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Coffee certification and forest quality:
Evidence from a wild coffee forest in Ethiopia

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Abstract

Shade coffee certification programs that aim to conserve the forest have attracted increasing research attention; however, such programs' impact on forest degradation remains unclear because of the absence of empirical evidence. Additionally, there is debate about whether certification programs create an incentive for producers to convert the surrounding natural forest into coffee areas, resulting in forest degradation. This study aimed to evaluate the impact of a shade coffee certification program on forest degradation in Ethiopia. Additionally, to provide empirical evidence for the debate, we examined the spillover effects of certification. We used remote sensing data and applied matching methods for the analysis. We found that the certified areas significantly conserved forest quality compared with the areas without the certification. Furthermore, the natural forest areas within a 100 m radius from the forest coffee boundary exhibited significantly reduced forest degradation compared with forest areas under similar environmental conditions.

Keywords: shade coffee; coffee certification; impact evaluation; remote sensing; Ethiopia; Africa

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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 et al. 1997; Hundera et al. 2013; Mas and Dietsch 2004; Moguel and Toledo 1999; Perfecto et al. 1996; Perfecto and Snelling 1995; Tadesse et al. 2014; Wunderle Jr and Latta 1996).

However, because of the low yield of the shaded coffee system, many forest areas currently operating under the shaded coffee 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 yields and incomes, this improvement comes with increased environmental costs, such as forest reduction, increased erosion, and chemical runoff (Perfecto et al. 1996; Rappole et al. 2003a; Staver et al. 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 and Varangis 2002; Perfecto et al. 2005; Philpott and Dietsch 2003; 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 Rivera (2011) reviewed 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) conducted in Mexico attempts to evaluate the effect of coffee certification on biodiversity conservation. Unfortunately, because they studied an area that was likely to meet the criteria used by the major certification programs, their results cannot prove that the certification program is effective in the conservation of biodiversity.

More recently, Takahashi and Todo (2013) more rigorously evaluate the impact of shade coffee certification on deforestation in Ethiopia and find 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 and Todo 2014). Additionally, Rueda et al. (2014) also report the positive effect of certification on forest 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, whether the coffee certification system successfully preserves forest quality remains unclear.

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) by arguing that such degradation can be prevented. Because no studies have yet examined such spillover effects of the coffee certification system, the debate between Philpott and Dietsch (2003) and Rappole et al. (2003b) has not yet reached a consensus.

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 (Fig. 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 and 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 Fig. 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 the 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 non-governmental organization (NGO) based in the United States 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 et al. 2010), it also provided the certification program in small scale farming areas to encourage the shaded coffee system and to encourage coffee producers to move toward greater sustainability (Mas and Dietsch 2004). Hence, many studies defined the ecological certification provided by the Rainforest Alliance as the shade coffee certification (Giovannucci and Ponte 2005; Mas and Dietsch 2004; Philpott et al. 2007; Philpott and Dietsch 2003). The 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 in the study 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 to 20% higher than the regular price. Although most producers also produced coffee using the improved seeds at their homesteads under the modern coffee system, 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 the forest areas from the 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 et al. 1998; Mitchard and Flintrop 2013; Tucker et al. 1985). Following the studies by Southworth et al. (2004) and Takahashi and Todo (2012), we determined a threshold value of the NDVI for the forest areas based on the information from the satellite images and fieldwork. We conducted ground-truthing 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 the 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 et al. 2004; Mertens et al. 2000).

We classified the forest areas into five categories that represent the 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 in the upper ones (classes 3 and 4), the upper classes had more canopy cover than the lower ones because the upper classes were formed by 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 plantation is not common in the forest area. In fact, other study conducted in the Belete-Gera RFPA by Ango et al. (2014) 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 the indigenous tree species and invasion by exotic trees rarely occurred in the study area.

