EVALUATING THE IMPACT OF FOREST STEWARDSHIP COUNCIL CERTIFICATION ON FOREST LOSS RATES IN CAMEROON’S LOGGING CONCESSIONS

by

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EXECUTIVE SUMMARY

As deforestation continues to threaten ecosystems and human livelihoods, numerous interventions have been designed to promote sustainable futures for forests and communities around the world. Many have been implemented with some success in the tropics, particularly when governments allocate land as protected areas or as sanctioned logging concessions. One market-based incentive system was introduced by the Forest Stewardship Council (FSC), an independent, non-governmental organization founded in 1993. The voluntary certification program for forest management enables logging companies to be recognized for adherence to FSC's Principles and Standards, which provide criteria for socially-, environmentally- and economically- responsible forest management practices.

This study utilized statistical matching methods to evaluate the impact of FSC certification on forest cover in the country of Cameroon in Central Africa. The government established its forestry policy with the 1994 passage of the Forest Law, which divided the land into the permanent forest estate (PFE) and the non-permanent forest estate. The government permits natural resource use within the PFE and requires the maintenance of natural land cover for perpetuity. Logging occurs in most of the 114 forest management units, which are parcels of land classified as part of the PFE and are located in five administrative regions in the southern portion of the country. Cameroon became involved with FSC in 1998, with the first forest management certificate awarded in 2005.

This study addresses the question: How does the FSC Forest Management certificate impact forest cover in Cameroon's forestry concessions? We hypothesized that compared to non-certified concessions, the FSC-certified logging concessions will exhibit a lower rate of conversion from forest to non-forest. Managed using ArcMap 10.2.2, geospatial data were collected for seven covariates: biophysical and accessibility characteristics found in the literature to be correlated with deforestation. The source for the outcome variable was the Global Forest Change dataset from Hansen et al. (2013a) containing tree cover data for a baseline year of 2000 and annual forest loss for each subsequent year through 2012. For this study, forest was defined as land area with tree cover of 50% or more. Random sample points were drawn at a density of approximately one per square-km. The values for the covariates and the response variable were extracted to each point, as well as the concession status and certification status were also attributed to each sample point.

Two statistical matching methods, conducted using the statistical software Stata 14 (StataCorp, 2015), provide a robust comparison between FSC-certified concessions and non-certified concessions. Because FSC-certification is a voluntary process, the treatment of FSC-certification was not randomly assigned to forest management units, and thus it is crucial to estimate the impacts after controlling for the relevant covariates, which influence the outcome of forest loss. In doing so, we reduce bias and produce a higher-quality comparison. The first approach was nearest-neighbor propensity-score matching. FSC-certified and non-certified points are matched on the basis of similar probabilities of becoming FSC-certified, given the effects of the covariates. The post-matching ordinary least squares regression model yields coefficients that indicate the average treatment effect on the treated (ATT). The second technique was a nearest-neighbors covariate matching estimator. In this approach matches are based on similarity measured in covariate space as Mahalonobis distances between FSC-certified and non-certified points.

Rarely in this study were we able to reject the null hypothesis that FSC certification has no impact on forest loss. For the study area overall, the post-propensity score matching OLS regression found that on average FSC certification significantly reduces the probability of forest loss by less than 1%. While matching methods have the potential of finding similar matches between treatment and control sample points, there is not a guarantee that the best match will be found. The validity of the estimated effects depends on the quality of the matches. Continued investigation into how to find the "most similar" match is crucial to improving the construction of impact evaluation studies. One approach to improvement is the application of calipers to restrict range of acceptable similarities the potential matches. A second improvement to future FSC impact evaluations is the incorporation of characteristics of the logging company to be found in forest management plans, such as harvest technique, volume harvested, and size of the company.

Due to the relative novelty of FSC-certification in Cameroon, our results call for repeated impact evaluations at meaningful time-intervals in order to assess the long-term effects of FSC-certification. The issue year of certification was not included in the approaches included in this study; therefore, subsequent research should analyze the temporal trend of forest loss in order to appropriately attribute forest loss to activity before or after certification was achieved. Overall, we believe the statistical matching methods can provide a robust comparison that controls for influential factors, and the approaches used in this study can be adapted for FSC impact evaluation in other countries.

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1.0 INTRODUCTION

1.1 Background

As the world human population continues to grow exponentially, the demand for both forest products and forest conversion increases in tandem. Deforestation in the tropics is occurring at an alarming rate for export-oriented industrialized agriculture to meet the demands of urban society (DeFries et al., 2010). The numerous consequences of deforestation include increased erosion and the degradation of water resources, higher turnover rates of trees in forest fragments, as well as the acceleration of species extinction (Laurance et al., 1998; Laurance, 2009; Wright and Muller-Landau, 2006).

Various policy interventions have been designed to promote sustainable futures for forests and communities around the globe. Many have been implemented with some success in the tropics, particularly when governments allocate land as protected areas or as sanctioned logging concessions (Joppa and Pfaff, 2011). Andam et al. (2008) found that 10% of lands under protection in Costa Rica would have been deforested had they not been protected. The titling of lands for indigenous peoples by the government of Peru also effectively protects forest area from clear-cutting (Oliveira et al., 2007). Furthermore, reduced frequency of fire events, which tend to be anthropogenically ignited, was determined by Nepstad et al. (2006) to be an additional benefit of protecting lands from deforestation in the Brazilian Amazon.

Aside from conventional environmental regulation, a number of market-based incentive strategies encourage better business practices. Consumer demand for environmentally-responsible products is on the rise, and companies that commit to organic or sustainable practices can designate their products as such with “eco-labels” and charge higher prices (International Institute for Environment and Development, 2014). Thus, voluntary participation in certification programs that employ sustainable forest management (SFM) practices has the potential to ease market access and provide businesses with a price premium for their timber (Auld et al., 2008). The concept of SFM aims at halting deforestation, while finding a middle ground between conservation and human use of the natural resources (Auld et al., 2008). Among SFM certification programs, one of the most recognizable are those of the Forest Stewardship Council.

1.2 Forest Stewardship Council

The Forest Stewardship Council (FSC), founded in 1993, is an independent, not-for-profit, non-governmental organization that aims to "promote environmentally appropriate, socially beneficial, and economically viable management of the world's forests" (FSC, 2015a). Through the certification system, FSC envisions a world in which the "forests meet the social, ecological, and economic rights and needs of the present generation without compromising those of future generations" (FSC, 2015a). The FSC certification system operates as a voluntary market-based incentive system to achieve responsible forest resource use, and is acknowledged as the "most rigorous, transparent and participatory certification" (Hale & Held, 2011). As importing countries such as the United States and those within the European Union impose more stringent regulations on the legality of goods and timber, voluntary certification provides one way for companies to increase their access to international markets (Auld et al. 2008).

Prior to the pursuit of certification, a logging company is required to be fully compliant with all applicable national and local laws. Third-party auditing companies ensure that the logging company is compliant with a strict set of FSC principles and critieria, and is responsible for pre-certification audits as well as annual audits after certification is achieved (FSC, 2015b). When a company is found to be non-compliant, a corrective action request (CAR) may be issued; multiple CARs will result in a suspension, or if the offense is sufficiently egregious, the company risks termination of its certificate (N. Sonne, personal communication, June 1, 2014).

