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Fikadu MITIKU ^{1,2}, Jan NYSSSEN ³ and Miet MAERTENS ²

Abstract

We analyze whether private sustainability standards can promote land-sharing between coffee cultivation and forest conservation in southwestern Ethiopia. We compare garden and forest coffee systems, including non-certified and Rainforest Alliance (RA) certified forest coffee, and evaluate yields, productivity and profits. We use original household- and plot-level survey data from 454 households and 758 coffee plots, and ordinary least squares and fixed effects regression models. We find that coffee intensification from semi-forest coffee to garden coffee does not yield any substantial economic benefits in terms of productivity or profit. We find that RA certification increases land and labor productivity and profits of semi-forest coffee production, mainly by guaranteeing farmers a better price and not by improving yields. These findings imply that in southwestern Ethiopia land-sharing between less intensive coffee production and conservation of forest tree species is a viable sustainability strategy from an economic point of view, and that coffee certification is a viable strategy to promote land-sharing and create the economic incentives for farmers to refrain from further coffee intensification.

Key Words: Forest coffee, Land-sharing, Rainforest Alliance, Coffee intensification, Sustainability Standards, Ethiopia

JEL classification: O13, Q12, Q17, Q18, Q56, Q57,

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1. Introduction

Sustainable agricultural production is a challenge. Especially in developing countries the trade-offs between socio-economic goals of increasing rural incomes and decreasing poverty and environmental goals such as biodiversity conservation are large (Bekessy et al., 2010). There is an ongoing debate on whether sustainability is best achieved through land-sharing or land-sparing (Green et al., 2005, Kremen, 2015, Kremen and Miles, 2012, Phalan et al., 2011, Tscharntke et al., 2012). The first entails the integration of both biodiversity conservation and agricultural production on the same land, presuming a less intensive production system and lower yields. The latter entails intensifying agricultural production to obtain higher yields on farmland while protecting other land from agricultural encroachment and sparing it for biodiversity conservation. Some ecological studies conclude land-sparing to be most beneficial for biodiversity conservation (Law et al., 2015, Phalan et al., 2011) while others find comparable biodiversity outcomes from both strategies (Yoshii et al., 2015). The economic outcomes and livelihood implications of these strategies have hardly been addressed – some exceptions include studies by Dressler et al. (2016) who include livelihood portfolios in an analysis on land-sharing in varied landscapes in the Philippines and Lusiana et al. (2012) who do take into account farmers' profits in exploring land-sharing for livestock fodder cultivation in Indonesia. With this study we contribute to filling this knowledge gap on the economic implications of land-sharing strategies.

We analyze whether private sustainability standards can promote land-sharing between coffee cultivation and forest conservation in Ethiopia. In particular, we investigate the economic benefits of coffee intensification and of Rainforest Alliance (RA) certification of less-intensive forest coffee systems. We compare garden and semi-forest coffee systems, including non-certified and RA certified semi-forest coffee, and evaluate yields, productivity and profits. We use original household- and plot-level survey data from 454 households and 758 coffee plots in Jimma and Kaffa zones in southwestern Ethiopia. We apply ordinary least squares regression models, controlling for a large set of plot- and household-level observable characteristics, and fixed effects regression models in which household-level unobservable heterogeneity is controlled for.

The focus on coffee is particularly relevant. The debate on land-sharing versus land-sparing as a sustainability strategy is especially fierce for coffee and other commodities that are grown at higher altitudes in forest marginal areas and that are vital for countries' foreign

exchange earnings and for the livelihoods of a large share of the population. A number of ecological studies point to negative effects of coffee intensification on biodiversity conservation (Hundera et al., 2013b, Hundera et al., 2013a, Hylander et al., 2013). Such studies rarely take into account economic benefits and work under the assumption that coffee intensification increases productivity and farm incomes; thereby assuming a trade-off between ecological and economic goals. There is only a handful of studies taking into account yields, and sometimes costs and revenues, in evaluating the implications of coffee intensification versus land-sharing between coffee production and forest conservation. Noponen et al. (2013) confirm that coffee intensification increases profits in Costa Rica, while other studies from Mexico and Indonesia show that coffee intensification does not improve yields or economic returns (Romero-Alvarado et al., 2002, Philpott et al., 2008, Peeters et al., 2003).

The focus on private sustainability standards as a tool to promote more sustainable agricultural production through land-sharing, and the particular focus on RA is relevant as well. Private standards are spreading rapidly in many agri-food sectors, and often promise to minimize the trade-offs between food production and biodiversity conservation, and to foster more sustainable production systems (Pinto et al., 2014). For example, RA is a market based mechanism that seeks to transform agriculture into a sustainable activity that strives to conserve on-farm biodiversity and improve livelihoods (Rainforest Alliance, 2015a) – and thereby implicitly supports a land-sharing strategy. RA certification is expanding and in 2014 RA certified farms accounted for 15.1% of world tea production, 13.6% of cocoa and 5% of coffee production (Rainforest Alliance, 2015b). Ecological studies show that RA enhances tree cover, forest quality and forest connectivity in coffee landscapes (Rueda et al., 2015, Takahashi and Todo, 2013, Takahashi and Todo, 2014, Hardt et al., 2015, Takahashi and Todo, 2017). Economic studies indicate that RA certification increases yields and incomes and reduces poverty – e.g. in Nicaragua (Ruben and Zuniga, 2011) and Ethiopia (Mitiku et al., 2017). Perfecto et al. (2005) raise doubt on the beneficial impact of RA certification and argue that the price premium for certified coffee does not compensate for low yields in less intensified shade coffee systems in Mexico. Most of these economic studies on the impact of RA (and other eco-) certification, however, do not take into account the intensification gradient in coffee production systems and do not control for plot-level heterogeneity.

Also the focus on Ethiopia is relevant. Land-sharing between coffee production and biodiversity conservation is a common practice in the Afromontane forest of southwestern Ethiopia, the birth place of *Coffea arabica* and known for its rich biodiversity. Nevertheless, forest thinning for coffee intensification and for conversion into other cropland is an on-going

process, accounting for over 36% forest cover loss in the last four decades in the region (Aerts et al., 2013, Hundera et al., 2013b, Getahun et al., 2013, Tadesse et al., 2014). RA certification was introduced in the coffee sector in southwestern Ethiopia in 2007 to exclusively certify coffee from forest coffee production systems. In this paper we investigate whether RA certification can prevent further intensification of forest coffee systems and promote land-sharing as a sustainability strategy.

2. Background

2.1. Coffee production systems in Ethiopia

Ethiopia is the main coffee producing country in Africa and the fifth worldwide (International Coffee Organization, 2013). Coffee accounts for 24% of Ethiopia's foreign exchange earnings (Minten et al., 2014) and contributes to the livelihood for more than a quarter of the country's population (Tefera and Tefera, 2014). Over the period 1990 to 2013, coffee production increased from 2.9 million bags (with one bag equivalent to 60 kg) to 8.1 million bags; and exports increased from 0.85 to 3.2 million bags (International Coffee Organization, 2013). About 95% of coffee production is realized by smallholder farmers with average landholdings below 2 ha and sometimes organized in cooperatives (Francom and Tefera, 2016).

Coffee is produced under four different production systems, along an intensification gradient: forest coffee accounting for 10% of total coffee production; semi-forest coffee accounting for 35%; garden coffee for 50%; and plantation coffee for 5% (Kufa, 2012). Forest coffee is not planted but is picked from natural coffee shrubs in undisturbed or less disturbed natural forests with no or very limited management efforts (Hundera et al., 2013b). Semi-forest coffee is produced in relatively disturbed natural forests where the upper canopy is thinned and coffee is sometimes randomly planted in the forest to increase the number of shrubs and coffee yields (Gole et al., 2008). Farmers usually slash undergrowth once a year to reduce competition for soil nutrients with other species. Garden coffee is planted on small-scale agricultural plots either in monoculture with scattered shade trees or intercropped with fruit trees, spices, false banana (*Enset ventricosum*) and khat (*Catha edulis*). Coffee plantations are large-scale coffee farms established by larger private investors with modern production techniques. While forest, semi-forest and garden coffee production systems have a long tradition in Ethiopia, coffee plantations are more recent. Coffee yields increase along this intensification gradient and are estimated at 50 to 150 kg of green coffee per ha for forest coffee, 100 to 200 kg/ha for semi-forest coffee, 400 to 500 kg/ha for garden coffee and 450-750 kg/ha for plantation coffee (Wiersum et al., 2008).

