Effects of quality coffee production on smallholders' adaptation to climate change in Yirgacheffe, Southern Ethiopia

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Abstract

Purpose – The purpose of this paper was to assess the effects of quality coffee production on climate change adaptation using household surveys and interview data gathered from coffee farmers in Yirgacheffe, southern Ethiopia.

Design/methodology/approach – A sample of 352 households, stratified into conventional coffee farmers 232 (66%) and specialty coffee producers 120(34%), was used. The propensity score model for participating in quality coffee production was estimated using 14 covariates, and the impact of quality coffee production on adaptation to climate change adaptation was examined. The results are augmented with qualitative data collected through focus group discussions and key informant interviews held with randomly selected smallholder farmers. A telecoupling theoretical perspective was used to understand the link between coffee farmers' adaptation practices and the demand for quality coffee, as coffee is a global commodity.

Findings – The PSM analysis reveals that quality coffee production positively influences climate change adaptation. This implies that conventional coffee producers would have performed better in adaptation to climate change if they had participated in quality coffee production. The results of group discussions also confirm the positive effects of quality coffee production on adaptation to climate change, which also suggests a positive spillover effects for sustainable coffee farm management.

Practical implications – This study suggests enhancing quality coffee production is essential if a more sustainable and climate change resilient coffee livelihood is envisioned.

Originality/value – Though many studies are available on adaptation to climate change in general, this study is one of the few studies focusing on the effects of quality coffee production on climate change adaptation by smallholders in one of the least developed countries, Ethiopia. This study provides a better understanding of the importance of adaptation strategies specific to coffee production, which in turn help

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develop a more resilient coffee sector, as coffee production is one of the most sensitive activity to climate change.

Keywords Quality coffee production, Climate change adaptation, Propensity score matching, Ethiopia

Paper type Research paper

1. Introduction

The impact of climate change is most severe in Africa, as its food production systems are among the most sensitive due to its extensive reliance on rainfed crops production and droughts are recurrent under natural climate variability (Moore *et al.*, 2012). The African coffee sector, which supports millions of smallholder families and generates the much-needed foreign currency to national government is particularly sensitive to climate change impacts. This is particularly the case with the Arabica coffee, which requires very specific environmental conditions for successful production (Ebisa, 2017), including an optimum mean temperature range of between 15°C and 23°C (Davis *et al.*, 2012).

Ethiopia is the origin and center of genetic diversity of the Arabica coffee plant and has a huge natural advantage and potential for quality coffee production in the form of organic and shade-grown coffee (Mojo *et al.*, 2015). Coffee has been cultivated, traded and consumed over centuries and still plays a central role in the local and national economy of the country (Gole *et al.*, 2008). Nearly a fifth of the national population depends on coffee for their livelihoods, where about five million smallholders produce 95% of the total production in a low input-output production system (Meskela and Teshome, 2014). It contributes up to 50% of the countrýs export commodity and more than 25% of the country's foreign exchange earnings (MOT [Ministry of Trade], 2012). Though Ethiopia is the first African coffee producer, it is the second exporter to the global market (Daviron and Ponte, 2007). This could be attributable to several reasons; inadequate pre-and post-harvest activities to produce coffees that meet the high quality requirement of the speciality coffee market and poor marketing systems. The high domestic consumption that takes up more than 50% of the total production (Petit, 2007) due to the country's strong coffee-drinking culture could play in the balance between the production and export of coffee in Ethiopia.

Quality coffee production has recently received attention from several scholars (Borrella *et al.*, 2015), and the production is defined by high quality and differentiation. It needs the capacity of farmers with high levels of knowledge on adaptation to climate change in land under pressure. Quality coffee has its own distinct market, and defined as all coffees that are not traditional industrial blends, either because of their high quality and/or limited availability on the producing side, or because of flavoring, or packaging (Ponte, 2002). Due to the fact that quality coffee generally requires a fair amount of knowledge and care, many coffee buyers and roasters in the specialty coffee market have direct relationships with the coffee producers from whom they purchase coffee. In this sense, consumers contribute directly to the livelihood of a "distant coffee producer," while also allowing them to build a sense "relationship with the individuals who produce the commodities, which has contributions to the adaptation practices by coffee farmers."

Ethiopia's role in the global coffee market lies mainly on the fine quality of its coffee; Ethiopian specialty coffee enjoys a high demand in the global market (Daviron and Ponte, 2007). Quality coffee refers to a single-origin and highest-grade, organically produced coffee, differentiated by its superior flavor and it claims price premiums (Minten *et al.*, 2018; Ponte and Gibbon, 2005). Different flavored coffee varieties that have internationally been reputed and marketed at premium prices are being produced in various parts of Ethiopia including Yirgacheffe (Degefa, 2016). The notion of speciality coffee in this paper refers to a variety of quality coffee that is grown with only organic inputs for three consecutive years prior to certification and annually inspected by third party certifiers. It is a type of quality coffee produced mainly by smallholders in Yirgacheffe area for the global market.

