6
Precipitation (mm)	1793	1814	1751	1889
Temperature (°C)	23.9	23.8	23.5	24.1

nearest neighbor covariate matching with replacement to match pixels of both uncertified concessions and national parks with control pixels. We use propensity-score matching for FSC concessions in linking each certified pixel to a comparison pixel in uncertified concessions (Tables A1–A3).

Using only the matched pixels, we then constructed a pixel-level panel dataset for 2001–2013. We have one observation per year for each of the 336,727 random pixels in our study area. All of the pixels in our sample were observed to be forested in 2000. We retained interventions only if they began after 2000, since our available forest information begins in 2000, and we analyze the impact of introducing any given intervention. We use panel regressions to estimate effects of the interventions on forest-loss rates, across the whole study area and for each region (Eq. (A1)). We also analyzed a concession-level panel dataset for evaluating the impact of FSC certification, as an appropriate robustness check upon the pixel-level analyses (Supplementary material).

Panel analyses that include effects for each observational unit (pixels or concessions) and for each year can effectively control for many confounding influences on forest-loss. Two critical factors that change over time, and affect both land use and deforestation pressures across entire countries, are the state of the economy and the governance by the federal government. Among spatial influences, two critical factors that differ across pixels – and thus also concessions – are transport costs and local institutions. Some of the variation in such influences is captured within the data sets that we employ. Other elements, however, are not easily measured for use within regressions as controls, highlighting the value of removing their influences from our analyses.

Panel analyses control for temporal influences by subtracting from each observation the average outcome in each year: forest loss in one place for one year is compared to the average for that year, removing temporal influences by focusing on whether loss under FSC is lower than the average for that year. Panel analyses control for spatial influences by subtracting from each observation the average outcome for that place, removing influences of spatial differences – even if unobservable – by focusing on whether loss under FSC is lower than the average forest loss for that place. Removing these influences better focuses the analysis on treatment impacts.

Finally, we do one further check of the panel analyses' underlying assumption that the change in outcome over time for controls, once treatment has started, is a good estimate of what changes in outcomes over time would have been in the treated locations had they not received treatment. Testing this assumption involves checking the trends in outcomes over time in the treated and the untreated locations, before any treatment occurred, to see trends are ‘parallel’, (i.e., the shifts in the outcomes over time before treatment are not significantly different for the treated units when compared to the untreated units). If so, that rules out one alternative explanation for a panel result, one that is the most common concern: trends' differences after treatment are not due to treatment; instead, they are simply a continuation of trends' differences of the same sign that existed before.

3. Results

3.1. Descriptive statistics across sites

With the descriptive statistics based on the sampled pixels (Table 1) we find that forest loss rates varied across the regions of Cameroon, with the greatest loss experienced in the Littoral region, followed by the South, then Southwest regions (Table 1). This background pressure can greatly influence the impacts of interventions. For instance, this pressure defines the maximum impact.

Looking across interventions (Table 2), the raw total forest loss rates from 2000 to 2013 were < 1% for each of the interventions. The average across all control forests was 2.3%. However, the differences in the average values for our biophysical and our accessibility variables show that the interventions' locations are different from each other and different from the average control sites (Table 2). National parks are more remote, averaging 15.3 km from a road versus 2.5 and 5.4 km for the certified and uncertified concessions, respectively. Control areas averaged 3.4 km from a road. National parks are twice as far from population centers as are concessions and five times as far as controls. Such key site differences could explain differences in forest loss between the controls and the interventions. They indicate the importance of including such variables to reduce biases in raw comparisons.

3.2. Checking parallel trends

In order to check the parallel trends assumption for each treatment, we ran a panel regression with year and unit effects that includes the following dummy variables instead of the treatment dummy: i) 4 years or more before the treatment, ii) 1–3 years before the treatment, iii) 1–3 years after the treatment, and iv) 4 or more years after the treatment. Therefore, we shift the ‘treatment test’ variable back in time so that significant coefficients before the treatment would indicate that the parallel trends assumption is not met. We found no significance in the pre-treatment years for National Parks and FSC certification, both at the pixel and the concession level (Supplementary material, Figs. A1–A3). Thus, for those interventions, the pre-treatment trends are ‘parallel’.