Coffee intensification and coffee expansion are responsible for substantial forest cover loss in Ethiopia. It has been estimated that in the last four decades in Southwestern Ethiopia, the conversion of forest coffee to semi-forest coffee resulted in a 34% reduction in woody forest species and the conversion of semi-forest coffee to garden coffee in a 37% species reduction (Tadesse et al., 2014). Coffee intensification is responsible for an important part of the forest cover loss of more than 50, 000 ha between 1973 and 2009 in three zones in Southwestern Ethiopia (Tegegne, 2017)

2.2. Rainforest Alliance Coffee Certification in Ethiopia

Private sustainability standards started to emerge in the coffee sector in Ethiopia quite recently, starting with Fairtrade and Organic standards in 2005 and followed by Rainforest Alliance (RA) and Utz standards in 2007 (Stillmacher and Grote, 2011). Fairtrade and Organic standards are the most widespread and mostly certify garden coffee; whereas RA is less widespread and exclusively certifies forest and semi-forest coffee. RA certification was introduced in Ethiopia with the support of the Japan International Cooperation Agency (JICA) and under the auspices of the Oromia Forest and Wildlife Enterprise (OFWE) which is responsible for forest conservation and participatory forest management in the Oromia Region. In the light of RA certification, farmers with forest and semi-forest coffee are organized in small participatory forest management groups known as *Waldaa Bulchiinsa Bosonaa* (WaBUB) in the Oromo language (*Afan Oromo*). These farmer groups are trained by OFWE in order to produce coffee according to the criteria of the Sustainable Agriculture Network (SAN) which is required for RA certification. To become RA certified, farmers are audited against a multitude of criteria organized under 10 principles, including management system, ecosystem conservation, wildlife protection, water conservation, working conditions, occupational health, community relation, integrated crop management, soil conservation, and integrated waste management (Rainforest Alliance, 2015a). In RA certification has to be renewed every year based on rigorous inspection of individual farmers' forest and semi-forest plots.

By 2010, the number of farmers supplying RA certified coffee in Ethiopia increased to 3050 (Takahashi and Todo, 2014). RA certified farmers usually supply dried coffee cherries to OFWE, where the coffee is dry-processed into green coffee beans and directly exported. The export supply chain for RA certified coffee is shorter than for other coffee, which is mostly supplied to coffee cooperatives, from where it is transported to cooperatives unions and exported through the Ethiopian Commodity Exchange (ECX) (Mitiku et al., 2017).

3. Data and Methods

3.1. Research area and data collection

We conducted this study in Jimma and Kaffa zones in southwestern Ethiopia. We collected household and plot level data in 2014 from a quantitative survey among 454 smallholder coffee producers; and qualitative data from semi-structured interviews with key informants in the coffee sectors. A multi-stage stratified random sampling strategy was used to select smallholder coffee farmers. Four districts in the two zones were purposively selected based on the presence of coffee certification schemes and the extent of forest, semi-forest and garden coffee cultivation: three districts from Kaffa zone and one district from Jimma zone were selected. In all but one district, two coffee cooperatives were selected from which a list of member farmers was obtained. Due to a low number of active coffee cooperatives, in one of the selected districts only one cooperative was selected and a list of non-cooperative farmers was added to the sampling frame. Finally, coffee farmers were randomly selected from the obtained lists. The sample includes 454 coffee farmers of which 81 are RA certified. From these farmers, we obtained detailed plot level data for all coffee plots, resulting in information from 758 coffee plots, including 399 garden coffee plots and 359 semi-forest coffee plots. The latter include 156 RA certified plots (RA plots) and 203 non-RA certified plots (NRA plots).

The survey was implemented using a structured questionnaire, consisting of detailed modules on household characteristics, land ownership and land use, coffee production and marketing, other crop production, livestock ownership and production, forest use, off-farm income, asset ownership and living conditions, and social capital. In addition, plot coordinates and elevations were collected using GPS devices. The data were collected by well-trained enumerators.

3.2. Descriptive and Econometric Analysis

In our analysis we focus on four outcome indicators: coffee yield, return to land, return to labor and profit. Coffee yield is calculated as the ratio of dry coffee cherry equivalent to the coffee area, and expressed in kg per ha. Return to land is calculated as the ratio of net coffee income to coffee area, and expressed in Ethiopian Birr (ETB) per ha. Net coffee income is calculated as the total revenue from selling coffee minus variable costs for coffee production, marketing and certification, including costs for hired labor. Return to labor is calculated as the ratio of net coffee income to total man-days (MD) of family labor used for coffee production and processing, and expressed in ETB per MD. Coffee profit is calculated as the net income from coffee minus the opportunity costs of family labor. Family labor is valued at the national

minimum wage – which is justified given the very limited off-farm employment opportunities in the research area.

We describe relevant household and plot level variables, making a distinction between RA certified and non-RA certified households and plots, and between garden and semi-forest plots. To reveal the impact of coffee intensification and coffee certification, we use different econometric models estimated at the plot level. First, we estimate the following linear regression models:

$$Y_{ij} = \alpha + \beta SF_{ij} + \delta P_{ij} + \tau X_j + a_j + \mu_{ij} \quad (1)$$

$$Y_{ij} = \alpha + \partial NRA_{ij} + \gamma RA_{ij} + \delta P_{ij} + \tau X_j + a_j + \mu_{ij} \quad (2)$$

Regressions are estimated separately for each of the four outcome variables Y_{ij} : coffee yield, return to land, return to labor and profits for plot i and household j . The main variable of interest in equation (1) is SF_{ij} , a binary variable indicating whether the plot is a semi-forest plot ($SF_{ij} = 1$) or a garden plot ($SF_{ij} = 0$). The main variables of interest in equation (2) are NRA_{ij} and RA_{ij} , binary variables indicating whether a plot is a semi-forest non-RA certified plot ($NRA_{ij} = 1$) respectively whether a plot is a semi-forest RA certified plot ($RA_{ij} = 1$). The estimated parameters β , ∂ and γ capture the differences in productivity and profits between garden and semi-forest plots; between garden and non-certified semi-forest plots; and between garden and certified semi-forest plots respectively. A comparison of these parameters allows to discuss productivity and profitability differences of coffee intensification and coffee certification. To control for observed heterogeneity, the models include a first vector of control variables P_{ij} representing plot level agro-ecological and other characteristics that may influence coffee yields and productivity. The vector includes the coffee area (in ha), the age of coffee shrubs (years), soil type (binary variables for Humic Nitisols, Humic Alisols and Lithic Leptosols), slope (degrees), distance from a road (m), distance from the cooperative (m), distance from a river (m), and elevation (m). The age of the coffee shrubs is revealed from the household survey data while all other plot level characteristics are derived from GPS and GIS information. A second vector of control variables X_j represents human, physical and social capital indicators at the household level: age, gender and education of the household head, number of workers and number of dependents in the household, number of livestock units owned (in TLU) and the number of relatives in the region. The models include a composite error terms comprising a household specific component a_j and a plot specific component μ_{ij} . The models are estimated using ordinary least squares (OLS) and heteroskedasticity-robust standard errors are reported.

Second, we estimate the fixed effects models specified in equations (3), (4) and (5). While including a large number of plot and households level control variables in the regressions above, the estimates might still suffer from endogeneity bias related to unobserved heterogeneity being correlated with coffee certification and productivity. To control for unobserved heterogeneity at the household level, we exploit the fact that a substantial share of households in the sample have both a garden and a semi-forest (either non-certified or certified) plot and apply a panel fixed effects approach with plot (instead of time) demeaned data – an approach suggested by Barrett et al. (2004) and applied by Minten et al. (2007) and Reira and Swinnen (2016). In fixed effects model (3), we use a subsample N_1 of 112 households owning at least one garden and at least one semi-forest plot, and perform a fixed effects transformation with plot-demeaned data⁴. Likewise, in model (4) and (5) we do a fixed effects transformation on a subsample N_2 of 54 households owning at least one garden and one RA certified semi-forest plot; respectively a subsample N_3 of 58 households owning at least one garden and one non-RA certified semi-forest plot.

$$\dot{Y}_{ij} = \beta' \dot{S}F_{ij} + \delta \dot{P}_{ij} + \ddot{\mu}_{ij}; \quad \forall j \in N_1 \quad (3)$$

$$\dot{Y}_{ij} = \gamma' \dot{R}A_{ij} + \delta \dot{P}_{ij} + \ddot{\epsilon}_{ij}; \quad \forall j \in N_2 \quad (4)$$

$$\dot{Y}_{ij} = \partial' \dot{N}R A_{ij} + \delta \dot{P}_{ij} + \ddot{v}_{ij}; \quad \forall j \in N_3 \quad (5)$$

The estimated parameters β' , ∂' and γ' capture within household productivity and profitability differences between garden and semi-forest coffee, between garden and non-certified semi-forest coffee, and between garden and certified semi-forest coffee; and can be interpreted as effects of coffee intensification and coffee certification. In these models plot-constant household level heterogeneity, e.g. stemming from unobserved differences in farmers' ability, entrepreneurship and motivation, is ruled out. Plot level unobserved heterogeneity cannot be ruled out completely but is likely very limited, given we control for a large number of observed plot level characteristics.

