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# Coffee Certification and Forest Quality: Evidence from a Wild Coffee Forest in Ethiopia

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**Summary.** — Shade coffee certification programs that aim to conserve the forest and to prevent forest degradation have attracted an increasing amount of attention. However, such programs' impact on forest degradation remains unclear because of the absence of empirical evidence. In addition, there is heated debate about whether certification programs create an incentive for producers to expand their coffee-growing areas, which may accelerate forest degradation in the surrounding natural forest. This study, which was conducted in Ethiopia, aimed to evaluate the impact of a shade coffee certification program on forest degradation. Additionally, to provide empirical evidence for the debate, we examined the spillover effects of certification to surrounding forest areas and used remote sensing data of 2005 and 2010 to classify forest areas based on their density. We applied matching methods, such as the propensity score matching with different algorithms, to compare forest coffee areas with and without the certification. We found that the certified forest coffee areas slightly increased in forest density. By contrast, we observed drastic forest degradation in the forest coffee areas without certification. We checked the sensitivity of our results and found that our results are robust to potential hidden bias. Furthermore, our empirical results revealed that the natural forest areas within a 100-m radius from the forest coffee boundary area exhibited significantly reduced forest degradation compared with forest areas under similar environmental conditions but that such positive and significant impact diminished after 100-m distance. These results indicate that the certification program is effective in alleviating forest degradation in the certified area and in the surrounding natural forest.


*Key words* — shade coffee, coffee certification, impact evaluation, remote sensing, Ethiopia, Africa

## 1. INTRODUCTION

Deforestation and loss of biodiversity are widespread problems in less developed countries, particularly in the nations of sub-Saharan Africa and Latin America (Hosonuma *et al.*, 2012; Mayaux *et al.*, 2013; Tilman *et al.*, 2001). Concurrently, many studies have noted the importance of traditional coffee production for forest conservation and biodiversity protection. Coffee is traditionally grown in the understory of shade trees, and the agroecosystems of shaded coffee preserve the forest and provide an important refuge for biodiversity (Buechley *et al.*, 2015; Greenberg, Bichier, Angon, & Reitsma, 1997; Hundera *et al.*, 2013; Mas & Dietsch, 2004; Moguel & Toledo, 1999; Perfecto, Rice, Greenberg, & Van der Voort, 1996; Perfecto & Snelling, 1995; Tadesse, Zavaleta, & Shennan, 2014; Wunderle & Latta, 1996).

Nevertheless, because of the shaded coffee system's low yield, many forest areas currently operating under that system are rapidly being converted into plantations for modern industrial coffee production(Jha *et al.*, 2014). According to Gobbi (2000), the average yield of the shaded coffee system is only 1.1 ton/ha, while the modern coffee system on average yields between 3.3 and 5.0 ton/ha. Lyngbaek and Muschler (2001) also show that the net profit of the shaded coffee system is lower than that of the modern coffee system at a given market price. Although the modern coffee system improves both yields and incomes, this improvement comes with increased environmental costs, such as forest reduction, increased erosion, and chemical runoff (Perfecto *et al.*, 1996; Rappole, King, & Vega Rivera, 2003a; Staver, Guharay, Monterroso, & Muschler, 2001).

To reduce coffee producers' incentives to convert to the modern coffee system, shade coffee certification programs have attracted increasing attention from conservation and development organizations (Fleischer & Varangis, 2002; Hundera *et al.*, 2013; Perfecto, Vandermeer, Mas, & Pinto, 2005; Philpott & Dietsch, 2003; Takahashi & Todo, 2013; Taylor, 2005). Certification programs seek to link environmental and economic goals by providing a premium coffee price to producers who maintain shade trees and thereby contribute to the protection of forest cover and biodiversity.

Blackman and Vega Rivera (2011) review the empirical literature on the benefits of coffee certification programs. However, previous studies cited in their study mainly focus on the economic benefits or impact of organic and fair trade certification without any regard to environmental effects. Another study by Mas and Dietsch (2004) conduct in Mexico attempts to evaluate the effect of coffee certification on biodiversity conservation. Unfortunately, because they study an area that was likely to meet the criteria used by the major certification programs, no farmers had obtained any certification. Therefore, their results cannot prove that the certification program is effective in the conservation of biodiversity.

More recently, Takahashi and Todo (2013) have more rigorously evaluated the impact of shade coffee certification on deforestation in Ethiopia, finding a significantly positive effect. Moreover, they reveal that the certification program examined in their study particularly affects the behaviors of economically poor producers in motivating them to conserve the forest (Takahashi & Todo, 2014). Additionally, Rueda, Thomas, and Lambin (2014) report the positive effect of certification on for-

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est cover using remote sensing data. However, the focus of these studies was the impact of coffee certification on forest quantity (e.g., size of forest area), not on forest quality (e.g., biomass and vegetation structure). Thus, it remains unclear whether the coffee certification system preserves forest quality.