However, we did find positive and statistically significant

Table 3
The panel regressions yielded coefficients that we interpret as the estimated impacts of interventions. We compared FSC certified concessions to uncertified concessions for the impacts of FSC (which are additional to the effects of just being a concession) and we compared both the uncertified concessions and the protected areas to controls (forests outside of interventions) for the impacts of those interventions. Negative values of coefficients indicate the experience of having avoided forest loss, on average annually, while positive values indicate that it increased forest loss. For the FSC Certification panel, we exclude observations in the Center because no loss was observed in our matched sample of pixels in that region, as well as observations in Littoral because there are no FSC certified concessions. We exclude pixels in Littoral from the "All" specification for FSC. Note that * denotes $p < 0.1$; ** denotes $p < 0.05$; and ***denotes $p < 0.01$.

	Unit of analysis	Panel regression coefficients by region					
		All	Southwest	Littoral	South	Center	East
FSC certified concessions	Pixel	−0.0002	0.0009	–	−0.0001		−0.0003**
Uncertified concessions	Pixel	−0.0013***	−0.0014**	−0.0088***	−0.0009**	−0.0027*	−0.0008***
National parks	Pixel	0.0001	0.0011	–	–	−0.0006	−0.0003**

coefficients in the pre-treatment years for uncertified concessions (Fig. A4). Thus, tree-cover loss was rising more quickly, on average, in uncertified concessions than in control forests during the pre-treatment years. As we found in our main results that in uncertified concessions tree-cover loss rose less quickly than in controls, on average, this test shows our results are not simply the extension of prior differences in trends.

3.3. National parks

Using regression with the pixel-level panel dataset to compare the forest loss rate for national parks to that of control forests we found on average no significant impact from national parks in reducing forest loss (Tables 3, A4). Analyzing each region separately, only the East region's parks yielded a statistically significant, albeit minimal, annual avoidance of forest loss (0.03%, $p < 0.01$). These findings might appear to contradict our initial descriptive statistics that show lower total forest loss rates in national parks compared to controls (Table 1). However, as just shown for biophysical and accessibility variables, national park characteristics are different from unmatched controls (Table 2). With effective matching prior to the regression, the matched subset of controls used in the regression is far more similar to the park sites, providing for a more appropriate comparison (Table A2). Compared to a matched-controls subset, national parks have slightly higher forest loss rates, although this increase is statistically insignificant (Fig. 2). The panel regression is in turn even more robust, as we included year effects (for temporal influences like the macroeconomy) and fixed effects (for spatially varying influences like transport costs).

3.4. Uncertified concessions

We used the pixel-level panel dataset to evaluate logging concessions that never received FSC certification, comparing their forest loss rates to the loss rates in their matched control forests. Within all of the uncertified concessions across the study area, we observed on average a small avoidance of forest loss, annually, of 0.13% ($p < 0.01$; Tables 3, A4). Among the regional analyses, however, the Littoral region has the highest forest loss pressure (Table 1) and here those uncertified concessions appear to prevent nearly a 1% forest loss annually (Table 3).

3.5. FSC certification

We used the pixel-level panel dataset to evaluate FSC certification by comparing the forest loss rate within the certified concessions to that within uncertified concessions (Tables 3, A4). Given the panel regression's strong controls for fixed spatial differences, we found that certified concessions had 0.02% lower forest loss rates post-certification, relative to pre-certification across the study area. This result is not statistically significant (Table 3).