Coffee production in Ethiopia has also important benefits in adapting to climate change through different coffee production and land management practices. More than 90% of Ethiopia's coffee is *de facto* organic (Mekuria *et al.*, 2004), and about 45% of the coffee comes from forest and semi-forest areas in which local biodiversity as well as traditional practices are generally maintained (Minten *et al.*, 2018). Even in areas where coffee is produced in gardens, it is grown under large trees such as indigenous leguminous trees (e.g. Acacia trees), highlighting that coffee is a shade loving tree (Meskela and Teshome, 2014). These coffee farm management practices of maintaining forest and indigenous trees have several implications for the coffee-based livelihoods and environmental sustainability.

However, the expanding trend of deforestation for more intensive cultivation to increase coffee production (since forest coffee has low yield) has been reported as a potential threat to environmental sustainability to many coffee producing countries including Ethiopia which is an environmental "hot spot" for coffee as a global commodity (Jena *et al.*, 2012). In particular, Petit (2007) remarked that the growing demand for quality coffee is currently becoming more important than in the past as the demand for differentiated coffee is going up, and this influences producer's coffee farm management practices. The notion of speciality coffee in this paper refers to a variety of quality coffee that is grown with only organic inputs for three consecutive years prior to certification and this is annually inspected by third party certifiers.

Coffee crops are highly sensitive to changes in climate, which can decrease both the quantity and quality of harvests (Meza, 2015). Obviously, adaptation is one of the strategies to mitigate the negative impacts of the ongoing climate change (IPCC [Intergovrnmental Panel for Climate Change], 2007). As quality coffee production involves various farm management practices, it is likely to have climate change adaptation benefits. These practices include using new cultivars, establishing apt shade level, intercropping coffee trees with legume trees and crops, pruning and taking up agroforestry (which id typical to the study area). It is also equally important to look into the economic aspects like the demand for quality coffee that drives quality coffee production and ensuing adaptation to climate change. Nevertheless, this has not been studied in any detail in Ethiopia.

Previous studies on coffee in Ethiopia Mojo *et al.* (2015), Minten *et al.* (2018), Kodama (2007) are focused on assessment of structural bottlenecks like institutional and marketing issues or biophysical factors related to coffee production, and on modeling current and projected impacts of climate change in a separate way. This paper, therefore, attempts to fill in an important knowledge gap by assessing the link between quality coffee production and climate change adaptation benefits by using Yirgacheffe area in southern Ethiopia as a case study site The specific objectives of the study are to:

- assess factors affecting quality coffee production by smallholders; and
- examine effects of quality coffee production on climate change adaptation in Yirgacheffe.

The remainder of the paper is organized as follows. Section 2 describes materials and methods, and Section 3 presents results. Section 4 presents discussions. Conclusions and issues for future research are presented in Section 5.

2. Materials and methods

2.1 Study area: Yirgacheffe district

Yirgachceffe is one of the six rural districts in Gedeo Administrative Zone, southern Ethiopia (Figure 1). Located between 6°09' and 6°32' N and $38^0$08' and $38^0$32' E, it is part of the eastern escarpment of the Rift Valley System of Ethiopia with altitudinal range of 1,501 to 2,500 m asl. The dominant soil type is Dystric Nitosols, which are known to be well-drained and suitable for perennial crops.

The climate of Yirgacheffe is humid, and measurements at Dilla ($6^0$20' N, $38^0$20'E at altitude of 1579 m asl) show that annual rainfall ranges between 1,200 and 1,800 mm, with a bimodal distribution. The main rainy season, which is known as *Kiremt*, lasts from June to November and the second rainy season, which is known as *Belg*, lasts from March to May. The mean annual temperature varies from 15^0C to 20^0C. The vegetation cover of the area includes different trees and shrubs, along with perennial crops like coffee and enset (*Ensete ventricosum*)[1]. The area is known for the widespread practice of agroforestry (Negash, 2007).

With a total area of 358.6 km^2 (based on area calculation from EthioGiS Data) and an average population density of 969 persons/km^2, the study area is one of the most densely populated parts of Ethiopia (its density exceeds the Regional [1] average of 916 persons/km^2 and far exceeds the national average of 118 persons/km^2) (Central Statistical Agency [CSA], 2017). Yirgacheffe is a high-quality Arabica coffee producing area, and it has the largest proportion (52%) of farmers producing coffee in the Gedeo Zone (Degefa, 2016). The livelihoods of people are heavily dependent on an indigenous agroforestry system, which involves growing coffee (*Coffea arabica*), *enset (Ensete ventricosum*) and varieties of fruits such as mango (*Mangifera indica) and* avocado *(Persea americana*). The coffee harvest time is from December to March. This agroforestry practice has contributed to a sustained human carrying capacity and supported enormous biodiversity and ecosystem services for many years (Legesse *et al.*, 2013), though the area has come under increasing pressure in the