Timber suppliers have the potential to earn three types of certification: 1) Forest Management, 2) Chain of Custody, and 3) Controlled Wood. This study focused on the forest management certificate because it directly affects the harvest strategies and thereby the forest ecosystem. For example, to minimize the adverse impacts of forestry activity, one standard of the certificate stipulates that "[the] areas scheduled for conversion […] total less than 5% of the total area of the FMU and shall enable clear, substantial, additional, secure, long-term conservation benefits across the forest management unit" (FSC-Cameroon, 2010).

By the end of 2014, a total of 1,303 FSC certificates were active across the globe, covering 183 million ha of forest (FSC, 2014). With such a large quantity of land now under certification, the FSC has great potential to promote environmentally-, economically- and socially- acceptable forestry practices worldwide. Approximately one quarter of certificates is for forest lands in the tropical and subtropical zones (FSC, 2014). Certification programs such as FSC were designed to promote responsible practices and transparency; however the ability of certification to produce a verifiable, beneficial impact on forests is the subject of much debate, as the level of compliance, auditing and enforcement, and measurable outcomes can range widely (Counsell & Loraas, 2002; Nebel et al., 2005).

Non-profit organizations are under increasing pressure from both consumers and funders to demonstrate and measure the success of their interventions, and this desire to demonstrate impacts is true for FSC (Sawhill & Williamson, 2001; FSC, 2010). Many of the aforementioned comparative studies on the effects of protecting land from deforestation employed statistical matching methods, which help to control for variables that predispose a unit for the outcome when the policy is not applied in a random manner. The goal is to demonstrate that between the treatment and control observations, the differences in the outcome variable, in this case forest loss, are caused specifically by the treatment, FSC certification. In a review of effective management studies in the Amazon, Nolte and Agrawal (2013) concluded that, if very carefully designed, the matching technique does indeed produce accurate results describing the effects of the intervention. Therefore, in this study we used statistical matching methods in order to evaluate the impact of FSC certification on forest cover within logging concessions.

1.3.1 Introduction to Cameroon

The Republic of Cameroon is located on the coast of Central Africa, bordering such countries as Equatorial Guinea, Gabon and Nigeria (Figure 1). The population of Cameroon is 21.7 million, with the capital city of Yaoundé, home to 1,739,000 people (Central Intelligence Agency, 2014). The economy of Cameroon is primarily based on a modest supply of oil and agriculture. In the coming years the government of Cameroon desires to increase economic opportunities by expanding the mining industry for diamonds, gold and iron (Schwartz, Hoyle & Nguiffo, 2012). China is the primary export partner to Cameroon, followed by the Netherlands and Spain; timber is a major item among Cameroon's exported goods, in addition to crude oil and petroleum products, cocoa beans, and cotton (Central Intelligence Agency, 2014). The city of Douala is a major port for exportation of goods, with about 90% of exported wood exiting the country via Douala (Eba'a Atyi, 1998).

Development and economic growth are progressing, with aid from the International Monetary Fund and the World Bank (World Bank, 2014). Unfortunately, the business atmosphere in Cameroon is not attractive to foreign investment, due to the slowness of the economic progress, which has been attributed to weak governance, coupled with a high amount of corruption (ranked 144th out of 177 countries) (World Bank, 2014; Transparency International, 2013).

1.3.2 The Forestry Sector in Cameroon

Cameroon has established its progressiveness in forestry policy with the establishment of the Ministry of Environment and Forests (MINEF) in 1992, which is now the Ministry of Forests and Fauna (MINFOF), and the passage of the Forest Law in 1994 (Cerutti et al., 2008). With the passage of the Forestry Law of 1994, the government of Cameroon divided the land into two broad land use types, the permanent forest estate and the non-permanent forest estate, which are further divided into numerous categories of land use and land tenure (Cerutti et al., 2008). The government permits natural resource use within the permanent forest estate (PFE) but requires that it must maintain natural ecosystem cover for perpetuity (WRI, 2012). The government set a target for 30% of total land area to be under the permanent forest estate; the target was surpassed to 35% when PFE land area totaled 16.3 million ha in 2011 (WRI, 2012). Of the PFE land area, 55% is designated as production forest and the remaining 45% is protected area (WRI, 2012). Within Cameroon's permanent forest estate, 5.5 million ha of land area are designated for logging within 103 of the 114 forest management units, which are located in five regions in the southern portion of the country (Figure 2, Table 4).

Major importers of timber have set regulations targeted towards limiting the importation of illegal timber. The United States passed the Lacey Act in 1900 to promote conservation of plants and animals; an amendment in the Farm Bill of 2008 specified that timber also requires legal sourcing for importation (Rainforest Alliance, 2015). Similar and more detailed mandates exist in the European Union for companies that import timber. European Union Timber Regulations (EUTR) in 2008 and formally adopted in 2012 (Rainforest Alliance, 2015). The EUTR were an addition to the Forest Law Enforcement, Governance and Trade (FLEGT) action plan of 2003, in which the goal is sustainable forest management, via the prevention of illegal timber importation, the improvement of the supply of legal timber, and the increase in demand for responsibly-sourced timber (European Forest Institute, 2014).

Following suit, legality certification is sought by many timber suppliers. Countries can develop Voluntary Partnership Agreements (VPA) with the EU to ensure legal sourcing of timber. Cameroon commenced negotiations for a VPA in November 2007, and an agreement was reached in 2010 (European Forest Institute, 2014). At present, Cameroon is in the implementation phase and will eventually begin issuing FLEGT licenses (European Forest Institute, 2014). Independent of FLEGT, two verification bodies provide certificates for legally harvested wood: the Bureau Veritas issues the Origine Légale des Bois (OLB), and the Société Générale de Surveillance (SGS) issues Timber Legality and Traceability Verification (TLTV) certificates (Eba'a-Atyi, 2009). After establishing legality of operation, a logging company may choose to pursue responsible forest management certification from FSC.

While the government of Cameroon has demonstrated some success towards its ambitious forestry policy, illegal logging continues in Cameroon. Illegally sourced wood has previously been estimated to account for 50% of total harvest, and the government has enabled harvesting at unsustainable rates without approved management plans, despite the legal framework that opposes such activity (Cerutti & Tacconi, 2006). Overall, the United Nations' Food and Agriculture Organization (FAO, 2010) estimated the loss of forest in Cameroon to be increasing to an annual loss rate of 1.07% in the 2005-2010 period.

As mentioned previously, the government of Cameroon intends to expand the mining industry for economic growth, leading to emerging land tenure issues as a result of overlapping permit areas for forest management units and mining zones (Schwartz, Hoyle & Nguiffo, 2012). At present, there are no legal provisions for areas of mixed land use, and the onus falls on the two companies to work out agreements of facilities, transportation, and land management (D. Halleson, personal communication, February 16, 2015). Similarly, FSC currently lacks provisions for incorporating mining exploration projects into audits, and therefore the auditing companies for FSC in Cameroon must develop their own method of taking into account the mining activities (D. Halleson, personal communication, February 16 2015).

1.3.3 FSC in Cameroon

The Congo Basin's first license was awarded in the country of Gabon to the company Leroy Gabon in 1996, but the license's validity was questioned and it was withdrawn within the year, resulting in decreased interest among other companies to partake in certification (Cashore et al., 2006). Nonetheless, Cameroon became involved with FSC in 1998, via the Cameroon Forest Certification Initiative (FSC-Cameroon, 2010). The country's first forest management certificate was awarded in 2005 to the company Wijma (FSC, 2014). More certifications were awarded in 2007, 2008 and 2010, and the certificates issued in 2013 brought Cameroon's total certified area above 1 million ha (Global Forest Trade Network, 2014) (Table 2).