Meanwhile, a heated debate continues as to whether coffee certification may trigger forest degradation in the surrounding non-coffee natural forest. As Rappole *et al.* (2003a) note, one potential problem with certification programs is that they can create incentives for producers to convert an existing primary forest area into an area that produces shade coffee. However, Philpott and Dietsch (2003) dispute the claims of Rappole *et al.* (2003a), arguing that such degradation can be prevented by providing financial incentives for coffee producers and establishing rigorous certification criteria. Because no studies have yet examined such spillover effects of the coffee certification system, the debate between Philpott and Dietsch (2003) and Rappole, King, and Vega Rivera (2003b) has not yet reached a consensus (Chandler *et al.*, 2013; Hundera *et al.*, 2013).

The purpose of this study is to evaluate the impact of a shade coffee certification program on forest degradation including its spillover effects on the surrounding forest without forest coffee. We selected Ethiopia as a case study. To evaluate the impact of certification rigorously, we applied the propensity score matching (PSM) method with different algorithms and controlled for selection bias. We estimated the impact of certification by comparing the forest coffee areas with and without the certification. Additionally, we tested the sensitivity of estimates to potential hidden biases.

## 2. DESCRIPTION OF THE STUDY AREA

### 2.1 *Description of the Belete-Gera RFPA*

We selected the Belete-Gera Regional Forest Priority Area (RFPA) as the study area (Figure 1). This region is part of the highland rainforest, and the natural vegetation in this area is subject to an annual precipitation of 1,500 mm and an annual average air temperature of approximately 20 degrees Celsius. The topography of the Belete-Gera RFPA is complex, consisting of undulating hills that range from 1,200 to 2,900 m in height with steep mountainous terrain in certain locations.

The Belete-Gera RFPA is one of Ethiopia's important biodiversity hot spots. Within the forest, we can observe wild mammals, such as baboons, monkeys, and giant forest hogs, and different types of bird species. However, despite the government's prohibition of wood extraction in the forest area, the forest cover in the RFPA has decreased significantly in recent years. In fact, satellite images show that 40% of the forest area has been cleared between 1985 and 2010 (Todo & Takahashi, 2011).

### 2.2 *Wild coffee production and coffee certification*

Coffee (*Coffea arabica*) is a native species that grows wild in the Belete-Gera RFPA. Because coffee production is not economically practical at high elevations (above 2,300 m), wild coffee is typically found in the forest at an altitude of approximately 2,000 m (indicated by the light and dark gray areas in Figure 1). The right to harvest each wild coffee area is granted to individual producers in accordance with traditional agreements among villagers. The rights holders (producers) manage their coffee areas, e.g., by maintaining shade trees and harvesting coffee gradually, but they rarely apply any chemicals. Producers commonly dry wild coffee after harvesting it and sell it as sun-dried, shade-grown coffee to local markets, but the selling price for this coffee has typically been fairly low (approximately 1 US dollar/kg in 2007 and 2008).

In 2006, a group of 555 coffee-producing households from three villages in the Belete-Gera sought to obtain shade coffee certification ("forest coffee certification") from the Rainforest Alliance. The Rainforest Alliance is a major international nongovernmental organization (NGO) based in the United States