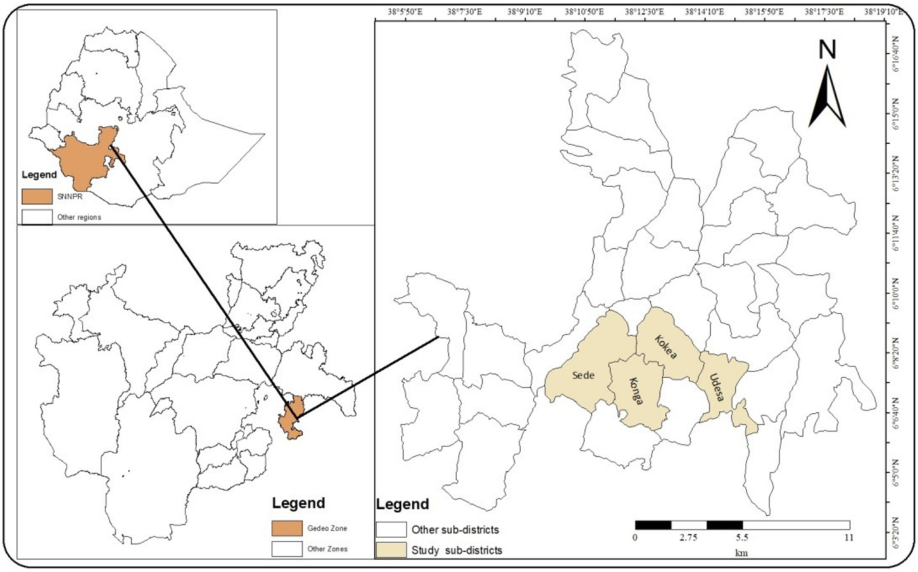

Figure 1.
Location map of the study area

last couple of decades (Negash, 2007). Four *Kebeles* (sub districts), namely, Qonga, Konkea, Sede and Udesea (Figure 1), were purposively selected considering that these sub-districts are well-known coffee producing areas and are also typical quality coffee production areas in the district.

2.2 Methods

2.2.1 Survey data collection. Based on consultations with staff of district office and preliminary field visit, two different groups of coffee framers were identified: speciality and conventional coffee farmers. Speciality coffee farmers, as designated by the district coffee development department, are characterized by coffee is grown with only organic inputs for three years prior to certification; farmers keep detailed records of methods and materials used in coffee production; and a third-party certifier annually inspects all methods and materials.

The vast majority of coffee producers in the study area are conventional coffee farmers; out of 4,309 farmers in the district, only 120 were speciality coffee producers. All of these 120 were included in the household survey sample. To select a representative sample from the conventional group, the authors used the list of conventional coffee farmers from the district office. Then, samples 232 household heads (which is 5.5% of the total) out of the 4,189 farmers were taken, using a systematic random sampling procedure. The overall number of survey participants was, therefore, 352. The sample size for study has been determined by using the formula of Kothari (2004) expressed as:

$$\mathrm{n} = \frac{z^2pq}{e^2} \tag{1}$$

where no is the sample size for the infinite population, z is the selected critical value of desired confidence level, p is the estimated proportion of an attribute that is present in the population, 1- $q = p$ and e is the desired level of precision. Thus, the sample size will be:

$$n = \frac{1.96x1.96xo.5.0.5}{0.05x0.05} = 384 \tag{2}$$

However, as there is a finite population size that is 4,309 households for the four sub-districts (Konga, Konkea, Sede and Udesa), the sample size can be corrected following Cochran (1977) as follows:

$$\boldsymbol{n} = \frac{\mathbf{no}}{1 + \left(\frac{\mathbf{no}-1}{N}\right)} \tag{3}$$

$$\boldsymbol{n} = \frac{384}{1 + \left(\frac{384-1}{4309}\right)} \quad \boldsymbol{n} = \frac{384}{1.09} \quad \mathbf{n} = 352 \tag{4}$$

Finally, as it has been mentioned earlier, the author gave 120 quota to the specialty coffee producers and the remainder (232) samples were taken based on systematic random sampling from a list of coffee farmers in the sub-districts.

The household survey was conducted via face-to-face interview during December and March 2018 with household heads using a structured questionnaire by the researcher and trained research assistants to collect data primarily on:

- factors affecting farmers' participation in quality coffee production; and
- coffee farmers' adaptation practices to climate change.

2.2.2 Methods of quantitative data analysis. The propensity score is the probability of treatment assignment conditional on measured baseline covariates (Austin, 2011). It involves matching treatment and control groups that are similar in terms of their observable covariates to yield an unbiased estimate of the treatment impact (Rosenbaum and Rubin, 1985). There are four ways of using the propensity score to reduce confounding: matching on the propensity score, stratification on the propensity score, inverse probability of treatment weighting using the propensity score and covariate adjustment using the propensity score. Stratification on the propensity score stratifies the entire sample into mutually exclusive subclasses using specified quantiles of the propensity scores and then matching the treated and untreated subjects of similar PS. When estimating the ATT, each stratum would be weighted proportionally to the number of treated subjects who lay within that stratum (Rubin and Thomas, 2006). The inverse probability of treatment weights are used when the distribution of baseline covariates in each treatment group will be the same as the distribution of baseline covariates in the overall unweighted sample. The covariate adjustment involves matching that involves regressing the outcome variable on an indicator variable denoting treatment status and the estimated propensity score.

In this study, matching on the propensity score was used to assess the effects of quality coffee production on adaptation to climate change by smallholder coffee producers. It allows us to establish control groups, as it is not possible to assign a household into quality coffee producers and conventional coffee producer through randomization. The PSM was used to balance the covariate difference between the speciality coffee farmers and the conventional coffee farmers based on logistic regression. SPSS version 27 and STATA 16.1 were used to analyze the propensity scores and then to assess the balance of covariates to participate in quality coffee production

The PSM works under the following assumptions (Caliendo and Kopeinig, 2005):

- it depends on conditional independence assumption (CIA), after controlling for the observable covariates (Z) the potential outcomes are independent of the treatment assignment;
- the common support is assumed to be satisfied, subjects with the same Z values have similar probability of being treated, indicated by the propensity scores; and
- PSM requires the fulfillment of the balanced scores, i.e. the covariate means of the two groups should be similar after the propensity score matching.