4. Results

4.1. Certified and non-certified households

Table 1 presents summary statistics for household characteristics and compares these among non-certified and RA certified households. The level of education in the research area is very low with on average 3.7 years of schooling of the household head. Total farm size is on average

⁴ For the fixed effects models we used the xtreg command in STATA 14, which automatically computes variable means, subtracts the means from the original variables, and runs a regression on the demeaned variables.

2.9 ha of which on average one third is allocated to coffee production. Statistics show that RA certified household are slightly younger than non-certified households, and own less land and livestock. They are more specialized in coffee production than non-certified households; they allocate on average 64% of their land to coffee and have more semi-forest coffee plots.

Table 1: Human, physical and social capital indicators for non-certified and certified households

Variables	Total sample	Non certified households	RA certified households
Human capital			
Female-headed hh	7%	8%	5%
Age of the hh head (years)	45.33 (0.67)	46.32 (0.75)	40.78*** (1.43)
Education of hh head (year)	3.67 (0.16)	3.67 (0.19)	3.64 (0.32)
Number of workers ¹	3.38 (0.07)	3.42 (0.08)	3.19 (0.18)
Number of dependents ¹	3.48 (0.099)	3.49 (0.11)	3.43 (0.25)
Physical capital			
Total farm area (ha)	2.93 (0.13)	3.01 (0.15)	2.52* (0.18)
Coffee area (ha)	0.97 (0.06)	0.83 (0.06)	1.61*** (0.15)
Number of semi-forest plots	0.79 (0.04)	0.54 (0.04)	1.93*** (0.10)
Number of garden plots	0.88 (0.03)	0.91 (0.04)	0.74 (0.07)
Livestock ownership (TLU ²)	4.47 (0.17)	4.855 (0.32)	2.70*** (0.32)
Social capital			
Number of relatives in the region	48.56 (3.92)	49.53 (4.60)	44.07 (55.87)
Number of observations	454	373	81

¹ Workers are household members in the age category 15 to 64 while dependents are household members in the age categories below 15 and above 64.

² Livestock ownership is measured in Tropical Livestock Units (TLU), assigning a weight of 0.7 for cattle and mule, 0.8 for horse, 0.5 for donkey, 0.1 for sheep and goat, and 0.01 for chicken.

Standard errors are given in parentheses. * p<0.1, ** p<0.05, and *** p<0.01 indicate significance levels for a two-sided t-test on the mean differences between non certified and RA certified households.

Source: Authors' calculation based on household survey and GIS data

4.2. Garden and semi-forest certified and non-certified plots

Table 2 presents summary statistics for agro-ecological and physical plot characteristics and compares these for garden, certified and non-certified semi-forest coffee plots. Plots have mostly Humic Nitisols (91.6%), an average slope of 9 degrees, an average elevation of 1,797

meter above sea level, and are located at 3.3 km from a river, 2.4 km from a road and 2.1 km from the coffee cooperative on average.

Table 2: Agro-ecological and physical characteristics of garden and semi-forest certified and non-certified coffee plots

Variables	Total coffee plots	Garden coffee plots	Semi-forest coffee plots		
			All	RA certified	Non certified
Humic Nitisols	91.6%	92%	91%	87% [*]	94.6% ^b
Humic Alisols	6.6%	5%	8% ^{**}	13% ^{***}	4.9% ^c
Lithic Leptosols	1.8%	3%	0.3% ^{***}	0%	0.5%
Slope (degree)	9.10 (0.18)	8.42 (0.24)	9.85 ^{***} (0.28)	11.49 ^{***} (0.46)	8.60 ^c (0.31)
Altitude (m.a.s.l)	1,797 (5.26)	1,797 (7.29)	1,797 (8.78)	1,847 ^{***} (10.12)	1,759 ^{**c} (9.74)
Distance to river (m)	3,269 (63.9)	3,354 (94.7)	3,173 [*] (84.4)	4,006 ^{***} (129)	2,533 ^{***c} (88.6)
Distance to road (m)	2,446 (123.1)	2,629 (198.2)	2,242 [*] (118.9)	2,123 (139.1)	2,334 (225.6)
Distance to cooperative (m)	2,157 (68.04)	1,924 (106.7)	2,416 ^{***} (124.1)	2,686 ^{***} (144.9)	2,208 ^{**c} (99.9)
Number of observations	758	399	359	156	203

Standard errors are given in parenthesis. * p<0.1, ** P<0.05, and *** p<0.01 indicate significance levels for a two-sided t-test on mean differences between garden plots on the one hand, and semi-forest, RA certified semi-forest and non-certified semi-forest plots on the other hand. ^a p<0.1, ^b p<0.05 and ^c p<0.01 indicate significance levels for a two-sided t-test on mean differences between RA certified and non-certified semi-forest plots.

Source: Authors' calculation based on household survey and GIS data

Semi-forest plots are slightly steeper than garden plots and are located a bit closer to rivers and roads but further from cooperatives. Especially RA certified semi-forest plots are steeper and located at a higher altitude than garden plots while non-certified semi-forest plots are located at a slightly lower altitude than garden plots. RA certified semi-forest plots are more likely to have Humic Alisols than garden and non-certified semi-forest plots; and are located further from rivers and cooperatives than these plots.

Table 3 presents summary statistics of inputs into coffee production and coffee prices, and compares these for garden, certified and non-certified semi-forest coffee plots. The average coffee area is 0.58 ha and is significantly larger for semi-forest, RA certified as well as non-certified, plots than for garden plots. The average age of the coffee shrubs is 15.6 years and shrubs on semi-forest plots, RA certified as well as non-certified plots, are significantly older than on garden plots.

Table 3: Inputs into coffee production and coffee prices for garden and semi-forest certified and non-certified coffee plots

Variables	Total coffee plots	Garden coffee plots	Semi-forest coffee plots		
			All	RA certified	Non certified
Coffee area (ha)	0.58 (0.03)	0.41 (0.03)	0.77*** (0.05)	0.69*** (0.06)	0.84*** (0.07)
Age of coffee shrubs (years)	15.65 (0.53)	11.84 (0.51)	19.89*** (0.92)	21.94*** (1.28)	18.31*** ^a (1.29)
Coffee shrubs per ha	5,834 (697)	7,008 (1,217)	4,530** (576)	4,198* (334)	4,784 (987)
Family labor (man- day/ha)	260.98 (31.56)	305.91 (41.31)	211.04* (48.22)	226.51** (99.89)	199.15** (37.47)
Hired labor (man-day/ha)	30.08 (4.63)	28.72 (7.44)	31.59 (5.20)	39.48 (6.83)	25.54 (7.55)
Labor cost (ETB/ha)	802.92 (246.62)	966.87 (463.11)	620.71 (79.85)	828.91 (117.20)	460.70 (107.66)
Capital costs ¹ (ETB/ha)	124.24 (25.81)	130.80 (32.08)	116.95 (41.28)	74.80 (18.79)	149.33 (71.55)
Coffee Price ² (ETB/kg)	15.73 (0.15)	14.92 (0.18)	16.63*** (0.24)	18.33*** (0.38)	15.31 (0.26)
Number of observations	758	399	359	156	203

¹ Capital cost includes costs such as plot audit cost for RA plots, seedling costs, and marketing costs such as transportation cost.

² Information on coffee prices were collected for each coffee plot as semi-forest and garden coffee is usually supplied separately – but it is possible that households mix coffee from different type of plots.