Non-governmental organizations partner with logging companies to provide strategic and technical assistance during the pursuit of FSC certification. The Global Forest Trade Network (GFTN), a division of the World Wildlife Fund, assists many timber companies to achieve certification with FSC by providing legal compliance training and by proxy of local NGOs by increasing their community-based capacity to monitor logging and mining activities and to also assist the timber companies (Global Forest Trade Network, 2014). An estimated 20-25% of Cameroon's logging area, including FSC-certified and non-certified areas, is managed with assistance from GFTN (N. Sonne, personal communication, June 11, 2014).

1.4 Study Question

This study addresses the question: How does the FSC forest management certificate impact forest cover in Cameroon's forestry concessions? The research draws comparisons between non-certified and certified forestry management units in terms of forest loss. Because FSC's principles and criteria were designed to implement management practices that surpass national requirements, we hypothesize that compared to those without certification, the FSC-certified forestry management units will exhibit a lower rate of conversion from forest to non-forest during the study period from 2000 to 2012.

2.0 METHODS

2.1.1 FSC Certificates in Cameroon

This study focused on the forest management units that ever were operated with a FSC forest management certificate during the period from 2000 to 2012. As of May 2013, five active FSC forest management certificates were held by logging companies, most of which operated multiple forest management units under one certificate (Table 2). In Cameroon the total forest area under FSC-certified forest management exceeded 1 million ha in 2013 (FSC, 2013). All certified and non-certified forest management units lie within five of the administrative regions of Cameroon that comprise the study area: South, Southwest, Littoral, Center and East.

2.2 Predictor and Response Variables

For the statistical analysis, geospatial data for seven predictor variables, or covariates, and one response variable were compiled into a geodatabase. The data were collected from the various sources listed below, and the projections and cell size were harmonized in the geodatabase using ArcMap 10.2.2 (ESRI, 2014).

First, the response variable was a binary indicator of forest loss, with a value of 1 indicating the occurrence of loss within the study period from 2001 to 2012, and a value of zero indicating no change compared to the baseline year of 2000, according to the Global Forest Change dataset from Hansen et al. (2013a). The dataset, a product of Landsat 5 TM and Landsat 7 ETM+ imagery, has a resolution of 30-m. Using the dataset's raster layer for percent tree cover data in the year 2000, we classify pixels as forest where tree cover was at least 50%, emulating the definition used in some analyses by Hansen et al. (2013b).

We selected predictor variables that have been shown to influence the likelihood of deforestation (Andam et al., 2008; Joppa & Pfaff, 2010). Three accessibility variables were included as metrics of the ease with which humans can access forests to harvest timber. Also, transportation costs constitute 70-85% of the total cost of operation (P. Cerutti, personal communication, July 1, 2014); therefore short distances to processing plants and markets are beneficial to the company. The following three accessibility variables were derived from layers in the Forest Atlas of Cameroon, produced by the World Resources Institute (2014).

- *Distance to nearest road (km)* – In Cameroon, logging companies transport their timber entirely via roads (P. Cerutti, personal communication, July 1, 2014).
- *Distance to nearest city (km)* – Previous studies showed that deforestation is related to proximity to agricultural markets, which are located in cities (Andam et al., 2008).
- *Distance to nearest processing plant (km)* – Most concessions process their wood in saw mills inside the concessions (P. Cerutti, personal communication, July 1, 2014).

We incorporated four biophysical characteristics that influence the suitability of land for alternative uses such as agriculture, thereby affecting the probability of forest conversion.

- *Elevation (m)* – The digital elevation model from NASA's Shuttle Radar Topography Mission is available for the globe from CGIAR-CSI (Jarvis et al., 2008).

- *Slope (degrees)* – Slope was derived in ArcGIS from the digital elevation model. Slope contributes to the suitability of land for other uses such as agriculture, which is a driver of forest conversion (Andam et al., 2008).
- *Temperature (°C)* – Current conditions (interpolations of observed data, representative of 1950-2000) from WorldClim.org (Hijmans et al., 2005).
- *Precipitation (mm)* – Current conditions (interpolations of observed data, representative of 1950-2000) from WorldClim.org (Hijmans et al., 2005).

Finally, locational variables were added to the core set of variables, in order to incorporate regional variation and to disaggregate the statistical results by region. Also, the designation of land for other use types was indicated with a separate binary variable for each.

- Administrative regions from the 2014 version of the Forest Atlas (World Resources Institute, unpublished): Littoral, Center, South, East, and Southwest.
- Other land use types from the 2014 version of the Forest Atlas (World Resources Institute, unpublished): Protected areas, mining permit areas, council forest, community forest, reserve forest, agriculture, and hunting areas.

2.3 Summarizing the Context Using Random Points

In order to understand the general context and trends of forest change in Cameroon, we surveyed the study region with random points distributed at a density of approximately one point per square-km. The values for the covariates, the response variable, and locational indicators were extracted for each point. We used 169,104 sample points to compile the summary statistics. For the two probit regression models we conducted, the resulting coefficients indicate the effect of each covariate on: 1) the probability of a forested sample point falling inside a concession, and 2) the probability of FSC certification to occur on a forested point in a concession. Finally a simple t-test compares the amount of forest loss between the FSC-certified and non-certified sample points.

2.4 Statistical Matching Analysis

Two statistical matching methods were conducted using the statistical software Stata 14 (StataCorp, 2015), provide a more robust comparison between FSC-certified concessions and non-certified concessions. Because FSC-certification is a voluntary process, the treatment of

FSC-certification was not randomly assigned to forest management units, and thus it is crucial to estimate the impacts after controlling for the relevant covariates, which influence the outcome of forest loss. In doing so, we reduce bias and produce a higher-quality comparison; however, a residual amount of imperfection will exist due to the influence of unobservable factors (Robalino & Pfaff, 2013).

The first approach was nearest-neighbor propensity-score matching (Robalino & Pfaff, 2013). This technique requires a treated observation and a control observation to be matched on the basis of similar propensity scores. A propensity score is the predicted probability of a point receiving the treatment, given characteristics we included as covariates. We used one-to-one matching between FSC-certified and non-certified points, with replacement, making it possible for one control point to be selected as the best match for multiple treated points. The post-matching OLS regression model yields coefficients that indicate the average treatment effect on the treated (ATT). The standard errors cannot be used to infer statistical significance of the results, as the values do not take into account that matching has occurred.

The second technique used was a nearest-neighbors covariate matching estimator (Abadie and Imbens, 2006). In this approach similarity is measured in covariate space as Mahalonobis distances between treated and control points.

The two approaches to matching were conducted including the entire set of predictor variables. Calipers, which limit the pool of potential matches by restricting the allowable amount of difference between points, were not used in either approach. We noticed strong correlations exist covariates; most notably, elevation strongly correlates with temperature and with precipitation. A second version of the matching methods was conducted using a subset of the predictor variables, while also restricting the analysis to the three administrative regions which were allowable for matching: Littoral, South and East.

3.0 RESULTS

3.1 Descriptive statistics

In Cameroon, we have a random sample of 169,104 points that fall in five regions that comprise the study area: South, Southwest, Littoral, Center, and East. For the year 2000, the proportion of concession area under forest cover was similarly high across the five regions, and was more variable and lower outside the boundaries of concessions (Table 3). This result reflects the fact that logging concessions are delineated in forested areas.