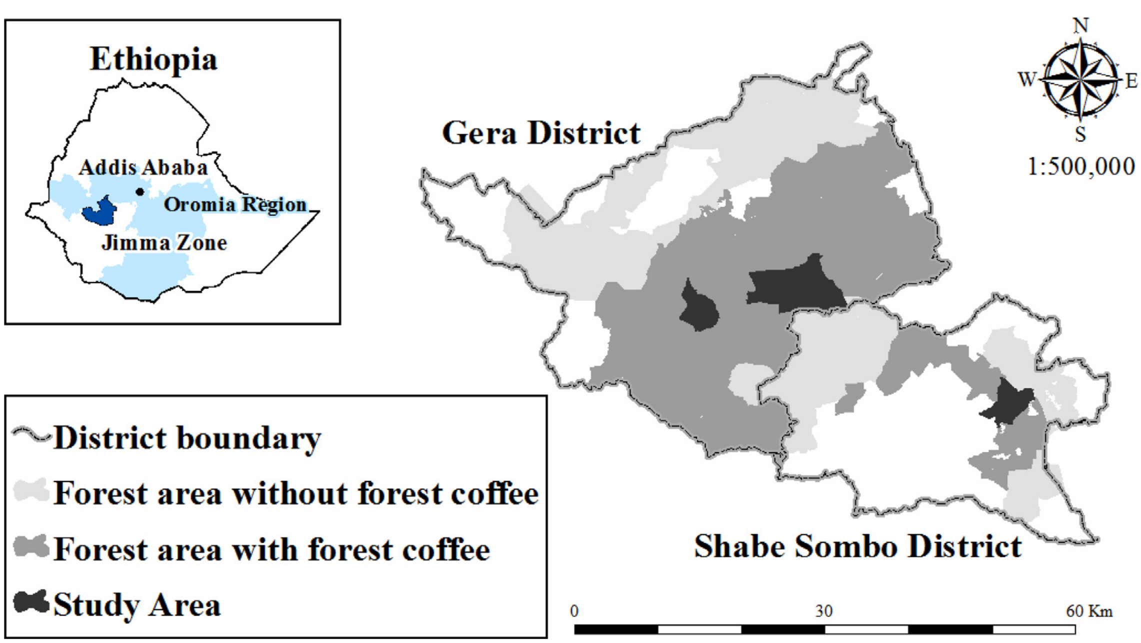


Figure 1. *A map of the Belete-Gera Regional Forest Priority Area, Ethiopia, showing the studied forest coffee-growing areas. The areas shown in dark gray represent the villages that produce forest coffee, and the light gray areas are the villages without forest coffee. The areas shaded black color are the study areas for this investigation.*

that provides certifications for many type of products, including coffee, tea, and bananas.

Although the Rainforest Alliance originally worked primarily with producers that owned larger plantations (Méndez, Bacon, Olson, Morris, & Shattuck, 2010), it also provided a certification program in small scale farming areas both to encourage the shaded coffee system and to encourage coffee producers to move toward greater sustainability (Mas & Dietsch, 2004). Accordingly, many studies defined the Rainforest Alliance's ecological certification as a shade coffee certification (Giovannucci & Ponte, 2005; Mas & Dietsch, 2004; Philpott, Bichier, Rice, & Greenberg, 2007; Philpott & Dietsch, 2003). The certification criteria used in the program include shade criteria for tree species richness and composition, tree height, tree density, number of strata in the canopy, and canopy cover. The details of the certification criteria are provided by Philpott *et al.* (2007) and the Rainforest Alliance (2009).

In 2007, three villages successfully received the certification from the NGO and obtained a price with the certification that was 15–20% higher than the regular price. Although most producers also produced coffee using the improved seeds at their homesteads under non-shaded condition, such coffee is, of course, strictly eliminated from the certified coffee. An auditor from the Rainforest Alliance visits annually to assess the condition of the certified area and the surrounding forest environment. If the expansion of the forest coffee area or degradation of the forest and biodiversity (e.g., logging of shade trees and loss of flora and fauna) is observed in the certified area, the certification can be withdrawn.

## 3. DATA

### 3.1 *Remote sensing data and classification*

For our analysis, we used the January 2005 and January 2010 satellite images of Landsat 7 ETM+(path/row 170/55), with a resolution of 30 m. We used a two-step process to classify the forest areas based on forest density.

First, we distinguished forest areas from non-forest areas (such as agricultural lands, young fallow lands, rangelands, cleared areas, bare soil areas, and urban areas) by utilizing the normalized difference vegetation index (NDVI). The NDVI is a measure of vegetation biomass that is commonly used to identify forest degradation (Lyon, Yuan, Lunetta, & Elvidge, 1998; Mitchard & Flintrop, 2013; Tucker, Townshend, & Goff, 1985). Following the studies by Southworth, Munroe, and Nagendra (2004) and Takahashi and Todo (2012), we determined a threshold value of the NDVI for forest areas based on the information from the satellite images and fieldwork. We conducted groundtruthing to collect locational data for 17 points on the boundaries that delineated the forest regions from the non-forest areas that existed during the study period (according to interviews with several local residents). We chose the area with the highest NDVI value for each year as the threshold value for the forest areas.

Second, after eliminating the non-forest areas from the satellite images, we classified the images using an unsupervised classification technique in which one of the clustering algorithms split the images into classes based on the NDVI values. One advantage of using unsupervised classification is that it does not require the user to have foreknowledge of the classes. We first set the number of clusters and established clustering criteria, such as the minimum number of pixels per cluster and the closeness criterion. In this study, we used the following specifications: the minimum number of pixels per cluster was 20, and the sample interval was 10 cells.

After establishing the criteria, cluster centers are randomly placed and each pixel is assigned to the closest cluster by Euclidean distance. Then, the centroids of each cluster are recalculated. Additionally, the established clusters are split into different clusters based on the standard deviation of the cluster or merged if the distance between the clusters is closer. These processes are repeated until the clustering criteria are satisfied. The unsupervised classification is commonly used in remote sensing to classify forests (Bray, Ellis, Armijo-Canto, & Beck, 2004; Mertens, Sunderlin, Ndoye, & Lambin, 2000).

We classified the forest areas into five categories that represent forest density: class 5 (i.e., the cluster with the highest NDVI values) indicates a dense deep forest and class 1 (i.e., the cluster with the lowest NDVI values) is a less dense forest. Because the NDVI is a measure of vegetation biomass, the scaling down of classification categories directly indicates the loss of biomass. Hence, if the forest areas moved down the classification scale between 2005 and 2010, we defined such decrements as an indicator of forest degradation.