Standard errors are given in parenthesis. * p<0.1, ** P<0.05, and *** p<0.01 indicate significance levels for a two-sided t-test on mean differences between garden plots on the one hand, and semi-forest, RA certified semi-forest and non-certified semi-forest plots respectively on the other hand. ^a p<0.1, ^b p<0.05 and ^c p<0.01 indicate significance levels for a two-sided t-test on mean differences between RA certified and non-certified semi-forest plots.

Source: Authors' calculation based on household survey data

The figures show that semi-forest plots, RA certified as well as non-certified plots, are cultivated less intensively with significantly lower coffee shrub density, significantly less family labor input and lower hired labor and capital costs – although the latter differences are statistically not significant. In general, most labor input into coffee production comes from family labor and costs of coffee production are rather low as input use in coffee production is very limited in the research area. Coffee prices are significantly higher for RA certified semi-forest coffee than for garden coffee, 18.3 ETB/kg compared to 14.9 ETB/kg on average. There is no difference in price for non-certified semi-forest coffee and garden coffee.

Figure 1 presents summary statistics on coffee management practices, and compares these for garden, certified and non-certified semi-forest coffee plots. In general, the use of chemical fertilizer, pesticides and herbicides is extremely low (and not indicated in the figure) but farmers apply animal manure (41%) and compost (18%). Farmers use manual soil tillage (34%), slash the undergrowth (72%), manual weed control (84%), and use cultural and

biological disease (46%) and pest control (35%) on their coffee plots. The figures show that almost all these management practices are more common on garden plots than on semi-forest plots, confirming the more intensive production system in garden coffee. There are also differences between RA certified and non-certified semi-forest plots with RA certified plots being less intensively tilled, fertilized (organically) and managed than non-certified plots.

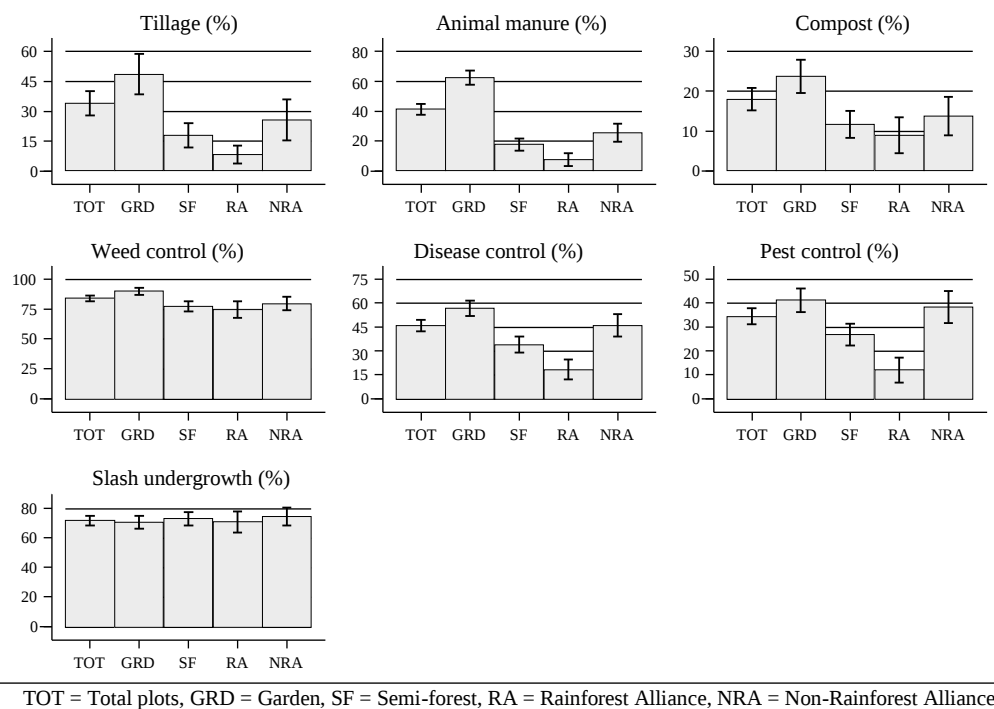


Figure 1: Coffee management practices for garden and semi-forest certified and non-certified coffee plots (error bars represent 95% confidence interval). *Source: Authors' calculation based on household survey data.*

4.3. Coffee productivity and profitability

Figure 2 presents summary statistics on yields, returns to land and labor and profits, and compares these for garden, certified and non-certified semi-forest coffee plots. Coffee yield in dry cherry equivalent is 805kg/ha on average with no differences between garden plots (858 kg/ha) and RA certified plots (841 kg/ha) but with yields on non-certified semi-forest plots being lower (671 kg/ha). The return to land is 11,143 ETB/ha on average and the return to labor 153ETB/man-day. Both the return to land and labor are highest on RA certified semi-forest plots, respectively 14,267 ETB/ha and 213 ETB/man-day compared to 10750 ETB/ha and 121 ETB/man-day for garden plots, and 9,514 ETB/ha and 169ETB/man-day for non-certified semi-forest plots. The average profit from coffee production is 6,452 ETB/ha with the highest profit on RA certified plots (10,419 ETB/ha).

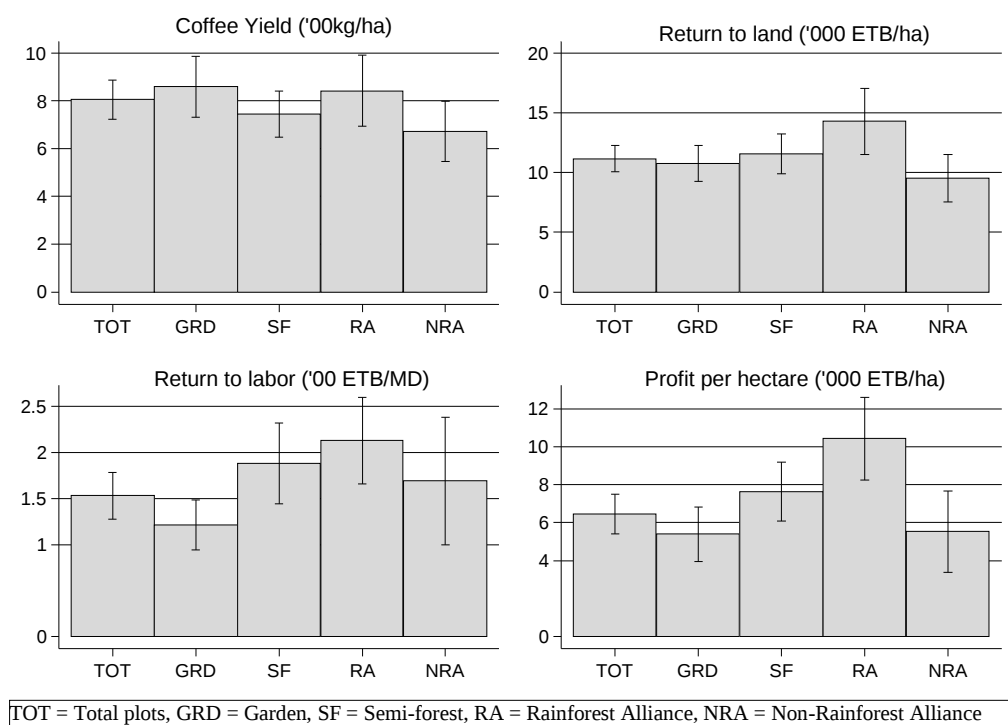


Figure 2: Coffee yields, return to land, return to labor and profits for garden and semi-forest certified and non-certified coffee plots (error bars represent 95% confidence interval).
Source : Authors' calculation based on household survey data

Table 4 summarizes the estimated parameters on semi-forest coffee; RA certified semi-forest coffee and NRA semi-forest coffee, in comparison with garden coffee, from the OLS and fixed effects models. The full regression results are reported in tables A2 to A5 in annex. The results show that, controlling for plot and household observable characteristics and for household-level unobserved effects, there is no significant difference in yield between garden and semi-forest coffee plots, whether RA certified or non-certified semi-forest plots. In addition, there are no significant differences in return to land, return to labor and profits between non-certified semi-forest plots and garden plots. We find significantly higher returns to land, returns to labor and profits on RA certified semi-forest plots than on garden plots, when observable plot and household characteristics are controlled for and when household fixed effects are controlled for.