The CIA assumption implies that participation decision is based on covariates, i.e. observable variables that simultaneously influence participation quality coffee production (in our ca) and outcome indicators (adaptation practices). Considering the assumptions mentioned earlier and previous studies (Abebaw and Haile, 2013; Francesconi and Ruben, 2012) and covariates that are deemed important in quality coffee production, the propensity scores were estimated using the logit model to match quality coffee producers with conventional producers. Further details are given below.

2.2.2.1 Choosing covariates and estimating propensity score. The selection of covariates in propensity score estimation is an important issue, and proper selection of independent variables is extremely crucial for the validity of propensity score matching. The general principle is that covariates affecting group assignment or outcome variables should be included (Caliendo and Kopeinig, 2005). In this study, a set of covariates that are deemed important for both participation in quality coffee production (group assignment) and adaptation practices (outcome) were selected (Table 1). This was based on review of theoretical arguments and literature and frequent field observation (Austin, 2011). The covariates were categorized into numerical (quantitative) and categorical (qualitative), for analysis purpose. The selected numerical covariates were age of household head, household size, experience in coffee farming, land holding size, coffee farm size, distance of coffee farms from coffee processing center, number plots and number of coffee plots. The categorical covariates were education and sex of household heads, access to information, access to credit and cooperative membership of households and perception of household heads about climate change.

The propensity score was estimated using logistic regression in which the set of covariates was considered as predictors and participation in quality coffee production was used as the dependent variable. The estimated propensity score (PS), for subject e (X_i), (i = 1 . . . N) is the conditional probability of being assigned to a particular treatment group given a vector of observed covariates x_i (Thoemmes, 2012):

$$Ln\left[\frac{p\ (z=1|x1\ldots .xn)/}{1-\ p\ (z=1|x1\ldots .xn)}\right] = \beta_0 + \sum_{j=1}^{P} \beta_j x_j \qquad (1)$$

where Z is the binary variable indicating treatment or control condition (z = 1 for treatment; z = 0 for control); x_1 . . . x_n are all covariates that are being used to predict group membership of the binary treatment variable. In our case where z = (0, 1) is the indicator of quality coffee production (dependent variable) and then z = 1, if a subject produces quality coffee and z = 0 if he or she produces conventional coffee; X is the multidimensional vector of observed covariates (explanatory variables).

2.2.2.2 Propensity score matching. The PSM method uses different algorithms like nearest neighbor caliper matching and kernel algorithms to form matched pairs of treated

Type of variable	Description of variable	Category	Expected effect
Explained	Participation in quality coffee production	Dummy	
Explanatory			
EDU_HH	Education of the HH head (% of literate)	dummy	+ve
AG_HH	Age of the HH head(years)	Continuous	+ve/−ve
D_FAR	Distance of plots from pulp center (Km)	Continuous	+ve/−ve
SE_HH	Sex of the HH head (% of male)	dummy	+ve
EXP_HH	Experience in coffee farming (Years)	continuous	+ve
ACC_INF	Access to information (% access)	dummy	+ve
HH_SIZ	Household size (number)	Continuous	+ve
ACC_CRT	Access to credit (% of access)	Dummy	+ve
T_LHS	Land holding Size(ha)	Continuous	+ve
COP_MEM	Cooperatives membership	dummy	+ve
N_PLOT	No of plots (number)	continuous	+ve
N_CPLOT	No of coffee plots(number)	continuous	+ve
CO_FARS'	Coffee farm size(ha)	continuous	+ve
Perc_CC	Perception about climate change	dummy	+ve

Table 1. Variables for PSM model in relation to speciality coffee producers

and untreated subjects. The nearest neighbor caliper algorithm matches subjects on the logit of the propensity score, using calipers of width equal to 0.2 of the standard deviation of the logit of the propensity score. In this algorithm, a subject is first selected at random from the intervention group and subsequently paired with a subject in the control group with the closest propensity score. The nearest neighbor matching using calipher was used in this study due to its simplicity to implement and understand. To ensure good matches, a caliper (maximum allowable distances between to two subjects) was defined, and a caliper of 0.08 (0.2 of the standard deviation of the propensity scores [0.4]) was used for matching (Rubin, 2001). The choice of caliper involves a tradeoff: a narrower caliper will yield more similarly matched pairs but may result in a small matched subsample and vice versa. The matching estimator is given as:

$$\tau^M = \frac{1}{N^T} - \Sigma iET\left\{Y_i^T - \Sigma iETW_{ij}Y_j^c\right\} = \frac{1}{N^T}\left\{\Sigma iETY^T - \Sigma iET\Sigma iETW_{ij}Y_j^c\right\} \quad (2)$$

where i, E, T, $N^c i$ denote the numbers of controls matched with observation and define the weights $W_{ij} = 1/N^c i$ and $W_{ij} = 0$ otherwise. M stands for the nearest neighbor matching, and N^T denotes the number of units in the quality coffee group. With this, 92 pairs were generated from the PSM for further analysis.