To confirm the forest condition of each classification category, we conducted a ground truth survey by using sample plots of 20 m by 20 m and collecting the following information: the number of trees, the tree species, the tree height for each species, the number of strata of trees, and the canopy cover. We attempted to investigate the class 5 forest areas; however, we could not enter these areas due to their rugged terrain. According to local residents, neither humans nor wild animals can access the deep dense forest.

The description of each classification category is presented in Table 1. We observed six different tree species in the class 1 forest area with a canopy cover that ranged from 60% to 70%. Although the number of trees in the lower classes (classes 1 and 2) was greater than that in the upper classes (classes 3 and 4), the upper classes had more canopy cover than the lower ones because the upper classes were formed of a great forest canopy with large trees. Approximately 85 and 90% of the class 3 and 4 forest areas were covered by forest canopy, respectively.

Additionally, the names of the tree species in each classification are provided in Table 2. We recorded a total of 12 tree species, all of which are indigenous forest trees. Although most of the villagers plant exotic trees, such as eucalyptus, around their homestead areas, tree planting is not common in the forest area. In fact, other study conducted in the Belete-Gera RFPA by Ango, Börjeson, Senbeta, and Hylander (2014) has found that only 2 tree species out of recorded 49 tree species were exotic trees (eucalyptus and *Cupressus lusitanica*) and they were mostly found in woodlot areas, not in natural forest areas. Therefore, the forest in each classification in our study is formed by indigenous tree species and invasion by exotic trees rarely occurred in the study area.

### 3.2 *Forest coffee areas and observation grids*

We selected four villages (the areas marked in black in Figure 1) as the areas for our study: two villages involved with the certification program as the treatment group and two villages randomly selected from villages not involved with the certification program as the control group. To identify the location of each forest coffee area, we conducted a field survey using a global positioning system (GPS) device and collected data from all of the forest coffee areas in the villages, examining

Table 1. *Characteristics of the four levels of forest disturbance/degradation at the forest coffee sites*

| | Number of trees | Number of tree species | Range of height (m) | Number of strata of trees | Canopy cover (%) |
|---|---|---|---|---|---|
| Class 1 | 14 | 6 | 20–35 | 2 | 60–70 |
| Class 2 | 21 | 4 | 15–35 | 2 | 80 |
| Class 3 | 10 | 6 | 20–45 | 2 | 85 |
| Class 4 | 11 | 6 | 15–50 | 3 | 90 |

*Note:* No class 5 areas studied in the study region.

Table 2. *Presence/absence of major tree species in forest areas*

| | Class 1 | Class 2 | Class 3 | Class 4 |
|---|---|---|---|---|
| *Syzygium guineense* | X | X | X | X |
| *Futeria* | – | X | X | X |
| *Olea welwitschii* | – | X | X | X |
| *Ficus sur* | X | – | X | X |
| *Polyscias fulva* | X | X | – | – |
| *Aceacia abyssinica* | X | – | – | – |
| *Ficus vasta* | X | – | – | – |
| *Cordia africana* | X | – | – | – |
| *Millettia ferruginea* | – | – | X | – |
| *Albizia gummifera* | – | – | X | – |
| *Apodytes dimidiata* | – | – | – | X |
| *Schefflera abyssinica* | – | – | – | X |

*Note:* X indicates the presence of a tree species, whereas – indicates the absence of that species.

240 forest coffee areas overall. Of these forest coffee areas, 148 areas were certified in 2007.

The target forest areas were divided into square-shaped cells (30 m by 30 m). We used each grid as an observation for the analysis. A total of 1,733 observation grids were divided into two categories: the forest coffee areas with the certification and the forest coffee areas without the certification. The numbers of observations for the forest coffee areas with and without the certification are 1,141 and 592, respectively.

The general characteristics of the observation grids are provided in Table 3. We observed that some of the grid characteristics of the forest coffee areas with and without the certification were significantly different. The summary statistics indicate that, compared with the areas without the certification, the certified forest coffee areas are located far from the village, but closer to the main road. Moreover, the forest coffee areas at high elevation are more likely to obtain the certification.

## 4. METHOD

### 4.1 *Impact of the certification program*

To quantify the conservation effort of the certification, we cannot use standard estimators, such as ordinary least squares (OLS), due to selection bias. Therefore, we employed a matching method to reduce selection bias. The matching method is commonly applied to estimate causal treatment effects by comparing outcomes between treatment and control groups.

One of the common matching methods used in the evaluation study is the PSM method (Caliendo & Kopeinig, 2008).