Probability of concession

The probit model that we used to explore what factors affect the probability of a forest being inside a concession (Table 5) showed that all the marginal effects at the means are close to zero, and for the whole study area and the effects of all covariates are statistically significant ($p<0.01$). A 10-degree increase in slope, on average, raises the probability of a forest point falling inside a concession by 2.0%. Also, a 1 km increase in distance to the nearest city raises the probability by 1.9%, on average. In contrast, all other biophysical and accessibility variables have a negative effect on the forest location being within a concession. For instance, forests at lower elevations with lower mean annual precipitation and mean temperature have a higher probability of being inside a concession. A 100 m increase in elevation decreases the probability by 7.1%, on average.

When the analysis is disaggregated by region, the direction of influence by some coefficients is opposite of that found in the analysis for the whole study area. For example, in the Littoral region, as slope increases, the probability of a forested location being inside a concession decreases, whereas the opposite is true for all other regions and for the aggregate study area. In Cameroon roads are the primary mode of transportation for logs (P. Cerutti, personal communication, July 1, 2014); accordingly, the probability of a forest location falling in a concession decreases by 1.5% for every 1 km increase in distance to the nearest road, on average. We observe that on average a higher distance to processing plants corresponds to a lower probability of a forest point falling inside a concession ($p<0.01$); the opposite effect is true for the Center and East regions.

Probability of FSC certification

The results of the second probit regression model describe how the covariates affect the probability of a forest being certified by FSC (Table 6). We restricted the analysis to points that fell inside logging concessions. For the study area overall, we found that all biophysical and accessibility characteristics were statistically significant ($p<0.01$).

These trends change in the regional analysis. None of the variables were significant at the 5% significance level in the Littoral and Center regions. These results possibly reflect the small sample size of points due to the occurrence of only one FSC-certified concession that is shared by the Littoral and Center regions.

We found significance ($p<0.01$) for all coefficients in the South, Southwest, and East regions. On average, elevation, slope, and temperature tend to have a negative effect on the probability of a forested concession point being under FSC certification. A 100 m increase in elevation lowers the probability by 5.9% on average. Increasing the distance to the nearest road decreases the probability by 15.7% of being under certification in the study area overall, but the opposite effect is true in the Southwest region.

3.2 Statistical matching using all predictor variables

OLS regressions

In the first OLS regression model, the binary variable for forest loss was regressed on the covariates, using the forested sample points across the study area that fall both inside and outside logging concessions. The resulting values for the average treatment effect on the treated (ATT) describe how FSC certification affects the probability of forest loss, as opposed to any area that was not under FSC certification (Table 7).

The coefficients resulting from the OLS regression indicate that on average, FSC certification reduced the probability of forest loss by 0.27% in the study region ($p<0.05$) over the twelve-year study period. At the 1% significance level, the probability of forest loss was influenced by all other covariates, with the exception of distance to cities.

When the forest loss variable was regressed separately for each region in the study area, we observe variation in the magnitude and statistical significance of the covariates on the probability of forest loss. In four of the five regions in the study, we find that FSC certification reduced the probability of forest loss by 0.27% but was not statistically significant. In contrast, in the Littoral region, the ATT is larger and positive; FSC certification increased the probability of deforestation by 6.9% ($p<0.01$). The coefficient for concession status is negative and statistically significant at the 1% level, both for the overall study area and for each individual region. For the study area, concession status reduced the probability of deforestation by nearly 1.4% ($p<0.05$).

An increase in distance to roads reduced the probability of forest loss, as did an increase in distance to processing plants, although in the analysis by region the direction of the effect was negative in Littoral and Center regions and positive in South, Southwest and East regions.

The second OLS model restricted the sample points to those located in areas that were ever designated to be logging concessions (Table 8). This approach yielded different results, with FSC certification reducing the likelihood of forest loss by 0.19% at the 1% significance level for the study region as a whole. However, in the regional analysis FSC certification was not found to be significant, but had a negative effect in all regions except for the Littoral, where the FSC certification increased probability of forest loss by 3.6%.

Sample points that are located where logging concessions intersect other land use types lacked a statistically significant difference in probability of forest loss. In the regional analyses, we find only two cases where the effect is statistically significant at the 1% level. First in the Southwest region, points located where logging concessions and mining concessions intersect exhibit a 1.7% increased probability of forest loss. Second in the Center region, we find that community forest reserve is increases by 3.3% the probability of forest loss.

Propensity Score Matching

After PSM the OLS regression for 21,363 matched points improved the covariate balance between the treatment and control groups, i.e. the average value for each covariate became more similar between the treatment and control groups as a result of the matching process. The matching analysis could not be done for the Southwest and Center regions because the random point sampling method failed to capture any of the forest loss pixels.

We find that for the study region, FSC certification reduced by 0.2% the likelihood of forest loss, at the 5% significance level, however the estimated coefficient was not significant for any of the regions (Table 9). Also the effect was positive in the Littoral region, but negative in the South and East regions. None of the biophysical indicators were found to be statistically significant.

In the regional analyses, we observe a number of instances where the algorithm in Stata omitted covariates due to collinearity and due to perfect prediction of the outcome. For the study area, all accessibility variables (distance to roads, distance to cities and distance to processing plants) negatively influence the probability of forest loss, but only distance to roads was statistically significant at the 5% level. In the regional analyses the accessibility variables were not found to be statistically significant.

Nearest Neighbor Covariate Matching

Lastly, the approach of nearest neighbor covariate matching was used to estimate the impact of FSC on the probability of deforestation. We found the (ATT) for the study area to be positive and but not statistically significant, which contrasts the statistical significance of negative effects found in the pre- and post- PSM OLS regressions (Table 10). In the regional analyses, the ATTs for all three were not significant. The effect was positive for the Littoral region, indicating a 0.5% increase in probability of forest loss. We found negative effects of FSC certification on forest loss in the South and East regions. In general we observe that the influence of FSC on the probability of forest loss is small and not statistically significant.

Comparing the different approaches for the whole study area, we find the largest magnitude of estimated effect in the post-PSM OLS regression, with FSC significantly reducing the probability of forest loss by 0.2%. The ATT for covariate matching, besides being positive instead of negative like the other estimates, has the smallest magnitude, increasing probability of forest loss by 0.02% although this effect is not statistically significant.

3.3 Statistical matching using a subset of predictor variables

In the previous matching analysis, two of the five regions, Southwest and Center, were omitted by the Stata algorithm. A second matching analysis restricts the sample points to the three regions that remained: Littoral, South, and East. Also, a smaller subset of five covariates were used to predict the outcome of deforestation. Elevation shared high correlation coefficients with temperature and precipitation, respectively, and therefore temperature and precipitation were omitted. Slope remained as an indicator of suitability for other land uses. The three accessibility covariates were included: distance to roads, distance to cities and distance to processing plants.

Five approaches to estimating the effects of FSC certification on forest loss yielded varying results (Table 11). Across the three regions, the pre-matching OLS regression indicated that FSC certification reduces the probability of forest loss by 0.16% significantly at the 1%

level. In contrast, FSC certification was not statistically significant in the post-matching OLS regression, nor in the covariate matching approach. These two approaches found the estimated reduction in probability of forest loss to be 0.07% and 0.15%, respectively. Again, in general after matching we observe a small and statistically insignificant effect of FSC on the probability of forest loss.

4.0 DISCUSSION

Our results suggest that the average impacts of FSC certification on forest loss are very small. This is true without applying statistical matching as well as using two different matching techniques. Rarely in this study were we able to reject the null hypothesis that FSC certification has no impact on forest loss. To provide a thorough and more accurate result, future research must take into account the issue year of certification. The issue year was not included in this study, but it is critical that an analysis of the temporal trend of forest loss enables the appropriate attribution of forest loss to activity before or after certification was achieved.