2.2.2.3 Testing the balance in covariates between the groups. The standardized mean difference is mostly used to check whether balance of the covariates had truly been achieved. The standardized mean difference compares the difference in means in units of the pooled standard deviation. Although there is no universally agreed upon criterion as to what threshold of the standardized difference (d) can be used to indicate good balances, Rubin (2001) suggests that it should be near zero or $d < 0.2$. For numerical covariates, the standardized difference (Cohen's d) was calculated as:

$$d = \frac{M_1 - M_2}{\sqrt{\frac{(n_1-1)SD_1+(n_2-1)SD_2}{(n_1+n_2)-2}}} \quad (3)$$

where M_1 and M_2 denote the sample mean of the covariate in treated and untreated subjects, respectively, whereas SD_1 and SD_2 denote the sample variance of the covariate in treated and untreated subjects, respectively, and n_1 and n_2 denote the sample sizes of treated and untreated subjects. For the dichotomous covariates, the standardized difference was computed as:

$$d = \frac{(\hat{p}\ intervention - \hat{p}\ control)}{\sqrt{\frac{\hat{p}intervention(1-\hat{p}\ intervention)+\hat{p}control(1-\hat{p}control)}{2}}} \quad (4)$$

where $\hat{p}_{intervention}$ and $\hat{p}_{control}$ denote sample proportion for a dichotomous variable in speciality and conventional coffee producers, respectively. The results are presented in Table 3.

2.2.2.4 Assessment of effects of quality coffee production on adaptation to climate change. The effect of the quality coffee production on adaptation to climate change was assessed in the matched subsample ($n = 92$ pairs). In effect, unbiased comparison between subjects with the same or similar propensity scores from the speciality and conventional coffee producers was undertaken. Therefore, subjects from the two groups with the same PS were assumed to be comparable as the covariates were balanced. Hence, if Y_1 denotes the potential outcome (adaptation to climate change) conditional on quality coffee production and Y_0 denotes the potential outcome conditional on conventional coffee production; the effect of quality coffee production Di is given by:

$$D_i = Y_{1i} - Y_{0i} \tag{5}$$

Here, 1 refers to treatment and 0 refers to non-treatment.

To evaluate treatment effect over the entire population, the authors found the average treatment effect (ATE):

$$\mathrm{ATE} = \mathrm{E}[\mathrm{D_i}] = \mathrm{E}(\mathrm{Y_1} - \mathrm{Y_0}) \tag{6}$$

Beyond the ATE, the average treatment effect for the treated (impact) was estimated as follows:

$$\mathrm{ATT} = \mathrm{E}\left(\mathrm{Y_1} - \mathrm{Y_0}/\mathrm{D_i} = 1\right) = \mathrm{E}\left(\mathrm{Y_1}/\mathrm{D_i} = 1\right) – \mathrm{E}\left(\mathrm{Y_0}/\mathrm{D_i} = 1\right) \tag{7}$$

where Y_1 is the outcome (adaptation) in the treated condition; Y_0 is the outcome in the control condition; and the D_i indicator variable (treatment status) denoting participation in quality coffee production. Finally, the odds ratio or marginal probabilities of the occurrence of the outcome (adaptation) were computed for binary outcomes as a measure of treatment effects (Austin, 2011).

2.2.3 Qualitative data collection. Focus group discussions (FGDs), in-depth interviews and field observation were used to collect qualitative data; these methods enable exploring questions with participants with the flexibility for asking further questions to clarify responses. The qualitative component of this study provides additional data to establish a deeper understanding on adaptation practices by coffee production types. Four FGDs were conducted with 7–10 participants of different ages, men/women, speciality and conventional coffee producers. For in-depth interviews, 16 farmers were selected (four from each of the four sub districts) and interviewed. The diversity of participants in the FGDs and in-depth interviews was maintained by consulting local experts. They were selected on a purposive sampling procedure, so it included both males and females aged between 28 and 79 with long-term knowledge of the area. Field observation was undertaken on the sites of coffee production for a month.

The FGDs and in-depth interviews were guided by checklists that included topics on:

- How they described quality coffee production?
- What they believed about the role(s) of quality coffee production in climate change adaptation?

What they believed adaptation practices as viable in their respective coffee production types. The interview questions were pre-tested with some participants during the preliminary field visit and some changes were made to adjust it to local circumstances. The interviews were continued until saturation was reached; until there was a repetition in the expression of themes and little new information was expressed (Skovdal and Cornish,2015). Analysis of the qualitative data involved coding, searching for underlying concepts, building themes and explaining overarching themes about the settings of quality coffee production and climate change adaptation.

3. Results

3.1 Propensity scores

The propensity score was estimated using a logistic regression model of the probability of participating in quality coffee production based on the set of pre-tested covariates. The distribution of propensity scores is shown in Figure 2. The box plot representation of the propensity scores before and after propensity score matching indicates the degree to which propensity score matching had achieved balancing covariates between the two groups.