Table 3. *Geographical characteristics of the certified and non-certified forest coffee areas*

| Characteristics | Forest coffee areas with certification | Forest coffee areas without certification | Total |
|---|---|---|---|
| Number of plots | 148 | 92 | 240 |
| Average size of forest coffee plot (ha) | 0.56 | 0.40 | 0.50 |
| | (1.08) | (0.76) | (0.97) |
| Number of observation grids | 1,141 | 592 | 1,733 |
| Distance to village (m) | 377.7 | 235.4** | 329.1 |
| | (417.0) | (195.9) | (363.4) |
| Distance to main road (km) | 1.1 | 2.1** | 1.5 |
| | (1.1) | (1.2) | (1.2) |
| Average elevation (m) | 1,913.7 | 1,882.8** | 1,903.2 |
| | (125.1) | (96.3) | (116.9) |
| Average slope (%) | 11.9 | 12.2 | 12.0 |
| | (6.3) | (5.3) | (6.0) |
| Proportion of fertile soil over the observations (%) | 98.0 | 97.9 | 97.9 |
| Proportion of grid facing south (%) | 58.3 | 21.1 | 33.8 |
| Proportion of grid facing north (%) | 0.3 | 3.1 | 2.1 |

*Note:* Numbers are means; numbers in parentheses are S.D. values. ** indicates a statistically significant difference at the 1% level.

For example, Blackman and Naranjo (2012) analyzed the environmental impacts of organic certification using the PSM method. In this study, we chose to use the PSM estimations with different matching algorithms. We used the forest coffee area with the certification as the treatment group, while the forest coffee area without the certification was employed as the control group. This study specifically examines the average effect of treatment on the treated (ATT), which is specified as follows:

$$ATT = E(Y_i(1) - Y_i(0)|D_i = 1), \quad (1)$$

where $D_i$ is a dummy variable indicating whether grid $i$ is an area with the certification ($D_i = 1$) or an area without the certification ($D_i = 0$). $Y_i$ is the change in forest classification between 2005 and 2010. ATT is the average difference between the change in forest quality in certified areas and the counterfactual transition that would exist if these areas were uncertified.

To identify the ATT, we must satisfy the following two assumptions: conditional independence and overlap (Rosenbaum & Rubin, 1983):

$$Y(1), Y(0) \coprod D|X \quad (2)$$

and

$$0 < \Pr(D = 1|X) = P(X) < 1. \quad (3)$$

The first assumption given by Eqn. (2) implies that a given set of observable characteristics $X$ is not affected by treatment; the potential outcomes are independent of the treatment assignment. The second assumption given by (3) ensures that the grids with the same $X$ values have a positive probability of obtaining the certification. Rosenbaum and Rubin (1983) designate these two assumptions as 'strong ignorability.'

To estimate the ATT, this study used the PSM method developed by Rosenbaum and Rubin (1983). The PSM estimator is simply the mean difference in outcomes over the common support, which is appropriately weighted by the propensity score. Hence, the ATT in equation (1) becomes the following:

$$ATT = E(Y_i(1)|D_i = 1, P(X_i)) - E(Y_i(0)|D_i = 0, P(X_i)). \quad (4)$$

An estimate of the first term on the right-hand side of Eqn. (4) is the average of the actual change in forest quality in the certified area, while the second term indicates the average change in uncertified areas with environmental characteristics similar to those of the treatment groups according to the propensity scores.

To match the treatment and control groups, four different matching algorithms were employed: (1) nearest neighbor 1-to-1 matching with caliper, whereby each certified grid is matched to the uncertified grid with the closest propensity score; (2) nearest neighbor 1-to-4 matching with caliper, whereby each certified grid is matched to the four uncertified grids with the closest propensity score and the counterfactual outcome is the average across these four; (3) nearest neighbor 1-to-8 matching with caliper; and (4) kernel matching, in which a weighted average of all uncertified grids is used to estimate the counterfactual outcome. Following Bernhard, Gartner, and Stephan (2008) and Fabling and Sanderson (2013), we used a caliper size of 0.001.

To obtain the PSM estimator of the effect of the treatment, we first used a probit model to examine how a target area for the procurement of certification is selected. The following variables were used as covariates in the probit estimation: distance to the village, distance to the main road, average elevation, average slope, a dummy variable for fertile soil, a dummy variable for facing south, and a dummy variable for facing north.

The dummy variable for fertile soil includes the nitisol and fluvisol soil types, which are suitable for any crop production including traditional coffee. The dummy variables for facing south take a value of 1 if the slope face of a grid faces the south; this variable controls for the high likelihood of catching the sun. Additionally, we included the dummy variable for facing north to control for the likelihood of sunless conditions.

Based on the propensity score from the probit estimation, we created a new control observation group to ensure that the treatment group and the new control group would have similar environmental characteristics. Usually, the standard errors for the PSM estimation are estimated by using bootstrapping, as suggested by Lechner (2002). Hence, we also used the bootstrapping standard error based on 100 replications, following Smith and Todd (2005).