The signs of the estimated parameters and their significance levels are largely consistent between the OLS models and the fixed effects models. The significant point estimates for RA semi-forest plots differ somewhat between the OLS and fixed effects models with substantially higher estimates for return to labor and profits in the fixed effects model and slightly higher estimates for return to land in the OLS model. These differences in parameter estimates relate

to further reduction in unobserved heterogeneity bias and to using subsamples of the full sample in the fixed effects models. The observed parameters are quite high. Returns to land on RA certified semi-forest plots are 4,217 to 4,962 ETB/ha higher than on garden plots; which implies an increase in return to land of 38 to 45% of the sample average. Returns to labor are 60 to 111 ETB/man-day higher on RA certified semi-forest plots than on garden plots; which imply an increase in return to labor of 31 to 73% of the sample average. Profits are 3,882 to 6,705 ETB/ha higher on RA certified semi-forest plots than on garden plots; which implies an increase in profit of 60 to 113% of the sample average.

Table 4: Summary of estimated parameters for semi-forest, RA certified and non-certified semi-forest coffee from OLS and fixed effects regressions

Outcome variables	OLS models			Fixed effect models		
	Semi-forest	NRA semi-forest	RA semi-forest	Semi-forest	NRA semi-forest	RA semi-forest
Coffee yield	33.71 (91.16)	-22.03 (103.8)	118.73 (109.4)	1.70 (107.9)	59.29 (185.4)	178.58 (113.2)
Return to land	2,364** (1,206)	661.2 (1,367.85)	4,962*** ^b (1,742)	2,283 (1,482)	2,474 (2,929)	4,217** (1,827)
Return to labor	33.72 (27.40)	15.98 (38.38)	60.79** (29.49)	26.95 (26.94)	12.23 (20.11)	111.48*** (40.69)
Profit per ha	1,842 (1,290)	543.6 (1,506)	3,882*** ^b (1,514)	4,234** (1,657)	3,117 (3,502)	6,705*** (1,940)

Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ and ^b $p < 0.05$ for a post estimation test between the RA and NRA coefficients. NRA= Non-certified semi-forest coffee plots, RA=Rainforest Alliance certified coffee plots. Source: *Author's calculation from own survey data*

Some other factors contribute to explaining differences in coffee yields, productivity and profits as well. We find productivity to be higher on smaller coffee plots while the age of the coffee shrubs has a positive but decreasing effect on productivity and profits. Also altitude and slope of the plot matter while the soil type does not influence yields and productivity, which is likely due to the use of a broad soil classification and low variability in soil type within the study area. Education is found to be positively related to productivity, which is in line with expectations. Also livestock ownership is positively related to coffee yields, which is explained by the use of manure for fertilization of coffee plots.

5. Discussion

Our results imply that coffee intensification from semi-forest coffee to garden coffee does not yield any substantial economic benefit. The coffee intensification process in the research area does not result in improved coffee productivity nor in increased profits. This finding contradicts our expectations and results from other studies, e.g. Noponen et al. (2013) who demonstrate that coffee intensification in Costa Rica does result in higher profits. Yet, our finding is in line with other studies from several regions, e.g. Philpott et al. (2008) who find no yield and revenue effect of coffee intensification in Sumatra, Indonesia, Romero-Alvarado et al. (2002) who find no yield effect of coffee intensification in Chiapas, Mexico, and Gordon et al. (2007) who find no income effect of coffee intensification in Mexico. The economic benefits of coffee intensification might be case-study specific. The fact that we do not find a yield and productivity impact of coffee intensification in our study area might relate to a low capital intensity of production and relatively low yields in garden coffee systems. Coffee shrub density is only one third lower in semi-forest coffee systems than in garden systems, and this lower shrub density might be compensated by higher quality coffee and lower alternate bearing due to the provision of shade – as suggested by others (Vaast et al., 2006). Also labor input is one third lower in semi-forest coffee than in garden coffee. Yet, farmers do remove herbs and shrubs in semi-forest coffee in order to reduce nutrient competition by other species and stimulate coffee yields. Our finding that intensification from semi-forest to garden coffee does not increase yields, productivity nor profits implies that in southwestern Ethiopia land-sharing between coffee and forest tree species is a viable strategy from an economic point of view.

Our results imply that RA certification increases productivity and profits of semi-forest coffee production. This effect mainly emerges through a price effect – with prices for RA certified coffee being 23% higher than for non-certified coffee – and not through a yield effect. This is to some extent contradicting findings in the literature. Perfecto et al. (2005) conclude that RA coffee certification in Mexico has no impact because the price premium does not compensate for the lower yield in shade coffee systems. For Nicaragua, Ruben and Zuniga (2011) find that RA certification reduces poverty and enhances household income, but that these effects mainly stem from a positive yield effect. Again, this points to case-study specific effects. The large positive impact of RA certification we find in southwestern Ethiopia, likely relates to the short supply chain for RA certified coffee. RA coffee is supplied directly to OFWE, where it is processed and directly exported (while non-RA coffee is supplied through cooperatives, cooperative unions and the Ethiopian Commodity Exchange) and premium prices are paid directly to farmers. Our finding that certified semi-forest coffee systems result in higher

productivity and profits than intensified garden coffee systems implies that coffee certification is a viable strategy to create economic incentives for land-sharing between less intensive coffee production and conservation of forest tree species.

Our results further imply that plot-level heterogeneity is important to take into account when studying the impact of coffee certification. Many economic studies on the impact of private sustainability standards, in the coffee sector or in other sectors, do not account for differences in production system, agro-ecological characteristics and other plot-level characteristics. Correlation between the location of plots or the age of coffee shrubs on the one hand and certification on the other hand is likely and may lead to bias in estimated effects if plot heterogeneity is not controlled for.

6. Conclusion

In this study, we use detailed household- and plot-level data and OLS and fixed effects models to analyze and compare the economic benefits of coffee intensification and RA certification of forest coffee systems. We find that coffee intensification from semi-forest coffee to garden coffee does not yield any substantial economic benefits in terms of productivity or profits. We find that RA certification increases land and labor productivity and profits of semi-forest coffee production, mainly by guaranteeing farmers a better price and not by improving yields. These findings imply that in southwestern Ethiopia land-sharing between less intensive coffee production and conservation of forest tree species is a viable sustainability strategy from an economic point of view, and that coffee certification is a viable strategy to promote land-sharing and create the economic incentives for farmers to refrain from further coffee intensification.

Our results, along with findings on the ecological benefits of forest coffee production systems in the literature, imply that coffee production in southwestern Ethiopia could be more sustainable if semi-forest coffee production systems are protected from further intensification. The lack of economic benefits from further intensification of semi-forest coffee implies that more stringent conservation measures could be incorporated in the current participatory forest management policies at a low opportunity cost. Certification of forest coffee could be part of such conservation measures. Yet, given that benefits from certification only emerge through a price effect and not through yield effects, further expansion of forest coffee certification schemes may create adverse effects. If consumer demand for certified forest coffee in international markets does not increase substantially, expansion of certification schemes may reduce the price premium farmers receive for certified coffee and diminish economic benefits.

Our study focuses only on the economic dimension of increased coffee intensification and coffee certification; we do not address environmental and ecological outcomes. Substantial evidence is available on the ecological benefits of forest coffee production systems or the consequences of coffee intensification in terms of loss in ecosystem services, biodiversity loss in particular. There is less evidence on the ecological consequences of coffee certification while some certificates such as RA focus specifically on biodiversity conservation. There is scope for ecological and multidisciplinary studies on the sustainability implications of coffee certification. Our study focuses on a rather narrow intensification range, comparing semi-forest and garden coffee, and thereby does not capture the full dimension of land-sharing versus land-sparing. Nevertheless, this focus is relevant as in this range the trade-off between ecological and economic benefits is likely the largest.