Standardized differences of the means were computed for each of the 14 covariates in the sample, and comparable balance was achieved using the propensity score matching (Tables 2 and 3). For the categorical variables, the standardized mean differences (d) before and after matching were computed based on the proportions of the values for each group equation (4), and summarized in Table 2. As shown in Table 2, while the values are greater than the absolute value of 0.2 before matching (except for educational level), those values that are less after matching indicate the propensity score matching was successful for further analysis.

Table 3 also depicts that while all the numerical covariates exhibited a significant difference between the groups and imbalance for comparison ($d > 0.2$) before PSM, a good balance ($d < 0.2$) was found after the PSM equation (3), which indicated effective balancing of the covariates for further analysis.

3.2 Effect of quality coffee production on adaptation to climate change

The main adaptation practices related to coffee production were assessed in terms of the average treatment effect on the treated (ATT). Logistic regression was used to estimate the marginal odds ratio of these adaptation practices as binary outcomes of quality coffee production by smallholders, and summarized in Table 3. The estimated marginal odds ratio for cultivar selection as adaptation practice was 0.53 (95% CI: [0.37, 0.68]). The effect of quality coffee production on the odds of cultivar selection was statistically significant ($p < 0.001$). This implies that the probability of using cultivar selection by the speciality coffee producers would be about 0.53 times greater than the probability that would be if they were conventional coffee producers. This highlights that quality coffee production had a statistically significant effect on the cultivar selection as an adaptation practice. In particular, speciality coffee producers recognized the need for new varieties of coffee that produced better yield in the face of climate change, as they mainly work to increase yield and quality targeting the global demand for quality coffee.

The estimated marginal odds ratio for irrigation use was 0.1 (95% CI: [−0.08, 0.28]), with no statistically significant difference (p = 0.27). The estimated effect of quality coffee production on mulching was −0.03 (−0.08, 0.28), with no significant effect (p = 0.75). Both groups of coffee farmers mentioned that they used grasses and enset (*Ensete ventricosum*) trashes to mulch the ground under coffee plants to increase moisture retention and

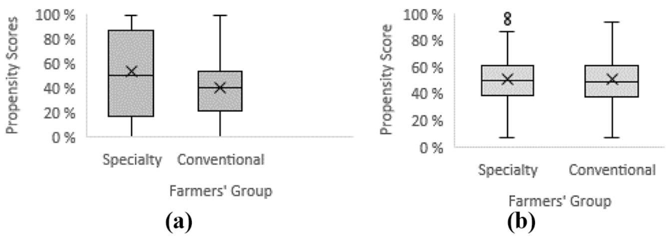

Figure 2.
Distribution of the propensity scores before (a) and after (b) matching

Table 2. Categorical variables' balances before and after matching

Covariates	Coffee Group	Before matching Mean	Before matching Standardized Mean difference	After matching Mean	After matching Standardized Mean difference
Sex of the HH head (% of male)	Specialty coffee	0.89	0.25	0.98	0.00
	Conventional coffee	0.80		0.98	
Education of the HH head (% of literate)	Specialty coffee	0.75	−0.14	0.56	0.04
	Conventional coffee	0.81		0.54	
Access to extension (% access)	Specialty coffee	0.52	0.54	0.75	0.04
	Conventional coffee	0.39		0.73	
Access to credit (% of access)	Specialty coffee	0.40	0.65	0.60	0.14
	Conventional coffee	0.13		0.52	
Cooperative membership (%)	Specialty coffee	0.32	−0.76	0.14	−0.16
	Conventional coffee	0.67		0.20	
Perceptions about climate change(%)	Specialty coffee	0.92	0.21	0.94	0.02
	Conventional coffee	0.85		0.93	

Note: Before matching (N = 120 for speciality and N = 232 for conventional coffee producers) and after matching (N = 92 for each groups)

Table 3.
Covariates (numerical variables) balance before and after matching the groups

Covariates	Before propensity matching			After propensity matching		
	Speciality Mean (SD)	Conventional Mean (SD)	*Standardized mean difference (d)*	Speciality Mean (SD)	Conventional Mean (SD)	*Standardized mean difference (d)*
Age of HH head (years)	40.4 (12.5)	44.0 (13.3)	−0.27	39.3 (12.7)	9.3 (13.6)	−0.008
Coffee farm size (ha)	2.0 (0.3)	0.7 (0.6)	0.36	2.0 (0.3)	2.0 (0.4)	0.055
Distance of plots from pulp center (km)	1.9 (1.7)	2.8 (2.3)	0.70	1.9 (1.7)	1.9 (1.6)	−0.010
Experience in coffee farming (years)	21.9 12.2)	24.8 (12.7)	0.80	27.7(14.9)	27.7 (15.5)	−0.005
Household size (number)	10.5 (4.7)	8.4 (4.3)	0.90	9.5 (4.3)	9.4 (4.4)	0.007
Land holding size (ha)	2.1 (0.8)	0.8 (0.7)	1.1	2.2 (0.5)	2.1 (0.3)	0.011
No of plots (number)	3.2 (1.6)	2.6 (1.5)	0.50	3.0 (1.4)	3.0 (1.5)	0.009
No of coffee plots (number)	2.4 (1.5)	1.9 (1.0)	0.48	2.0 (1.1)	1.9 (1.1)	0.081
Propensity score	0.5 (0.2)	0.3 (0.2)	0.49	0.5 (0.1)	0.5 (0.1)	0.06

efficiently use the limited available water. Mulching increases infiltration and improves soil moisture and helps coffee farmers make their coffee production systems more resilient to climate variability. The estimated marginal odds ratio for rainwater harvesting was 0.7 (95% CI: [0.6, 0.8]); indicating a significant effect of quality coffee production on this adaptation practice ($p < 0.001$). This indicates speciality coffee farmers are 0.7 times more likely to undertake rainwater harvesting than it would be if all of them were conventional coffee producers. Informal discussions with coffee producers and field observations also confirmed that speciality coffee farmers were more likely to undertake rainwater harvesting than conventional coffee producers. Rainwater harvesting was used mainly to mitigate effects of dry spells during the coffee growing season.