To check the characteristics of the treatment group and the control group after the matching procedure, we conducted two types of balancing tests. First, a $t$-test was used to compare the mean of each covariate between the treatment and control groups after the matching procedure. If the matching was successfully accomplished, the mean difference after matching should be insignificant. Second, we compared the pseudo R-squared values between before and after the matching procedure, suggested by Sianesi (2004). If the matching was successful, then the pseudo R-squared after the matching should have a lower value than that before the matching.

Although we controlled the selection bias by using the observable environmental variables, the effects of the certification may be contaminated by unobserved factors (hidden bias). In our case, because we do not have the village-level variables, the village characteristics may be the possible hidden bias and affect our results. To check the sensitivity of our results, we calculated Rosenbaum bounds (Paul R Rosenbaum, 2002), which indicates how strongly unobservable factors must influence the selection process to undermine the matching results.

The amount of the hidden bias is specified as $\Gamma$. If the amount of the hidden bias is unity ($\Gamma = 1$), it is equivalent to the scenario of no-hidden bias. In contrast, $\Gamma = 1.5$ indicates that hidden bias would increase the odds of obtaining the certification for the treatment group compared to the control group by an additional 50%. In other words, a larger value of $\Gamma$ indicates the robustness of the existence of the certification effect, even under unobserved elements. In this study, we calculated the critical value of $\Gamma$ shown as $\Gamma^{\dagger}$, which alters the results of our statistical inference at the 10% level.

### 4.2 *Spillover effect of the certification program*

As Rappole *et al.* (2003a) argue, the certification program may create an incentive for producers to expand their forest coffee area to maximize their profit. If the argument by Rappole *et al.* (2003a) is true, the negative spillover effect of the certification should be observed in the natural forest areas (i.e., forest areas without forest coffee) around the certified forest coffee areas. Therefore, we hypothesize that the natural forest areas around the certified area are associated with forest deterioration (Hypothesis 1).

In contrast, Philpott and Dietsch (2003) explained that such negative spillover effects may be prevented. If the certified coffee producers received a sufficient price premium through the certification, they may be motivated to maintain the surrounding forest conditions to continuously participate in the certification program. In this case, the certification program may positively affect the surrounding natural environment instead of causing a negative spillover effect. Therefore, the alternative to Hypothesis 1 is that the certification program has a positive spillover effect on the natural forest areas around the certified area (Hypothesis 2).

To test our hypotheses, we employed the nearest neighbor 1-to-1 matching method with caliper and compared the change in forest quality among the natural forest areas around the certified areas and natural forest areas with similar environmental characteristics. We first created six buffer zones from the certified forest coffee area boundary of 150-m by 25-m intervals. These areas within the buffer zones are potential areas affected by the spillover effect of the certification. Second, we created six buffer dummy variables with a value of 1 if a grid was within the buffer. Then, we selected those grids in the buffer zone as the treatment group for the PSM estimation and matched them with other natural forest areas outside the buffer. Because six buffer zones were created, we performed six PSM estimations, using the grids in each buffer as a treatment group. In these PSM estimations, we excluded all forest coffee areas from the observation.

We expect that the ATT is negative if negative spillovers of the certification occurred. In contrast, the ATT should be positive when the positive spillover effect is present.

## 5. RESULTS

### 5.1 *Matching procedure*

We performed probit estimations and found that the majority of the variables had significant effects (Table 4). The goodness of fit can be measured by the pseudo R-squared value, and our probit estimation showed fairly large pseudo R-squared values, such as 0.27.

Based on the propensity score from the probit estimation, we created a new control observation group to ensure that the treatment group and the new control group would have similar environmental characteristics. A common support condition must be implemented to satisfy the overlap assumption. In other words, in the treatment group, we omitted observations from the treatment group whose propensity scores were higher than the maximum score or lower than the minimum score of the observations in the control group. The treatment effect was calculated by comparing the average outcome for all treated observations on common support with a weighted average of all control observations on the common support.

To check the characteristics of the treatment group and the control group after the matching procedure, we conducted two types of balancing tests. Table 5 shows the results of balancing tests for the PSM with the nearest neighbor 1-to-1 matching method. The results of the *t*-test showed that the differences in all covariates became insignificant after the matching procedure, which indicates that the characteristics of the control group were sufficiently similar after matching. Furthermore, we found that the pseudo R-squared values drastically decreased from 0.27 to 0.01 after matching, which indicates that the after-matching probit had no explanatory power. The results of balancing tests for the PSM with other matching algorithms also indicated the similar results. Hence, these balancing tests confirmed that there was no systematic difference among the covariates used for matching between the treatment and after-matching control groups (new control group).

### 5.2 *Impact of the forest coffee certification*

Nearest neighbor 1-to-1 matching indicated that the certified forest coffee areas were conserved or their quality slightly increased (Table 6), suggesting that the certified producers managed their coffee areas in a sustainable manner.