References

- Aerts, R., Berecha, G., Gijbels, P., Hundera, K., Van Glabeke, S., Vandepitte, K., Muys, B., Roldán-Ruiz, I. & Honnay, O. (2013). Genetic variation and risks of introgression in the wild *Coffea arabica* gene pool in south-western Ethiopian montane rainforests. *Evolutionary Applications*, 6(2), 243-252.
- Barrett, C. B., Christine, M. M., Oloro, V. M. & Joeli, B. (2004). Better Technology, Better Plots, or Better Farmers? Identifying Changes in Productivity and Risk among Malagasy Rice Farmers. *American Journal of Agricultural Economics*, 86 (4), 869-888.
- Bekessy, S. A., Wintle, B. A., Lindenmayer, D. B., McCarthy, M. A., Colyvan, M., Burgman, M. A. & Possingham, H. P. (2010). The biodiversity bank cannot be a lending bank. *Conservation Letters*, 3(3), 151-158.
- Dressler, W., de Koning, J., Montefrio, M. & Firn, J. (2016). Land sharing not sparing in the “green economy”: The role of livelihood bricolage in conservation and development in the Philippines. *Geoforum*, 76, 75-89.
- Francom, M. G. & Tefera, A. (2016). Ethiopia: Coffee Annual, Coffee Production and Exports Remain Steady. Addis Ababa: USAID Foreign Agriculture Service.
- Getahun, K., Van Rompaey, A., Van Turnhout, P. & Poesen, J. (2013). Factors controlling patterns of deforestation in moist evergreen Afromontane forests of Southwest Ethiopia. *Forest Ecology and Management*, 304 (0), 171-181.
- Gole, T. W., Borsch, T., Denich, M. & Teketay, D. (2008). Floristic composition and environmental factors characterizing coffee forests in southwest Ethiopia. *Forest Ecology and Management*, 255(7), 2138-2150.
- Gordon, C., Manson, R., Sundberg, J. & Cruz-Angón, A. (2007). Biodiversity, profitability, and vegetation structure in a Mexican coffee agroecosystem. *Agriculture, Ecosystems & Environment*, 118(1-4), 256-266.
- Green, R. E., Cornell, S. J., Scharlemann, J. P. W. & Balmford, A. (2005). Farming and the Fate of Wild Nature. *Science*, 307(5709), 550-555.
- Hardt, E., Borgomeo, E., dos Santos, R. F., Pinto, L. F. G., Metzger, J. P. & Sparovek, G. (2015). Does certification improve biodiversity conservation in Brazilian coffee farms? *Forest Ecology and Management*, 357, 181-194.
- Hundera, K., Aerts, R., Beenhouwer, M. D., Overtveld, K. V., Helsen, K., Muys, B. & Honnay, O. (2013a). Both forest fragmentation and coffee cultivation negatively affect epiphytic

- orchid diversity in Ethiopian moist evergreen Afromontane forests. *Biological Conservation*, 159(0), 285-291.
- Hundera, K., Aerts, R., Fontaine, A., Mechelen, M., Gijbels, P., Honnay, O. & Muys, B. (2013b). Effects of Coffee Management Intensity on Composition, Structure, and Regeneration Status of Ethiopian Moist Evergreen Afromontane Forests. *Environmental Management*, 51(3), 801-809.
- Hylander, K., Nemomissa, S., Delrue, J. & Enkosa, W. (2013). Effects of Coffee Management on Deforestation Rates and Forest Integrity. *Conservation Biology*, 27(5), 1031-1040.
- International Coffee Organization. (2013). Available: http://www.ico.org/new_historical.asp [Accessed on 20 December 2014]
- Kremen, C. (2015). Reframing the land-sparing/land-sharing debate for biodiversity conservation. *Annals of the New York Academy of Sciences*, 1355(1), 52-76.
- Kremen, C. & Miles, A. (2012). Ecosystem Services in Biologically Diversified versus Conventional Farming Systems: Benefits, Externalities, and Trade-Offs. *Ecology and Society*, 17(4).
- Kufa, T. (2012). Recent coffee research development in Ethiopia. *Presented at Ethiopian Coffee Export Conference: Strengthening the Legacy of Our Coffee*. Hilton, Addis Ababa.
- Law, E. A., Meijaard, E., Bryan, B. A., Mallawaarachchi, T., Koh, L. P. & Wilson, K. A. (2015). Better land-use allocation outperforms land sparing and land sharing approaches to conservation in Central Kalimantan, Indonesia. *Biological Conservation*, 186, 276-286.
- Lusiana, B., van Noordwijk, M. & Cadisch, G. (2012). Land sparing or sharing? Exploring livestock fodder options in combination with land use zoning and consequences for livelihoods and net carbon stocks using the FALLOW model. *Agriculture, Ecosystems & Environment*, 159, 145-160.
- Minten, B., Randrianarison, L. & Swinnen, J. (2007). Spillovers from high-value agriculture for exports on land use in developing countries: evidence from Madagascar. *Agricultural Economics*, 37(2-3), 265-275.
- Minten, B., Tamiru, S., Kuma, T. & Nyarko, Y. (2014). Structure and Performance of Ethiopia's Coffee Export Sector. *Working Paper 66*. Addis Ababa: International Food Policy Research Institute (IFPRI).
- Mitiku, F., de Mey, Y., Nyssen, J. & Maertens, M. (2017). Do Private Sustainability Standards Contribute to Income Growth and Poverty Alleviation? A Comparison of Different Coffee Certification Schemes in Ethiopia. *Sustainability*, 9(2), 246.
- Noponen, M. R. A., Haggard, J. P., Edwards-Jones, G. & Healey, J. R. (2013). Intensification of coffee systems can increase the effectiveness of REDD mechanisms. *Agricultural Systems*, 119, 1-9.
- Peeters, L. Y. K., Soto-Pinto, L., Perales, H., Montoya, G. & Ishiki, M. (2003). Coffee production, timber, and firewood in traditional and Inga-shaded plantations in Southern Mexico. *Agriculture, Ecosystems & Environment*, 95(2-3), 481-493.
- Perfecto, I., Vandermeer, J., Mas, A. & Pinto, L. S. (2005). Biodiversity, yield, and shade coffee certification. *Ecological Economics*, 54(4), 435-446.
- Phalan, B., Onial, M., Balmford, A. & Green, R. E. (2011). Reconciling Food Production and Biodiversity Conservation: Land Sharing and Land Sparing Compared. *Science*, 333(6047), 1289-1291.
- Philpott, S., Bichier, P., Rice, R. & Greenberg, R. (2008). Biodiversity conservation, yield, and alternative products in coffee agroecosystems in Sumatra, Indonesia. *Biodiversity and Conservation*, 17(8), 1805-1820.

- Pinto, L. F. G., Gardner, T., McDermott, C. L. & Ayub, K. O. L. (2014). Group certification supports an increase in the diversity of sustainable agriculture network–rainforest alliance certified coffee producers in Brazil. *Ecological Economics*, 107(0), 59-64.
- Rainforest Alliance. (2015a). *Rainforest Alliance, Certification, Verification and Validation Services* [Online]. Available: <http://www.rainforest-alliance.org/certification-verification> [Accessed on 04 January 2016].
- Rainforest Alliance. (2015b). *SAN/Rainforest Alliance Impacts Report. Evaluating the Effects of the SAN/Rainforest Alliance Certification System on Farms, People, and the Environment* [Online]. Available: http://www.rainforest-alliance.org/sites/default/files/publication/pdf/SAN_RA_Impacts_Report.pdf [Accessed on 04 January 2016].
- Riera, O. & Swinnen, J. (2016). Household level spillover effects from biofuels: Evidence from castor in Ethiopia. *Food Policy*, 59, 55-65.
- Romero-Alvarado, Y., Soto-Pinto, L., García-Barrios, L. & Barrera-Gaytán, J. F. (2002). Coffee yields and soil nutrients under the shades of Inga sp. vs. multiple species in Chiapas, Mexico. *Agroforestry Systems*, 54 (3), 215-224.
- Ruben, R. & Zuniga, G. (2011). How standards compete: comparative impact of coffee certification schemes in Northern Nicaragua. *Supply Chain Manag*, 16 (2), 98-109.
- Rueda, X., Thomas, N. E. & Lambin, E. F. (2015). Eco-certification and coffee cultivation enhance tree cover and forest connectivity in the Colombian coffee landscapes. *Regional Environmental Change*, 15(1), 25-33.
- Stillmacher, T. & Grote, U. (2011). Forest Coffee Certification in Ethiopia: Economic boon or ecological bane? *ZEF working paper series* 76. Bonn.
- Sustainable Agriculture Network. (2010). *Sustainable Agriculture Standard* [Online]. Available: http://www.san.ag/biblioteca/docs/SAN-S-1-4_Sustainable_Agriculture_Standard.pdf [Accessed 03 Jan 2017].
- Tadesse, G., Zavaleta, E., Shennan, C. & FitzSimmons, M. (2014). Policy and demographic factors shape deforestation patterns and socio-ecological processes in southwest Ethiopian coffee agroecosystems. *Applied Geography*, 54(0), 149-159.
- Takahashi, R. & Todo, Y. (2013). The impact of a shade coffee certification program on forest conservation: A case study from a wild coffee forest in Ethiopia. *Journal of Environmental Management*, 130(213), 48-54.
- Takahashi, R. & Todo, Y. (2014). The impact of a shade coffee certification program on forest conservation using remote sensing and household data. *Environmental Impact Assessment Review*, 44(2014), 76-81.
- Takahashi, R. & Todo, Y. (2017). Coffee Certification and Forest Quality: Evidence from a Wild Coffee Forest in Ethiopia. *World Development*, 92, 158-166.
- Tefera, A. & Tefera, T. (2014). Ethiopia: Coffee Annual, Coffee Annual Report. *ET 1402*. Addis Ababa: USDA Foreign Agriculture Service.
- Tegegne, H. K. (2017). *Impact of deforestation on biodiversity, soil carbon stocks, soil quality, runoff and sediment yield at southwest Ethiopia's forest frontier*. PhD thesis, Ghent University.
- Tscharntke, T., Clough, Y., Wanger, T. C., Jackson, L., Motzke, I., Perfecto, I., Vandermeer, J. & Whitbread, A. (2012). Global food security, biodiversity conservation and the future of agricultural intensification. *Biological Conservation*, 151(1), 53-59.
- Vaast, P., Bertrand, B., Perriot, J.-J., Guyot, B. & Génard, M. (2006). Fruit thinning and shade improve bean characteristics and beverage quality of coffee (*Coffea arabica* L.) under optimal conditions. *Journal of the Science of Food and Agriculture*, 86(2), 197-204.