The estimated marginal odds ratio for shade management was 0.5 (95% CI: [0.38, 0.68]), with statistically significant effect of quality coffee production on shade management ($p <$ 0.001). This means the probability that speciality coffee producers undertake shade management was 0.5 times greater than that would be if these farmers were not participating in speciality coffee production. In-depth interviews with the sub-district experts also revealed that speciality coffee producers practiced shade management more than conventional coffee producers did. Shade trees planted near coffee plants have the ability to block out the sun's direct impact on the plants and modify the local climate, reducing by up to 5^0C (Bongase, 2017). During fieldwork, it was observed that more frequent and modified shade trees existed in the speciality coffee famers' farms than in the conventional coffee farmers' farms. For example, while the optimal shade cover for coffee production is 40%–50% (Denu *et al.*, 2016), in-depth interviews indicated that coffee farmers did not have awareness about the optimal level of this shade cover.

Shifting coffee seedlings time was another adaptation practice identified in the study area. The estimated marginal odds ratio for shifting coffee seedlings time was 0.5 (95% CI: [0.37, 0.62]), with statistically significant effect of quality coffee production on undertaking this adaptation practice (p <0.001). This indicated that speciality coffee farmers were 0.5 times more likely to carry out shifting nursery seasons of coffee seedlings than that would be if they were conventional coffee producers. Focus group discussions with district experts also indicated speciality coffee producers were more likely to shift nursery periods of coffee seedlings based on the onset and offset of the rainy season, mainly due to their closer links to extension workers from the local coffee development department and better access to information about demand for quality coffee in the global market.

The estimated marginal odds ratio for crop diversification was −0.3 (95% CI: [−0.42, −0.07]). The effect of quality coffee production on the odds of crop diversification was statistically significant (p = .006). This implies that specialty coffee farmers were 0.3 times less likely to used crop diversification as adaptation practice than that would be if all of them were conventional coffee producers. Participants from the conventional coffee producers also believed that crop diversification through intercropping and rotation with the coffee plants would help buffer against coffee yield risks caused by climatic adversities and was considered as an economic way out during thin coffee seasons. It was also confirmed from field observation that conventional coffee growers cultivated multi-cropped coffee farms, particularly comprising enset (*Ensete ventricosum)*, avocado *(Persea americana*) and banana (*Musa acuminata*).

Expectedly, the estimated marginal odds ratio for shifting to other crops in response to worries about the climate sensitivity of coffee plants was −0.06 (95% CI: [−0.21, 0.09]), showing no statistically significant effect of quality coffee production (p = 0.46). This suggests that the probability speciality coffee producers would shift to other crops from coffee production was 0.06 times less than that would be if none of the farmers had participated in quality coffee production. Shifting out of coffee production is not an easy option due to the strong attachment to the coffee cultivation and cultural acceptance of alternative crops in the study area. A coffee development expert from Yirgacheffe district recounted that "the local community chooses to die with dried coffee tree(s) due to climate change than shifting to other crops." This implies that coffee production in the study area is not only a matter of economic aspect of livelihoods but it also encompasses cultural aspects shared among the different generations of the local community (Table 4).

The estimated marginal odds ratio for undertaking off-farm activities was −0.22 (95% CI: [−0.35, 0.08]), with statistically significant effect of quality coffee production on it (p = 0.002). This indicated speciality coffee producers were 0.22 times less likely to engage in off-farm activities than it would be if none of the farmers were participating in speciality coffee production. In other words, conventional coffee farmers were more likely to engage in off-farm activities. FGDs also indicated that smallholders (mainly conventional coffee producers) had resorted to other small-scale businesses such as petty trading and wage employment in construction. The marginal odds ratio for migration was −0.3 (95% CI: [−0.47, −0.11]), with statistically significant difference between the two groups of coffee producers (p = 0.002). This implies that the probability to migrate in response to climate change impact for speciality coffee farmers was 0.3 less than the probability that would be if all of them were conventional coffee producers; indicating that conventional coffee farmers were more likely to migrate in response to climate change than the speciality coffee producers.

The average number of coffee trees per household for speciality coffee producers was about 87 trees greater than the average that would be if none of these farmers were participating in quality coffee production at 95% CI: (2.8, 177); with statistically significant difference (p = 0.05). This suggests that quality coffee production contributes to pruning old coffee trees that have been reported to be a problem to improve coffee yield and quality in the study area. The average amount of compost applied per household by speciality coffee producers was about 1.4 m^3/hectare greater than the average that would be if none of these farmers were participating in quality coffee production. The difference in application of compost was statistically significant ($P < 0.001$); indicating that quality coffee production improves application of organic inputs like compost to maintain quality of their coffee production.