By contrast, the forest areas without the certification suffered forest quality deterioration measuring 1.71. Because our matching estimation compared the change in forest classification scales (i.e., scale range between 0 and 5), this result indicated that the non-certified forest coffee areas moved down the classification scale by at least one level during the study period. According to our field observations, as shown in Table 1, declining one level of classification scale may indicate the loss of 5 percent of canopy cover.

One of the possible reasons for the drastic degradation in the control group is transformation to the modern coffee system. The high yield of the modern coffee system motivates non-certified producers to convert forest coffee areas to the modern system with fewer shade trees, which results in forest degradation. However, our results suggest that the certification program successfully reduces producers' incentives of conversion and increases their incentives for conserving the forest quality.

Our estimation results are quite robust. The results of the PSM estimations with other matching algorithms also showed the similar results, indicating that the certified forest coffee areas significantly conserved the forest quality compared with the non-certified forest coffee areas.

Finally, we check the sensitivity of our results by calculating Rosenbaum bounds. The critical value of odds ratio (i.e., the amount of the hidden bias) took values between 8.8 and 9.1

Table 4. *Results on the determinants of certification areas from the probit estimation*

| | Benchmark estimation | |
|---|---|---|
| Distance to village (km) | 0.971** | (7.11) |
| Distance to main road (km) | −0.556** | (−13.03) |
| Average elevation (m) | 0.004** | (10.67) |
| Average slope (%) | 0.017** | (2.63) |
| Fertile soil dummy | −0.117 | (−0.32) |
| South dummy | −0.786** | (−10.27) |
| North dummy | 1.336 | (2.36) |
| Constant | −7.467** | (−8.01) |
| Observations | 1,733 | |
| Pseudo $R^2$ | 0.27 | |

*Note:* Numbers in parentheses are z-statistics. ** indicates a statistically significant difference at the 1% level.

Table 5. *Results of balancing tests for nearest-neighbor 1-to-1 matching*

| | Nearest neighbor 1-1 | |
|---|---|---|
| | Difference before matching (1) | Difference after matching (2) |
| Distance to village (km) | 0.142** | −0.002 |
| Distance to main road (km) | −0.955** | −0.042 |
| Average elevation (m) | 30.900** | −8.100 |
| Average slope (%) | −0.278 | −0.293 |
| Fertile soil dummy | 0.016 | −0.008 |
| South dummy | −0.384** | −0.041 |
| North dummy | 0.029** | −0.010 |
| Pseudo $R^2$ | 0.27 | 0.01 |

*Note:* ** indicates a statistically significant difference at the 1% level.

Table 6. *Forest quality comparison between forest coffee areas with and without certification*

| Matching method | Nearest neighbor 1-1 | Nearest neighbor 1-4 | Nearest neighbor 1-8 | Kernel matching |
|---|---|---|---|---|
| Mean of treatment group | 0.141 | 0.141 | 0.141 | 0.141 |
| Mean of matched control group | −1.713 | −1.724 | −1.722 | −1.719 |
| Difference: ATT | 1.854 | 1.865 | 1.863 | 1.860 |
| Standard error | 0.144 | 0.143 | 0.143 | 0.143 |
| *t*-Value | 12.90** | 13.01** | 12.99** | 13.01** |
| Rosenbaum bounds critical level of odds ratio ($\Gamma^{\dagger}$)[a] | 8.8 | 9.0 | 9.1 | 9.1 |
| Observations | 1,184 | 1,184 | 1,184 | 1,184 |

*Note:* ** indicates a statistically significant difference at the 1% level.
[a] Critical value of odds of differential assignment to forest coffee certification due to unobserved factors, i.e., value above which ATT becomes insignificant.

Table 7. *A comparison of forest quality between natural forest areas around the certified forest coffee plots at various distances and other natural forest areas*

| Matching method | 0 m–25 m buffer | 25 m–50 m buffer | 50 m–75 m buffer | 75 m–100 m buffer | 100 m–125 m buffer | 125 m–150 m buffer |
|---|---|---|---|---|---|---|
| Mean of treatment group | −0.265 | −0.351 | −0.437 | −0.520 | −0.614 | −0.651 |
| Mean of matched control group | −0.531 | −0.668 | −0.688 | −0.635 | −0.693 | −0.707 |
| Difference: ATT | 0.266 | 0.317 | 0.251 | 0.116 | 0.079 | 0.056 |
| Standard error | 0.063 | 0.053 | 0.06 | 0.056 | 0.054 | 0.061 |
| t-Value | 4.24** | 5.96** | 4.20** | 2.07* | 1.45 | 0.93 |
| Observations | 2,880 | 5,508 | 4,794 | 4,668 | 4,572 | 4,048 |

*Note:* ∗∗ and ∗ indicates the statistically significant differences at the 1% and 5% levels.