While matching methods have the potential of finding similar matches between treatment and control sample points, there is no guarantee that the best match will be found. The validity of the estimated effects depends on the quality of the matches. The lack of statistical significance in the regional analyses may be due to the residual need to improve the balance between treatment and control groups. Continued investigation into how to find the "most similar" match is crucial to improving the construction of impact evaluation studies. The covariates can improve the robustness of the comparison when an adequate amount of accurate, relevant information is supplied by the selected characteristic. One approach to improvement is the application of calipers to restrict range of acceptable similarities the potential matches. A second improvement to future FSC impact evaluation is the incorporation of characteristics of the logging company found in the forest management plans, such as harvest technique, volume harvested, and size of the company. For any additional covariates, the information must be as complete as possible in order for the quality of the matches to actually improve by their inclusion.

Furthermore, the observed difference between treated and control points could reflect the fact that deforestation rates were already very low in the country overall, and thus the additional application of FSC principles and standards has low potential for resulting in additionality. The small observed difference is also influenced by the small extent of the study period. Given that many of the certificates under study were first issued in the mid-2000's, the effect we are estimating is the short-term effect. To emphasize, the logging companies in Cameroon utilize a 30-year rotation cycle, more than double the length of our study period. Impact evaluations should be conducted continually, with meaningful time intervals such that the long-term effects of certification may be understood.

A potential source of uncertainty in the results is the Global Forest Change data, which, although quite reliable across the globe, has received criticism for the "lack of differentiation between forest cover types" (Tropek et al., 2014). An error of commission may result, where a pixel is still classified by the algorithm as forest, whether it is primary forest or a palm oil plantation. Also, forest loss does not necessarily equate with deforestation, as Hansen et al. (2013b) emphasize in explaining the utility of their data; natural forests as well as managed forestry have a continual dynamic of both loss and gain, which is important to take into account. While Hansen et al. (2013a) provide a data layer for forest gain, this layer could not yet be used as a reliable indicator of actual forest gains, as it contains errors of commission which would lead to an underestimation of net forest loss (Tropek et al., 2014). Lastly, in the Global Forest Change data, it is not possible to attribute a particular cause to observed forest loss. The data derived from remotely sensed imagery indicates its occurrence, yet technicians monitoring change on the ground monitoring are necessary to explain why.

While the effects of FSC certification on forest loss are estimated to be very small, the certification has the potential to have an impact on the more subtle process of degradation. The Landsat imagery, from which the Global Forest Change dataset is derived, provides information for whole-pixel classification for forest loss. However, human disturbance operates in a broad range of scales, including scales finer than the 30-m resolution of Landsat imagery. In the context of tropical forests, the subtle canopy changes due to selective logging, which in Cameroon was estimated to extract less than one tree per ha in 2006 (Cerutti, Nasi & Tacconi, 2008), are difficult to detect with 30-m resolution imagery. Therefore, future studies could investigate the effects of FSC on the process of forest degradation, potentially by using sub-pixel analysis of satellite imagery such as spectral unmixing.

5.0 CONCLUSIONS

An increasing percentage of Cameroon's 5.5 million ha of forest management units is operated under the principles and standards established by the FSC. Due to the relative novelty of FSC-certification in Cameroon, our results call for repeated impact evaluations at meaningful time-intervals in order to assess the long-term effects of FSC-certification. The issue year of certification was not included in the approaches included in this study; therefore, subsequent research should analyze the temporal trend of forest loss in order to appropriately attribute forest loss to activity before or after certification was achieved. Overall, we believe the statistical matching methods can provide a robust comparison that controls for influential factors, and the approaches used in this study can be adapted for FSC impact evaluation in other countries.

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8.0 TABLES AND FIGURES

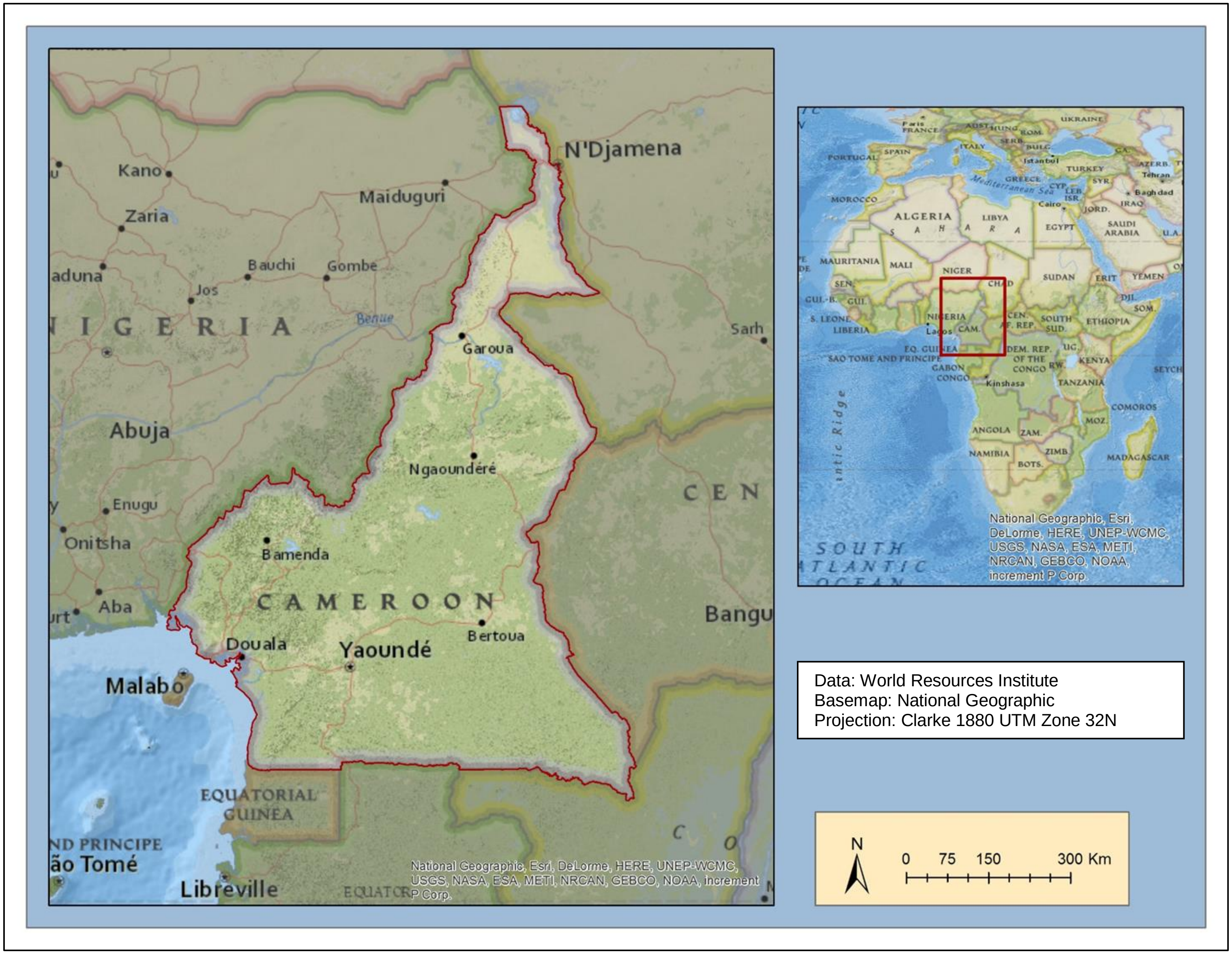

Figure 1. Map of Cameroon's location in Central Africa, neighboring Nigeria, Equatorial Guinea, Gabon, and other countries.