Adaptation practices (for Speciality vs conventional coffee farmers)	Coef.	Std. Err.	z	$p > z$	[95% Conf. Interval]
Cultivar selection	0.53	0.08	6.7	0.000**	(0.38,0.68)
Irrigation	0.10	0.09	1.9	0.27	(−0.08, 0.28)
Mulching	−0.03	0.08	0.32	0.75	(−0.17, 0.12)
Rainwater harvesting	0.73	0.06	11.48	0.000**	(0.60, 0.84)
Shade management	0.53	0.07	7.12	0.000**	(0.38, 0.67)
Shifting coffee seedling time	0.50	0.06	7.6	0.000**	(0.37, 0.63)
Crop diversification	−0.25	0.09	−2.73	0.006*	(−0.42, −0.07)
Shifting to other crop production	−0.06	0.08	−0.75	0.46	(−0.21, 0.09)
Off-farm activities	−0.22	0.07	−3.17	0.002*	(−0.35, 0.08)
Migration	−0.30	0.09	−3.17	0.002*	(−0.47, −0.11)
No of pruned coffee trees/year	87.4	46.1	1.90	0.05*	(2.8, 177)
Compost applied(m^3/ha)	1.4	0.18	7.9	0.000**	(1.1, 1.7)

Note: ** and * indicate statistical significance at 0.01 and 0.05 level, respectively

Table 4.
Impact of quality coffee production on adaptation practices by smallholders

In general, the practices that enable to adapt to climate change in the context of quality coffee production were agronomic practices like shade management, pruning and stumping, mulching, small scale irrigation, use of new cultivars of coffee, increasing water efficiency in coffee production and processing and crop diversification that considers the quality and quality of the coffee products. This agrees with the findings of Adane and Bewket (2021) stated that on-farm land use practices would have added benefits to climate change adaptation. Moreover, quality coffee production has a positive effect on cultivar selection, irrigation, shade management, rainwater harvesting, compost application and pruning old coffee trees as adaptation practices. On the other hand, it has a negative effect on migration, crop diversification, off-farm activities, which were reported to be applied by the conventional coffee farmers.

4. Discussion

The results of this study indicate that quality coffee production has positive effects on farm level adaptation to climate change. While almost all of the surveyed farmers undertook different adaptation practices, the impact assessment indicates differences between the two groups compared in terms of extent of use of adaptation practices, which is attributable to quality coffee production. In general, quality coffee producers were more likely to carry out use of new cultivars, rainwater harvesting, shade tree management and shifting nursery seasons for coffee seedlings than the conventional coffee producers. The application of compost and pruning of old coffee trees were also more likely to be carried out by quality coffee producers than conventional producers. The quality coffee producers were more likely to undertake these adaptation practices to maintain quality of their produce in response to the growing demand for quality coffee in the national and global coffee markets.

Both groups of coffee producers undertook irrigation, mulching and shift to other crops with statistically non-significant differences. This might be a reflection of the local circumstance, such as availability water for irrigation and availability of plant leaves and grasses for mulching. Asked about shifting from coffee production to other crops, informants from both groups of coffee producers asserted lack of intention to do so, indicating that coffee production is deeply entrenched in the culture of the local community.

On the other hand, crop diversification, off-farm activities and migration as adaptation options were found to be more likely to be undertaken by the conventional coffee producers than the speciality coffee producers. Crop diversification is an integrated management option, which combines coffee production with food crops production, to increase opportunity of the farmers to get subsistence income and livelihoods. It was learned that as conventional coffee producers had lower cash income to buy food than the speciality producers, they tend to produce food crops on their coffee farms. Migration and off-farm activities like local petty trading and daily labor were more likely to be used by the conventional producers because of their lower cash incomes from their coffee farms.

Our findings are generally consistent with findings from earlier similar studies that have reported better on-farm adaptation practices of quality coffee producers than conventional producers (Lin, 2007). Similarly, Burnham and Ma (2016) and Denu *et al.* (2016) concluded that quality coffee production contributes to climate change adaptation. Apparently, speciality coffee producers worked to increase quality and yield of their coffee to meet the growing quality standards (e.g. organic), and in the process they undertake different adaptation practices.

5. Conclusion

This study reveals that coffee farmers adjusted their farming practices to adapt their coffee production to climate change. It also found that a significant association exists between most adaptation practices and quality coffee production. The findings highlight how quality coffee production influences adaptation practices. While off-farm adaptation practices were more likely to be carried out by conventional coffee producers, speciality coffee producers were more likely to undertake mostly on-farm adaptation practices to maintain quality of their production for the national and global markets. This indicates that particularly the global demand for quality coffee drives smallholders' decisions to undertake various quality-maintaining adaptation practices to climate change. While further research is needed to firmly establish connections between climate change adaptation practices and the demand for quality coffee at "a distance," this study concludes that the demand for quality coffee in the global market influences adaptation practices by smallholders in coffee producing areas and countries. In terms of methods, this study demonstrates that the propensity score matching method is a useful approach to assess the effects of quality coffee production on adaptation to climate change by balancing confounding factors that are deemed important.

Note

1. Regional refers to one of the federating states of Ethiopia in Southern Ethiopia.

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