3.2. The forest coffee areas and observation grids

We selected four villages (the areas marked in black in Fig. 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 the forest coffee areas in the villages for a total of 240 forest coffee areas. 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 and Kopeinig 2008). 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:

$$ATT = E(Y_i(1) - Y_i(0) \mid D_i = 1), \tag{1}$$

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 counter-factual 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 and Rubin 1983):

$$Y(1), Y(0) \coprod D \mid X \qquad (2)$$

and

$$0 < \Pr(D = 1 \mid X) = P(X) < 1. \qquad (3)$$

The first assumption given by equation (2) implies that a given set of observable characteristics *X* are 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 made use of 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:

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

An estimate of the first term on the right-hand side of Equation (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 similar environmental characteristics to 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 et al. (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 (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 Γ. 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 Γ indicates the robustness of the existence of the certification effect, even under unobserved elements. In this study, we calculated the critical value of Γ 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) argued, the certification program may create an incentive for the 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 the certification program. In this case, the certification program may positively affect the surrounding natural environment rather than 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 showed 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 ($\Gamma^{\dagger}$ row, Table 6). Although there is no clear standard threshold value to determine the existence of hidden bias, Apel et al. (2010) report that the estimation results in applied research often become sensitive to Γ 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 to 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 to 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.

From these results, we conclude that the forest coffee certification system had a positive impact on preventing forest degradation not only in the certified areas but also 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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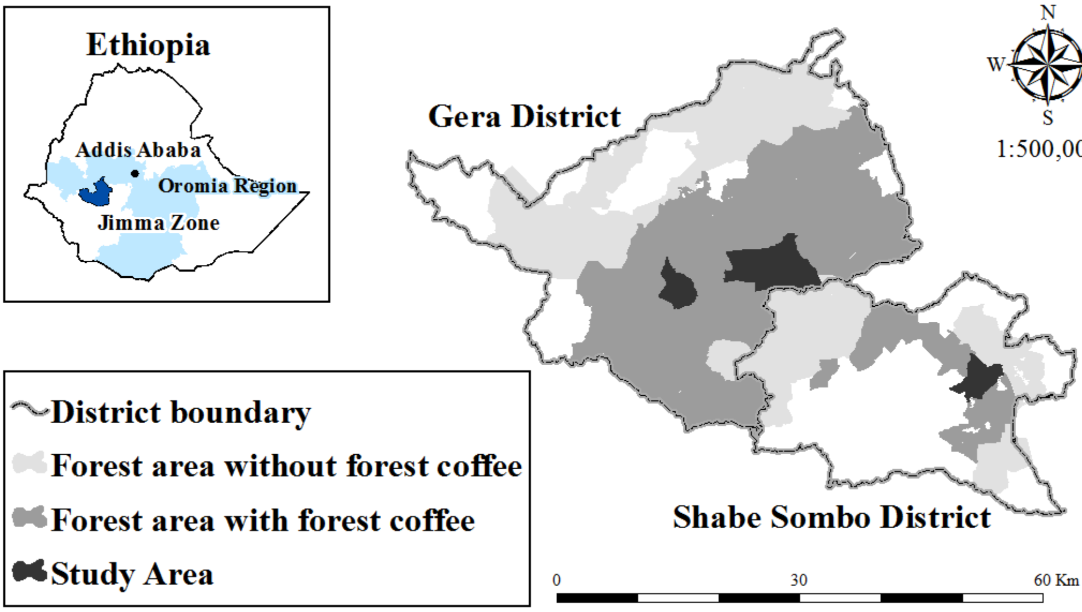
Figure Captions

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.

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: The 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	–	–
Accacia 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 tree species, while – means absence of the species.

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 statistically significant difference at the 1% level.

Table 4: Results on the determinants of certification area 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 statistically significant difference at the 1% level.

Table 5: Results of balancing tests for the 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 statistical significance 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 ($\Gamma^{\dagger}$)	8.8	9.0	9.1	9.1
Observations	1,184	1,184	1,184	1,184

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

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 statistically significant differences at the 1 and 5% levels.