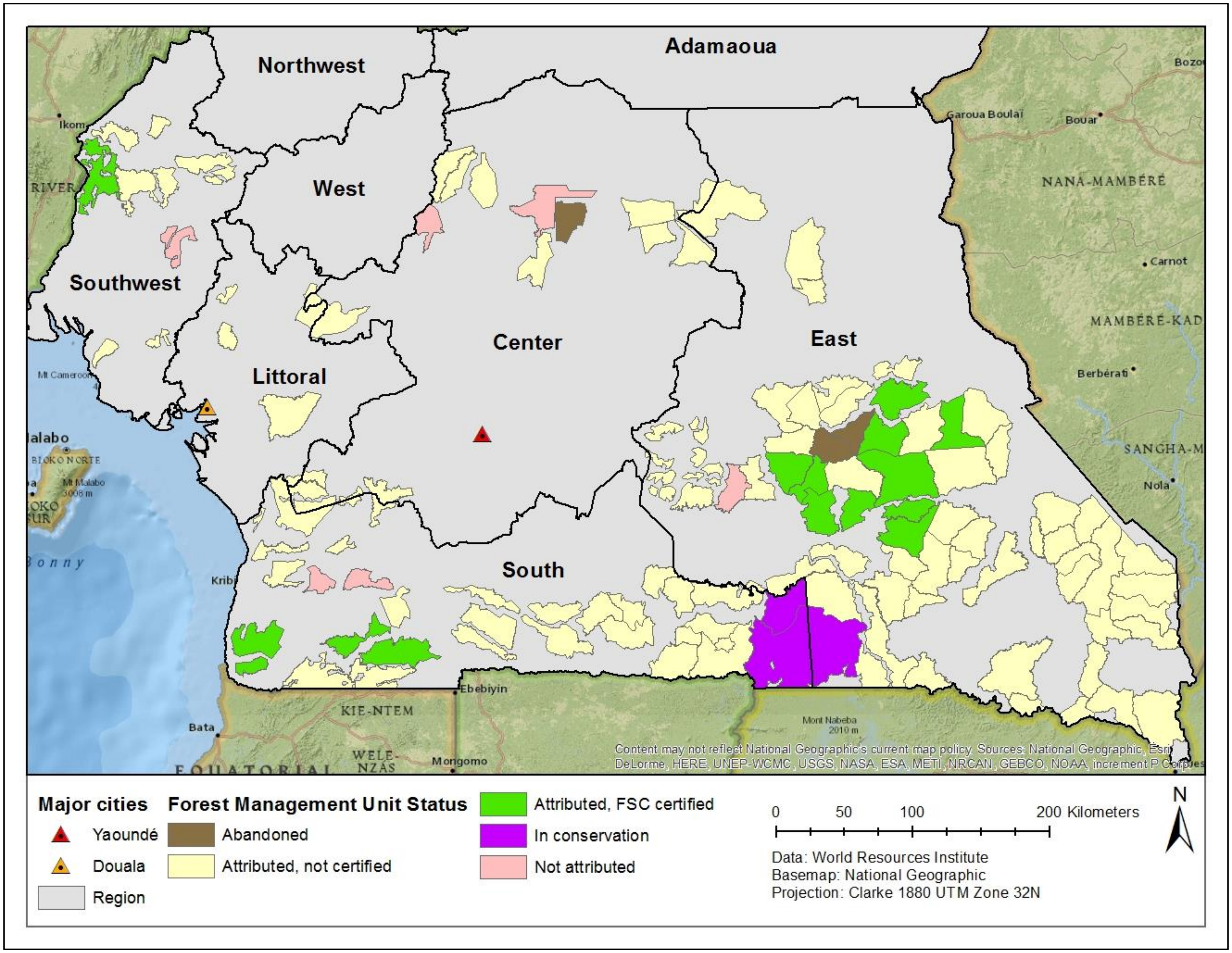

Figure 2. Locations of forest management units, with the status as of 2014, in the southern portion of Cameroon.

Table 1. Cameroon's partners in trade, as estimated in the year 2012 (Central Intelligence Agency, 2014).

Export Partners	**Percent of total (in 2012)**	**Import Partners**	**Percent of total (in 2012)**
China	15.2%	China	18.7%
Netherlands	9.7%	France	14.9%
Spain	9.1%	Nigeria	12.3%
India	8.6%	Belgium	5.2%
Portugal	8.1%	United States	4.4%
Italy	6%	India	4.2%
United States	5.5%		
France	4%		

Table 2. FSC Forest management certificates in Cameroon that were ever active during study period from 2000 to 2012 (FSC, 2013).

Company	License	First Issue Date	End Date
TRC	FSC-C005014	2008	2013*
Wijma	FSC-C007738	2005	Still active
Pallisco, Assene Nkou, SODETRANCAM	FSC-C021687	2008	Still active
SFIL	FSC-C041197	2010	Still active
CAFECO	FSC-C074328	2010	Still active

*Certificate was terminated in 2013

Table 3. Proportion of forests inside and outside concessions in the baseline year of 2000, and the number of forest management units per region.

Region	Ever concessions during the period 2000-2012		Never concessions during the period 2000-2012		Total N
	%	N	%	N	
Southwest	99.45%	2,349	87.41%	13,436	15,785
Littoral	95.97%	1,073	83.12%	10,905	11,978
Center	89.85%	4,533	74.41%	33,346	37,879
South	99.88%	12,193	99.03%	21,743	33,936
East	99.93%	30,013	80.51%	39,513	69,526
All	98.80%	50,161	82.41%	118,943	169,104

Table 4. The number of forest management units per region.

Region	Number of forest management units
Southwest	8
Littoral	2
Center	9
South	28
East	63
Center/South	2
Littoral/Center	1
Littoral/Center/South	1
All	114

Table 5. A Probit model to explain where logging concessions tend to occur. The coefficients indicate each covariate's effect on the probability of a forest point to fall inside a concession. T-statistics are shown in parentheses. * p<0.05; ** p<0.01.

Concession	All	Southwest	South	Littoral	Center	East
Elevation (m)	-0.0007116	0.0000889	-0.0009742	0.0005705	0.0006066	-0.0032566
	(67.13)**	(2.67)**	(32.45)**	(17.20)**	(26.10)**	(73.88)**
Slope (degrees)	0.0020373	0.0014691	0.0023219	-0.0009263	0.0013372	0.0042727
	(6.85)**	(3.61)**	(3.39)**	(2.47)*	(3.34)**	(5.05)**
Temperature (°C)	-0.0827928	0.0601358	-0.0249720	0.1338383	0.1867939	-0.7018940
	(54.56)**	(11.82)**	(6.39)**	(23.88)**	(36.25)**	(81.15)**
Precipitation (mm)	-0.0002281	-0.0000329	-0.0005167	-0.0000608	0.0001501	-0.0004429
	(54.47)**	(2.63)**	(31.62)**	(9.26)**	(18.04)**	(14.95)**
Distance to roads (km)	-0.0153662	0.0004320	0.0174565	-0.0011039	-0.0076220	-0.0321444
	(71.86)**	(0.78)	(20.67)**	(1.69)	(20.38)**	(92.93)**
Distance to cities (km)	0.0185713	0.0008279	0.0190002	0.0082248	0.0070499	0.0187829
	(120.55)**	(1.56)	(38.22)**	(15.34)**	(20.10)**	(81.51)**
Distance to processing plants (km)	-0.0002585	-0.0033756	0.0015556	-0.0023723	0.0013794	0.0011708
	(5.26)**	(20.97)**	(10.31)**	(18.90)**	(20.63)**	(12.52)**
N	169,104	15,785	33,936	11,978	37,879	69,526

Table 6. A Probit model to explain where FSC certification tends to occur. The coefficients indicate each covariate's effect on the probability of a forested point in a concession to be FSC certified. T-statistics are shown in parentheses. * p<0.05; ** p<0.01.