($\Gamma^{\dagger}$ row, Table 6). Although there is no clear standard threshold value to determine the existence of hidden bias, Apel, Blokland, Nieuwbeerta, and van Schellen (2010) report that the estimation results in applied research often become sensitive to $\Gamma$ as small as 1.15. Therefore, we judge that our results are not sensitive to unobserved characteristics.

In summary, obtaining the certification prevents the degradation of forest when compared with areas without the certification. Thus, these results lead to the conclusion that the forest coffee certification program had a significant impact on the forest degradation.

### 5.3 *Spillover effects to the surrounding forest areas*

To evaluate the spillover effect of the certification on the surrounding natural forest, we followed the same matching procedure discussed above. We tested six PSM estimations, all of which passed the balancing tests.

The results provided in Table 7 showed that although the quality of forest in the closest buffer zone (such as with a range of 0 m to 25 m) declined slightly, forest degradation in the matched control areas was significantly larger than that of the treatment group, indicating that the forest quality was preserved in forest areas around the certified coffee areas compared with the natural forest areas under same environmental conditions. These results suggest that the certified coffee producers maintain the natural environment around their certified areas.

Furthermore, the difference between the treatment and control groups grows as the buffer area increased to the 25-m to 50-m range. Although there was a significant difference between the treatment and matched control group within the 100-m distance from the forest coffee boundary, we could not find any significant difference after 100-m distance, which implies that the quality of forest in the treatment group is not significantly different from that of the control group.

These results demonstrate that providing coffee certification did not induce the forest degradation in the surrounding forest areas. Instead, in the forest areas within a 100-m radius, forest degradation was significantly alleviated. Therefore, we reject Hypothesis 1 in favor of Hypothesis 2.

As we discussed earlier, such positive spillover effects of the certification may occur due to the economic incentives of the certified producers. In the case of Belete-Gera, the forest conditions of the certified areas are investigated annually by the NGO auditor and the certified producers are aware that the certification is withdrawn if the forest conditions around the certified areas have deteriorated. Thus, the certified producers may be motivated to conserve the surrounding environment to continue the certification program and receive the premium price for their shade-grown coffee. In fact, during interviews with certified producers who received the 15–20% price premium in 2007, all the interviewees reported that they were satisfied with their returns and willing to continue their involvement in the certification program.

## 6. DISCUSSION

We applied the matching methods to evaluate the impact of a forest coffee certification program on forest degradation. Whereas the density of the certified forest coffee areas slightly increased, the quality of the forest coffee areas without the certification decreased.

Additionally, we investigated the spillover effects of the certification on the surrounding natural forest areas. The results revealed that the natural forest areas within a 100-m radius of a certified coffee boundary showed significantly reduced forest degradation when compared with other natural forest areas under similar environmental conditions. However, such positive and significant impact diminished after 100 m.

Our empirical results provide insights into the debate between Philpott and Dietsch (2003) and Rappole *et al.* (2003b). While Rappole *et al.* (2003a) note the high probability of converting natural forest to shade coffee, Philpott and Dietsch (2003) argue that this type of degradation can be prevented by providing financial incentives for coffee producers and establishing rigorous certification criteria. In the area under study, the certified producers sold their coffee at a 15–20% higher price than that of regular coffee. Additionally, the Rainforest Alliance requests a high standard of criteria for certification and monitors the conditions of the certified areas annually. In all likelihood, the economic incentive and rigorous certification criteria accompanied by the audit system may motivate the certified producers to conserve their forest coffee areas and surrounding natural forest areas.

These results could provide useful information in the field of sustainability certification schemes. Like other eco-label certified products, such as fair trade coffee and organic coffee (Rice, 2003), certified forest coffee is usually defined as sustainable coffee. Although each certification program has its own primary goals (Ponte, 2004)—e.g., the main purpose of fair trade certification is to guarantee a price floor for marginal producers in less developed countries (Basu & Hicks, 2008)—other certification programs also include environmental criteria. In fact, several empirical studies find that other sustainability certification programs are associated with environmentally friendly management practices (Blackman & Naranjo, 2012; Ibanez & Blackman, 2016). However, the existing literature on fair trade and organic certification programs primarily focuses on the socioeconomic impact or effect on agricultural practices (Blackman & Vega Rivera, 2011), while less attention is devoted to investigating how other sustainability certification programs affect forest conservation and protection of the surrounding environment. The results of our analysis suggest that we can expect a conservation effect for both certified and surrounding areas by establishing rigorous certification criteria and an audit system. Thus, we may be able to enhance sustainable development through sustainable coffee certification schemes by reconsidering the certification criteria and strengthening regulations that protect the surrounding environment.

Overall, we conclude that the forest coffee certification system had a positive impact on preventing forest degradation not only in the certified areas but also in the surrounding forest regions. Although we found empirical evidence to support the effectiveness of the certification system, our current analysis could not assess which elements of the certification program have a significant impact on preventing degradation. Therefore, further study is necessary to investigate the mechanism by which forest quality is conserved to provide cost-effective programs for forest conservation.

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