We also want to make use of this estimate to highlight the importance of including year effects in panel regressions. Without removing time trends in the controls, the rise in loss rates inside concessions over time (Table A4) makes it seem like FSC certifications raised forest loss – merely because FSC occurs more often later in our

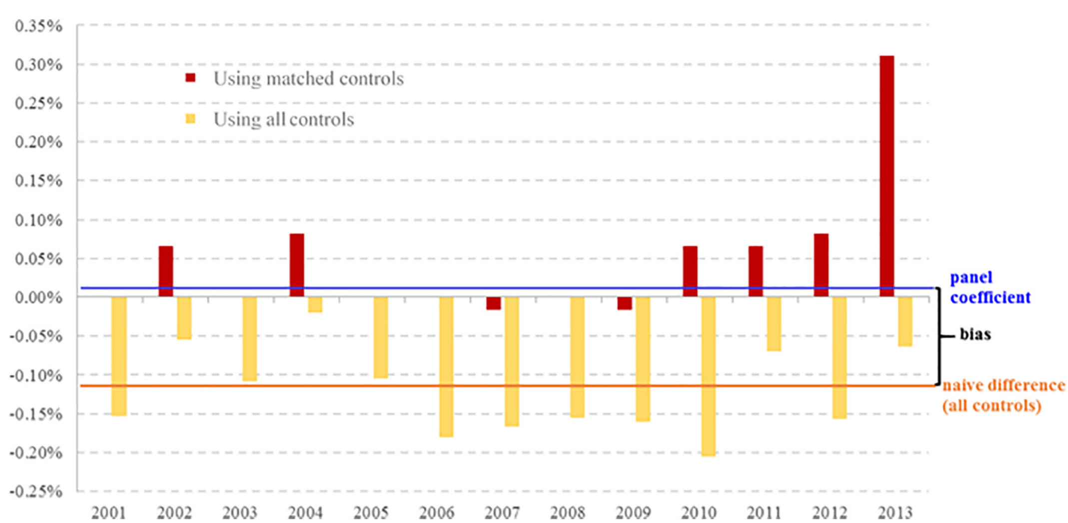

Fig. 2. Removing bias from national park forest loss rates. For national parks, this graph depicts comparisons of national parks to controls using two differences in the annual rates of forest loss. Before matching, the differences suggest parks experienced reduced forest loss (yellow bars). After matching, the differences suggest parks experienced increased forest loss (red bars). However, the panel coefficient is not statistically different from zero, suggesting that forest loss rates in national parks and control forests were essentially the same, on average. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

time period when the rates of forest loss increased. When we include all the appropriate spatial and temporal controls for the different regions, we found no statistically significant differences in forest loss between FSC certified and uncertified concessions (Table 3). These results imply that, at least to date, in this context, FSC certification has provided little if any additional reduction of forest loss compared to uncertified concessions. The results from panel analyses using pixels are supported by the concession-unit panel analyses (Supplementary material).

4. Discussion

We applied a rigorous approach to evaluating the avoidance of forest loss by public and private land use policies in Cameroon in the years from 2000 to 2013. Overall, our analyses demonstrate that to date FSC certification has provided little if any additional reduction of forest loss rates, compared with the uncertified concessions. Certified and uncertified concessions had the same effect on forest loss rates. The uncertified concessions minimally lowered forest loss rates, when compared to matched control forests. National parks had no significant effect on forest loss rates.

In the Littoral region, where the background deforestation pressure was the greatest, we found that uncertified concessions have avoided significant forest loss. It is likely that this region has elevated forest loss due to the proximity of its forests to the port city of Douala, where timber exits the country for international markets (Cerutti et al., 2016a; Verhegghen et al., 2016). Unfortunately, a lack of FSC certification in that region prevented us from assessing the impacts of FSC certification when facing higher deforestation pressure. Yet the result for uncertified concessions may indicate a foundation for FSC impacts upon forest loss in the future within this and other higher-forest-pressure locations. This finding may indicate the ability of and incentives to private companies to defend their legal rights to use the forests, perhaps by restricting access.

In this context, national parks did not significantly reduce forest loss. As described above, national parks are relatively remote, and experience lower deforestation pressure. In a study that assessed the forest cover change patterns across the landscape, Bruggeman et al. (2015) found that the surrounding residents encroach on Cameroon's national parks with agricultural fields. Furthermore, Vimal (2017) described limitations of the government's ability to restrict access to parks. While our result was not significant, the overall increase in forest loss could indicate an emerging challenge for national parks to enforce their boundaries in light of increasing deforestation pressure.