- Wiersum, K. F., Gole, T. W., Gatzweiler, F., Volkmann, J., Bognetteau, E. & Wirtu, O. (2008). Certification of Wild Coffee in Ethiopia: Experiences and Challenges. *Forests, Trees and Livelihoods*, 18(1), 9-21.
- Yoshii, C., Yamaura, Y., Soga, M., Shibuya, M. & Nakamura, F. (2015). Comparable benefits of land sparing and sharing indicated by bird responses to stand-level plantation intensity in Hokkaido, northern Japan. *Journal of Forest Research*, 20(1), 167-174.

Appendix

Table A1: Results from OLS regression models estimating the effect of semi-forest coffee on yield, return to land and labor, and profit

	Coffee yield	Return to land	Return to labor	Profit per ha
Semi-forest	33.71 (91.16)	2364.23** (1202.64)	33.72 (27.40)	1842.48 (1290.25)
Coffee age	2.47 (7.77)	110.46 (102.71)	4.25** (2.11)	191.44** (86.72)
Coffee age2	-0.06 (0.09)	-1.61 (1.17)	-0.05** (0.03)	-2.22** (1.02)
Coffee area	-637.46*** (96.50)	-7542.78*** (1275.45)	120.70*** (29.84)	-1348.69 (1167.18)
Coffee area2	64.61*** (12.97)	746.27*** (161.68)	-14.26*** (3.18)	82.74 (129.83)
Distance to coop	0.06 (0.07)	0.14 (0.53)	-0.01* (0.01)	0.23 (0.57)
Distance to road	-0.08*** (0.02)	-0.99*** (0.18)	-0.00 (0.00)	-0.51*** (0.16)
Distance to river	-0.04 (0.04)	-0.16 (0.42)	0.01** (0.01)	0.18 (0.42)
Humic Nitisols	209.96 (160.96)	507.41 (1959.75)	-87.71 (54.83)	-2383.61 (2283.64)
Humic Alisols				-3734.97 (3179.52)
Lithic Leptosols	283.74 (218.36)	2230.96 (2632.06)	-31.18 (63.87)	
Slope	3.57 (8.02)	-18.89 (108.35)	-5.71* (3.28)	91.60 (105.58)
Altitude	0.64 (0.45)	1.20 (5.63)	-0.22* (0.12)	3.37 (5.33)
Head's sex	-136.09 (123.03)	-3141.47* (1791.64)	-18.67 (35.28)	-2571.81 (1646.39)
Head's age	-2.78 (3.13)	-101.12** (42.20)	-2.13* (1.17)	-114.77*** (38.67)
Head education	16.04 (12.80)	305.38* (182.74)	6.86* (3.56)	646.00*** (167.72)
Total adult	53.24** (25.00)	673.73* (366.65)	-11.97 (8.97)	677.75* (391.27)
Total dependents	-0.75 (28.67)	80.48 (355.44)	-11.70* (6.33)	-378.18 (297.77)
Livestock (TLU)	21.19** (9.85)	152.12 (124.39)	3.30 (2.92)	187.94 (132.04)
Social capital	1.24* (0.67)	12.92 (8.42)	0.05 (0.12)	19.11** (8.56)
Constant	-349.91 (974.64)	12661.21 (10866.03)	694.26** (309.22)	261.47 (10241.53)
Number of observations	758.00	758.00	758.00	752.00
F-test	6.30	7.96	3.06	5.45
Prob > F	0.00	0.00	0.00	0.00
R2	0.12	0.11	0.07	0.09

Standard errors in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Table A2: Results from OLS regression models estimating the effect of RA and NRA semi-forest coffee on yield, return to land and labor, and profit

	Coffee yield	Return land	Return labor	Profit per ha
NRA semi-forest	-22.03 (103.83)	661.19 (1367.85)	15.98 (38.38)	543.60 (1505.84)
RA semi-forest	118.73 (109.44)	4962.17*** (1742.36)	60.79** (29.49)	3881.76** (1513.78)
Coffee age	1.40 (7.66)	77.79 (100.87)	3.91* (2.17)	166.49* (88.22)
Coffee age2	-0.05 (0.09)	-1.23 (1.16)	-0.05* (0.03)	-1.93* (1.04)
Coffee area	-632.92*** (96.34)	-7403.80*** (1266.23)	122.15*** (29.60)	-1262.87 (1167.72)
Coffee area2	64.14*** (13.11)	731.76*** (164.54)	-14.42*** (3.13)	74.02 (128.81)
Distance to coop	0.06 (0.07)	0.16 (0.53)	-0.01* (0.01)	0.25 (0.55)
Distance to road	-0.08*** (0.02)	-0.96*** (0.18)	-0.00 (0.00)	-0.49*** (0.16)
Distance to river	-0.05 (0.05)	-0.36 (0.45)	0.01* (0.01)	0.02 (0.44)
Humic Nitisols	213.30 (158.97)	609.61 (1926.78)	-86.65 (54.29)	-2684.36 (2178.01)
Humic Alisols				-4133.28 (2987.47)
Lithic Leptosols	298.73 (210.81)	2689.15 (2596.27)	-26.41 (62.68)	
Slope	2.63 (8.01)	-47.60 (106.95)	-6.01* (3.16)	68.25 (101.69)
Altitude	0.60 (0.45)	-0.13 (5.56)	-0.24** (0.12)	2.39 (5.28)
Head's sex	-123.42 (123.97)	-2754.18 (1801.48)	-14.64 (36.11)	-2285.66 (1667.19)
Head's age	-2.31 (3.18)	-86.68** (42.30)	-1.98 (1.25)	-103.91*** (39.03)
Head education	15.83 (12.86)	298.96 (184.26)	6.79* (3.56)	640.38*** (168.71)
Total adult	53.59** (25.02)	684.46* (367.40)	-11.86 (9.00)	689.97* (391.13)
Total dependents	-0.80 (28.64)	79.15 (354.24)	-11.72* (6.34)	-379.33 (297.49)
Livestock (TLU)	22.48** (9.93)	191.38 (125.43)	3.70 (3.04)	218.85* (129.86)
Social capital	1.27* (0.68)	13.92 (8.60)	0.06 (0.13)	19.86** (8.70)
Constant	-272.08 (963.59)	15039.65 (10752.78)	719.04** (299.99)	2416.14 (10207.59)
Number of observations	758.00	758.00	758.00	752.00
F-test	5.98	8.00	3.57	6.08
Prob > F	0.00	0.00	0.00	0.00
R2	0.12	0.11	0.07	0.09

Standard errors in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Table A3: Results from fixed effects regression models estimating the effect of semi-forest coffee on yield, return to land and labor, and profit