FSC	All	Southwest	South	Littoral	Center	East
Elevation (m)	-0.0005906	-0.0011202	-0.0045185	0.0000059	0.0000000	-0.0005991
	(22.12)**	(6.07)**	(36.61)**	(0.43)	(0.00)	(13.40)**
Slope (degrees)	-0.0027405	-0.0032063	-0.0227592	0.0000071	0.0000000	-0.0015447
	(5.19)**	(1.75)	(15.49)**	(0.48)	(0.00)	(2.40)*
Temperature (°C)	-0.2526608	-0.1239173	-1.3146785	0.0013795	0.0000000	-0.3095682
	(57.06)**	(3.94)**	(49.27)**	(0.43)	(0.00)	(36.92)**
Precipitation (mm)	0.0003626	-0.0005086	0.0002361	-0.0000036	0.0000000	-0.0005854
	(42.38)**	(5.34)**	(7.18)**	(0.46)	(0.00)	(25.12)**
Distance to roads (km)	-0.0157170	0.0139302	-0.0258495	-0.0000440	-0.0000000	-0.0223901
	(38.74)**	(6.04)**	(26.64)**	(0.46)	(0.00)	(40.09)**
Distance to cities (km)	0.0023731	0.0373003	0.0242250	0.0000453	0.0000000	-0.0012728
	(12.05)**	(11.37)**	(34.43)**	(0.44)	(0.00)	(8.09)**
Distance to processing plants (km)	0.0016508	0.0076778	-0.0075856			0.0000328
	(19.06)**	(9.28)**	(25.64)**			(0.37)
N	50,161	2,349	12,193	1,073	4,533	30,013

Note: The coefficients show the marginal effects at the means. We excluded the variable of distance to processing plants for the models of Center and Littoral because some variables were omitted. This analysis only includes forested points that fall inside concessions.

Table 7. OLS regression explaining the probability of deforestation of forest points. T-statistics are shown in parentheses. * p<0.05; ** p<0.01.

Deforestation	All	Southwest	Littoral	Center	South	East
FSC	-0.0026925	-0.0060099	0.0696829	-0.0029676	-0.0021009	-0.0015939
	(2.34)*	(1.07)	(4.73)**	(0.44)	(0.96)	(1.40)
Concession	-0.0136185	-0.0088461	-0.0607076	-0.0108256	-0.0137835	-0.0098816
	(17.75)**	(2.82)**	(9.28)**	(4.74)**	(8.33)**	(10.77)**
Elevation (m)	-0.0000098	-0.0000299	-0.0000060	0.0000269	-0.0000061	0.0000074
	(3.28)**	(5.06)**	(0.51)	(2.25)*	(0.91)	(1.02)
Slope (degrees)	-0.0005781	-0.0002045	-0.0004258	-0.0007043	-0.0004960	-0.0000070
	(8.67)**	(1.45)	(1.50)	(3.58)**	(3.46)**	(0.05)
Temperature (°C)	-0.0013624	-0.0045725	-0.0025766	0.0049183	0.0000013	0.0003305
	(2.94)**	(5.31)**	(1.42)	(1.97)*	(0.00)	(0.24)
Precipitation (mm)	0.0000158	0.0000222	0.0000417	0.0000183	0.0000052	-0.0000063
	(10.63)**	(5.87)**	(6.68)**	(4.28)**	(1.50)	(1.21)
Distance to nearest road (km)	-0.0002721	-0.0007064	-0.0025500	-0.0000739	-0.0001572	-0.0003724
	(5.28)**	(3.51)**	(4.56)**	(0.39)	(0.91)	(7.12)**
Distance to nearest city (km)	-0.0000703	0.0003794	0.0008883	-0.0012199	-0.0001232	-0.0000767
	(1.69)	(2.13)*	(1.68)	(6.74)**	(0.97)	(1.96)
Distance to nearest processing plant (km)	-0.0000368	0.0001813	-0.0008073	-0.0001743	0.0000156	0.0000381

	(3.23)**	(3.12)**	(7.63)**	(5.23)**	(0.49)	(2.68)**
Littoral	0.0162661					
	(11.95)**					
Center	0.0167461					
	(10.04)**					
South	0.0096764					
	(6.15)**					
East	0.0156889					
	(8.78)**					
Protected area	-0.0141456	-0.0158300	-0.0264941	0.0093737	-0.0150777	-0.0074647
	(13.04)**	(5.87)**	(4.99)**	(2.15)*	(5.99)**	(5.46)**
Mining	0.0017564	0.0004646	0.0343514	-0.0007739	-0.0000183	0.0002253
	(2.90)**	(0.17)	(8.49)**	(0.42)	(0.01)	(0.31)
Council forest	-0.0138892	-0.0215444	0.0058408	-0.0115772	-0.0140242	-0.0101140
	(9.74)**	(3.32)**	(0.71)	(2.98)**	(5.08)**	(6.07)**
Community forest	-0.0047004	-0.0123657	0.0193269	-0.0084574	-0.0065043	-0.0015650
	(3.72)**	(1.77)	(2.33)*	(3.06)**	(2.37)*	(1.05)
Reserve forest	-0.0131735	-0.0031477	-0.0106809	-0.0098517	-0.0082985	-0.0105944
	(7.12)**	(0.70)	(1.71)	(1.52)	(2.43)*	(3.13)**
Agriculture	0.0634923	0.0894126	0.1176004	0.0195196	0.0542540	-0.0131540
	(25.62)**	(16.03)**	(10.56)**	(2.44)*	(15.36)**	(1.30)

Hunting	-0.0041587			-0.0044186	-0.0054321	-0.0010755
	(4.63)**			(1.57)	(2.15)*	(1.04)
Constant	0.0206851	0.0768800	0.0298912	-0.1305699	0.0145965	0.0123168
	(1.50)	(2.90)**	(0.64)	(1.89)	(0.53)	(0.30)
R^2	0.02	0.03	0.05	0.01	0.02	0.01
N	169,104	15,785	11,978	37,879	33,936	69,526

Table 8. OLS regression explaining the probability of deforestation of forest points inside forest concessions. t-statistics are shown in parentheses. * *p*<0.05; ** *p*<0.01.