In a larger historical context, minimal impacts upon forest loss rates from FSC and national parks may be surprising, given the widespread use of national parks and global recognition of FSC as the standard for sustainable forest management (Hale and Held, 2011; Juffe-Bignoli et al., 2014). Yet ecological benefits are only one goal of certification and reduction of forest loss is only one way to measure such benefits. FSC's focus upon a variety of environmental, social and economic benefits means that a variety of additional indicators could be used to evaluate FSC certification. Nonetheless, for this important outcome, our results demonstrate the value of having spatial and temporal controls that address common sources of bias. We believe they convincingly rule out large effects from certification in reducing forest loss within Cameroon over our study period.

In measuring forest loss by satellite image analysis, our methods show effects at a grain size of 0.09 ha (30-m pixel), yet are unable to account or monitor the more subtle effects of forest degradation. Cerutti et al. (2008) estimated extraction in Cameroon to occur at a rate of less than one tree per hectare in 2006. Such changes are challenging to accurately monitor over broad areas and across decades. Degradation monitoring is of high importance and concern for FSC certification as well as for protected areas but for it to be accurate at a country scale necessitates ancillary validation data for coarser imagery like Landsat (e.g., a selective logging dataset constructed by Matricardi et al. (2005) for Matto Grosso in Brazil) or high-quality imagery with higher spatial resolution and temporal frequency to avoid clouds in the tropics, such as 5-m RapidEye (e.g. Pfeifer et al., 2016). These newer satellites show promise for broad scale degradation mapping now and into the future. Thus, while datasets such as Hansen et al. (2013) currently offer the great strengths of global coverage, cost-efficiency and reliability for trends in deforestation, they do not reveal the subtler forest canopy changes due to selective logging (Bustamante et al., 2015). There would be value in doing extended or complementary tests of the effects from concessions – certified and uncertified – using field measures of forest degradation or surveys of the richness and abundance of wildlife populations.

At the scale of the concession, additional information could improve controls and thereby possibly reduce biases within impacts estimates. We would recommend that FSC and other certification bodies require further information collection as part of improving their certification and auditing processes – although we must acknowledge that a lack of parallel increases in information for the uncertified concessions would limit the gains. For example, geospatial data for the boundaries of the annual allowable cuts, which are subdivisions of the concessions designated for harvest in a specific year, and for the logging roads would complement future studies to evaluate management decisions, forest cover loss, and forest degradation at a finer scale. We should note that FSC, to their credit, has begun to post some audit reports online (https://info.fsc.org/certificate.php).

Our result of minimal avoidance of forest loss to date due to FSC certification also could derive in part from the time frame of our study. The earliest certifications within Cameroon began in 2005. Thus, we observe at most eight years of post-certification outcomes. For a temporal perspective, logging companies in Cameroon utilize a 30-year rotation cycle (Cerutti et al., 2015). More complete evaluations of FSC or generally private companies' forest management and extraction rights will require careful repeated evaluations over longer time intervals to assess long-term effects.

We look forward to more evaluations of FSC certification and other forest-management policies in varied contexts. Our analyses provide the best possible estimates at this time, for Cameroon, of the avoided forest loss that should be attributed to particular forest interventions during our period of study. The methods that we presented above go beyond the historically conventional approach of cross-sectional analyses to assess the impacts from forest interventions using panel data regressions which, critically, remove effects from purely temporal and spatial differences. Our analyses rule out any large effects of FSC certification upon forest loss rates in Cameroon from 2000 to 2013, while also highlighting that concession impacts in higher pressure regions may lay a foundation for FSC impact in the future. Over time, data type and availability should improve to allow for assessing the subtler forest impacts of these policies, the results of which will in turn contribute to improved strategies to address both economic goals and conservation.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2018.09.013.

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