Variables	Coffee yield	Return to land	Return to labor	Profit per ha
Semi-forest	1.70 (107.88)	2283.13 (1481.68)	26.95 (26.94)	4234.29** (1657.25)
Coffee age	34.90 (26.92)	424.80** (203.86)	-0.22 (2.24)	555.37** (239.72)
Coffee age2	-0.36 (0.29)	-4.16* (2.31)	0.00 (0.03)	-5.14** (2.42)
Coffee area	-808.88*** (297.75)	-6816.64*** (2095.95)	74.20 (55.61)	474.61 (3338.31)
Coffee area2	113.62** (48.17)	784.59** (335.19)	-0.59 (11.17)	-151.14 (414.73)
Distance to coop	-0.04 (0.07)	0.23 (0.88)	-0.06 (0.04)	0.71 (0.82)
Distance to road	-0.17 (0.13)	-2.09 (1.88)	0.03 (0.04)	-3.36* (1.87)
Distance to river	0.33* (0.18)	1.01 (1.55)	0.10** (0.05)	0.95 (1.43)
Altitude	-0.90 (0.97)	-19.22 (11.81)	-0.70** (0.29)	-36.27*** (12.49)
Humic Alisols	-692.89 (434.01)	-8486.87** (3896.33)	-152.80 (184.36)	-8048.70* (4651.03)
slope	4.46 (14.29)	-117.44 (245.16)	-1.20 (3.94)	116.52 (193.93)
Constant	1666.62 (1835.97)	44105.57** (20810.67)	1127.18** (440.36)	63476.37*** (22762.30)
Number of observations	295.00	295.00	295.00	292.00
F-test	1.30	1.68	1.73	3.34
Prob > F	0.24	0.09	0.08	0.00
R2	0.15	0.10	0.19	0.14

Standard errors in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Table A4: Results from fixed effects regression models estimating the effect of RA certified semi-forest coffee on yield, return to land and labor, and profit

	Coffee yield	Return to land	Return to labor	Profit per ha
RA semi-forest	178.58 (113.23)	4216.59** (1827.27)	111.48*** (40.69)	6704.79*** (1940.28)
Coffee age	6.27 (10.09)	74.38 (169.58)	-0.65 (3.62)	138.76 (135.01)
Coffee age2	-0.10 (0.12)	-1.01 (1.96)	0.01 (0.05)	-1.19 (1.44)
Coffee area	-1021.32*** (191.30)	-11112.16*** (3364.03)	-103.05 (105.03)	-2782.78 (5021.90)
Coffee area2	203.28*** (37.32)	2128.48*** (654.82)	78.16*** (26.71)	489.66 (981.26)
Distance to coop	-0.12* (0.07)	-0.55 (1.09)	-0.05 (0.05)	0.13 (1.20)
Distance to road	0.03 (0.16)	-0.23 (2.92)	0.05 (0.07)	0.25 (2.98)
Distance to river	0.19 (0.12)	1.10 (2.02)	0.03 (0.07)	-1.49 (2.47)
Altitude	-1.45 (0.90)	-27.98* (15.71)	-0.80* (0.46)	-23.68 (15.34)
Humic Alisols	-12.99 (319.43)	-3389.51 (6879.78)	-55.83 (262.32)	-3542.73 (7313.00)
slope	3.05 (9.74)	111.72 (226.83)	-1.07 (4.36)	-17.81 (235.75)
Constant	3179.14* (1603.28)	61670.83** (28218.51)	1530.41** (722.36)	52833.50* (27575.74)
Number of observations	163.00	163.00	163.00	161.00
F-test	3.87	2.44	5.77	2.74
Prob > F	0.00	0.02	0.00	0.01
R2	0.24	0.15	0.43	0.18

Standard errors in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Table A5: Results from fixed effects regression models estimating the effect of NRA semi-forest coffee on yield, return to land and labor, and profit

Variables	Coffee yield	Return to land	Return to labor	Profit per ha
NRA semi-forest	59.29 (185.43)	2473.55 (2929.06)	12.23 (20.11)	3116.70 (3502.35)
Coffee age	76.03 (67.15)	830.44* (436.20)	-3.96 (3.50)	1178.09** (527.31)
Coffee age2	-0.54 (0.53)	-4.66 (3.69)	0.06** (0.03)	-10.04** (4.28)
Coffee area	-1075.84* (537.30)	-8508.22** (3569.33)	-9.59 (33.24)	1671.59 (6385.67)
Coffee area2	132.71* (68.69)	845.25** (408.50)	0.95 (3.65)	-292.49 (601.04)
Distance to coop	0.34 (0.25)	3.70* (1.89)	0.01 (0.02)	0.85 (2.70)
Distance to road	-0.16 (0.28)	-5.77* (3.13)	-0.05 (0.03)	-3.07 (3.93)
Distance to river	0.25 (0.33)	-4.23 (3.29)	-0.02 (0.02)	3.09 (3.30)
Altitude	1.72 (2.19)	3.06 (17.78)	-0.17 (0.13)	-38.06* (22.44)
slope	27.33 (62.71)	-882.13 (841.44)	-4.56 (4.37)	849.28 (616.33)
Humic Nitisols	771.45 (1092.02)	-5024.70 (11221.71)	246.52 (162.91)	-3402.96 (9002.66)
Constant	-4815.76 (5388.16)	23182.73 (39686.04)	366.37 (354.29)	46247.39 (47992.66)
Number of observations	132.00	132.00	132.00	131.00
F-test	0.67	1.18	1.54	2.02
Prob > F	0.76	0.32	0.14	0.04
R2	0.20	0.21	0.07	0.21

Standard errors in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Table A6: Summary of the criteria used to inspect Rainforest Alliance certified forest coffee in southwestern Ethiopia. The criteria are organized and implemented based on SAN standard 2010, version 4 (Sustainable Agriculture Network, 2010). Source: summarized from Internal Inspection manual of the study area.

Principles	Total # of Criteria	Order of criteria in the principle	Selected and applied criteria for RA coffee Internal Control system in Southwestern Ethiopia	Importance of the criteria
1. Social and Environmental management system	11	1.10	Product Handling Procedures Forest coffee is separately dried and stored from garden coffee, and is not mixed with coffee from other farmers	MUST
2. Ecosystem conservation	9	2.2	NO expansion of forest coffee into natural forests	MUST
		2.6	Maintain natural vegetation along water bodies (e.g. streams and springs)	
		2.8	The forest canopy has more than two layers with higher than 40% shade cover	
3. Wild life protection	6	3.2	NO cutting of indigenous tree to provide habitat for wild life	MUST
		3.3	NO hunting, capturing and trafficking wild animals	
4. Water conservation	9	4.5	NO direct discharge of wastewater into natural water bodies	MUST
		4.7	NO depositing any solid wastes into natural water bodies	MUST
5. Fair Treatment and good working condition for employees	20		Working conditions	
		5.9	For children of the farm under the age of 15, physical safety is secured and educational obligations are not interfered	MUST
		5.18	Had Internal Control System (ICS) training sessions from WaBUB Internal Inspection Team (WIIT)	
			If the farm hire workers	
		5.2	NO discrimination in hiring and treating workers due to their race, religion, gender, etc.	MUST
		5.4, 5.14	Pre-arrangement of wages and other working conditions, e.g. the provision of housing, which are not less than the standard of the area, upon the consensus with the workers	MUST
		5.8	NO hiring of worker under the age of 15	MUST
		5.10	NO forced labor	MUST
6. Occupational Health and safety program	20	6.1	Have an occupational health and safety programme to minimize occupational risks	
		6.18, 6.19	Have measures and equipment to respond to potential natural and human emergencies	
7. Community relations	6		No criteria from this principle is indicated in study area	
8. Integrated Crop Management	9	8.1	Have an integrated pest-management practices for minimizing agrochemical uses	
		8.4	NO use and storage of banned agrochemicals in the farm (Banned agrochemicals: Aldrin, DDT, Dieldrin, Heptachlor, Malathion, etc.)	MUST
9. Soil Management and conservation	5	9.1	Measures to prevent or reduce soil erosion are taken	
		9.2	Have soil or crop fertilization programmes	
10. Integrated waste management	6	10.1	Have an integrated domestic waste management programme	
		10.5	Have proper waste handling (place waste receptacles, collect and dump them regularly)	