Deforestation	All	Southwest	Littoral	Center	South	East
FSC	-0.0018753	-0.0021476	0.0363305	-0.0052508	-0.0009911	-0.0010696
	(3.26)**	(0.48)	(1.56)	(0.61)	(0.99)	(1.42)
Elevation (m)	-0.0000063	-0.0000404	0.0000837	0.0000283	0.0000106	-0.0000171
	(1.30)	(1.23)	(1.13)	(1.57)	(1.28)	(2.25)*
Slope (degrees)	-0.0001757	0.0003239	-0.0003653	-0.0001156	-0.0001322	-0.0001621
	(2.51)*	(1.07)	(0.65)	(0.47)	(1.32)	(1.35)
Temperature (°C)	-0.0012653	-0.0043596	0.0209647	0.0059966	0.0020183	-0.0032200
	(1.46)	(0.78)	(1.57)	(1.71)	(1.16)	(2.37)*
Precipitation (mm)	0.0000012	0.0000666	0.0000193	0.0000062	0.0000030	-0.0000188
	(0.65)	(3.65)**	(0.83)	(0.63)	(1.14)	(3.29)**
Distance to nearest road (km)	-0.0001567	0.0003488	-0.0017775	-0.0005908	0.0000527	-0.0001586
	(3.70)**	(0.79)	(1.48)	(1.84)	(0.64)	(3.01)**
Distance to nearest city (km)	-0.0000360	-0.0013269	-0.0003747	-0.0004151	-0.0000865	-0.0000319
	(1.20)	(2.01)*	(0.41)	(1.76)	(1.39)	(0.94)
Distance to nearest processing plant (km)	-0.0000224	-0.0001718	-0.0006946	-0.0000398	0.0000008	0.0000031
	(1.85)	(1.13)	(2.14)*	(0.69)	(0.03)	(0.19)
Littoral	-0.0001711					

	(0.09)					
Center	-0.0010210					
	(0.57)					
South	-0.0045990					
	(2.35)*					
East	-0.0032592					
	(1.55)					
Protected Area	-0.0021106	-0.0059033	0.0017495	0.0020362	-0.0005370	-0.0015523
	(0.64)	(0.18)	(0.02)	(0.10)	(0.10)	(0.40)
Mining	0.0008713	0.0169259	0.0099377	0.0015062	-0.0002329	0.0000466
	(1.63)	(3.86)**	(1.46)	(0.25)	(0.29)	(0.06)
Council forest	-0.0032604		0.0067320	-0.0092643	-0.0025566	-0.0044808
	(0.36)		(0.08)	(0.15)	(0.21)	(0.40)
Community forest	0.0008088	-0.0331114	-0.0063529	0.0332804	-0.0023496	0.0000382
	(0.34)	(1.41)	(0.13)	(2.70)**	(0.74)	(0.01)
Reserve forest	-0.0041776	-0.0149944		-0.0073138	-0.0023319	-0.0009689
	(0.57)	(0.65)		(0.27)	(0.32)	(0.04)
Agriculture	-0.0062000	-0.0051945	0.0095432		-0.0037599	
	(0.88)	(0.31)	(0.12)		(0.52)	
Hunting	0.0003388			0.0003691	-0.0006065	0.0017586
	(0.52)			(0.11)	(0.55)	(1.61)

Constant	0.0405651	-0.0479296	-0.5836004	-0.1626690	-0.0557070	0.1203204
	(1.58)	(0.25)	(1.70)	(1.56)	(1.18)	(2.97)**
R^2	0.00	0.03	0.01	0.01	0.00	0.00
N	50,563	2,313	1,056	4,438	12,164	30,592

Table 9. Post-Propensity Score Matching OLS regression explaining the probability of deforestation of forested points inside forest concessions. Standard errors are shown in parentheses. * *p*<0.05; ** *p*<0.01.

	All	Littoral	South	East
FSC_v2	-0.0020713	0.0014823	-0.0009197	-0.0017395
	(0.0008)*	(0.0021)	(0.0013)	(0.0011)
Elevation (m)	0.0000002	0.0000535	-0.0000046	-0.0000236
	(0.0000)	(0.0001)	(0.0000)	(0.0000)
Slope (degrees)	-0.0000828	-0.0008823	-0.0001299	-0.0003089
	(0.0001)	(0.0009)	(0.0001)	(0.0002)
Temperature (°C)	-0.0005937	0.0177294	-0.0006822	-0.0030628
	(0.0017)	(0.0184)	(0.0029)	(0.0029)
Precipitation (mm)	0.0000042	0.0000844	-0.0000027	-0.0000109
	(0.0000)	(0.0001)	(0.0000)	(0.0000)
Distance to roads (km)	-0.0002479	-0.0011482	0.0002057	-0.0006351
	(0.0001)*	(0.0012)	(0.0002)	(0.0004)
Distance to cities (km)	-0.0000735	-0.0001634	-0.0002524	-0.0000571
	(0.0001)	(0.0002)	(0.0002)	(0.0001)
Distance to processing plants (km)	-0.0000024			0.0000180
	(0.0000)			(0.0000)
Littoral	-0.0001468			
	(0.0045)			

Center	-0.0025442			
	(0.0032)			
South	-0.0020305			
	(0.0037)			
East	0.0003384			
	(0.0034)			
Protected area	-0.0022036		0.0003274	
	(0.0006)**		(0.0009)	
Mining	0.0003230	0.0097386	-0.0004889	-0.0006385
	(0.0010)	(0.0100)	(0.0013)	(0.0016)
Council forest	-0.0036162			
	(0.0040)			
Community forest	-0.0041006		-0.0022800	-0.0042654
	(0.0010)**		(0.0013)	(0.0010)**
Reserve forest	-0.0031983		-0.0027442	
	(0.0017)		(0.0021)	
Agriculture	-0.0046220		0.0001697	
	(0.0023)*		(0.0014)	
Hunting	0.0016631		-0.0004786	
	(0.0017)		(0.0004)	
Constant	0.0124878	-0.6818165	0.0282588	0.1109590

	(0.0479)	(0.6998)	(0.0873)	(0.0830)
R^2	0.00	0.02	0.00	0.00
N	21,363	214	5,571	12,663

Table 10. Five different approaches estimate the effect of FSC on deforestation of points that fell in areas that were ever concessions during the study period from 2000 to 2012.

Approach	All	Southwest	Littoral	Center	South	East
Pre-matching difference in means†	-0.0016**	-0.0086*	-0.0022	-0.0041	-0.0016*	-0.0006
Pre-matching OLS regression	-0.0018753**	-0.0021476	0.0366305	-0.0052508	-0.0009911	-0.0010696
Post-matching PSM difference in means+	-0.002453502		0.004878049		-0.001495886	-0.001767986
Post-PSM OLS regression	-0.0020713*		0.0014823		-0.0009197	-0.0017395
Covariate matching (ATT)	0.0002374		0.004878		-0.0002493	-0.000544

Notes: This analysis includes only forested points that fell in areas that were ever concessions in the study area. Southwest and Center regions were omitted from the matching approach due to the failure of the point-sampling method to capture forest loss inside of FSC-certified concessions.

†A t- test was used to evaluate the difference in means between protected and unprotected units.

+The statistical significance of the post-PSM difference in means was not calculated.

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

Table 11. Using subset of variables and restricting analysis to three regions (Littoral, South and East), five different approaches estimate the effect of FSC on deforestation of points that fell in areas that were ever concessions during the study period from 2000 to 2012.

Approach	All	Littoral	South	East
Pre-matching difference in means†	-0.001087	-0.0021725	-0.0015865	-0.000621
Pre-matching OLS regression	-0.0016374**	0.0145219	-0.0012750	-0.0013544
Post-matching PSM difference in means+	-.000691503	0	-.000997258	-.000951992
Post-PSM OLS regression	-0.0007153	0.0004604	-0.0009676	-0.0009223
Covariate matching (ATT)	-.0014694	0.004878	-0.0017452	-0.000136

Notes: This analysis includes only forested points that fell in areas that were ever concessions in the Littoral, South and East regions.
†A t- test was used to evaluate the difference in means between protected and unprotected units.
+The statistical significance of the post-PSM difference in means was not calculated.
* p<0.05; ** p<0.01