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Setting the standard: Does Rainforest Alliance Certification increase environmental and socio-economic outcomes for small-scale coffee producers in Rwanda?

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Abstract

Sustainability certification has become an important tool for promoting sustainable agricultural value chains. Nevertheless, its economic and environmental effects on the producer level remain unclear. We investigate the relationship of Rainforest Alliance Certification with socio-economic and environmental outcomes in Rwanda and consider potential tradeoffs between dimensions. To reduce potential selection bias in the econometric estimation, we use inverse probability weighted regression adjustment. We find no significant association between certification and socio-economic indicators but a significant correlation between certification and good agricultural practices and biodiversity-related practices. Effects on economic outcomes and biodiversity-related practices are linked; their relationship differs across climatic regions.

KEYWORDS

agricultural economics, ecological economics, environmental economics

JEL CLASSIFICATION
Q1 Agriculture, Q5 Environmental Economics

Voluntary sustainability standards have become a key approach to promote sustainable agricultural value chains. As a voluntary market-based instrument, sustainability standards aim to improve various environmental, social, and economic dimensions of agricultural production systems (Bray & Neilson, 2017). Certification schemes define a range of criteria that farmers need to comply with and typically promise price premiums and other benefits in exchange (DeFries et al., 2017). Sustainability standards vary concerning the aspects they emphasize – from social conditions to environmental protection – and rely on different strategies to enhance sustainable production practices. Rainforest Alliance Certification includes criteria on environmental issues, such as biodiversity and forest conservation, and economic outcomes for smallholder farmers. In this paper, we focus on Rainforest Alliance Certification and its implications for economic and environmental outcomes, considering the case of smallholder coffee farmers in Rwanda. The coffee sector is pioneering in the certification of sustainability of tropical food crops (DeFries et al., 2017). Over the past decade, the amount of coffee produced adhering to certification requirements has continued to increase (Panhuysen & Pierrot, 2020).

Previous studies on the impacts of sustainability certification have focused on either economic (Coulibaly, Chiputwa, Nakelse, & Kundhlande, 2017; Ruben & Hoebink, 2015; Ruben & Fort, 2012; van Rijsbergen, Elbers, Ruben, & Njuguna, 2016) or environmental benefits of certified coffee production (Hardt et al., 2015; Perfecto, Vandermeer, Mas, & Pinto, 2005; Takahashi & Todo, 2013; Tscharntke et al., 2015). Research has shown that participation in certification schemes can reduce coffee farmers' livelihood vulnerability (Bacon, 2005; Donovan & Poole, 2014), increase income and reduce poverty (Mitiku, de Mey, Nyssen, & Maertens, 2017), and increase food security (Chiputwa & Qaim, 2016). Regarding the environment, studies found that certification reduces chemical input use in coffee production and increases the adoption of environmentally friendly management practices (Blackman & Naranjo, 2012).

Only a few studies to date have jointly investigated the environmental and economic outcomes of sustainability certification. Accordingly, whether certification can improve farm-level environmental and economic outcomes simultaneously remains an open question. Yet, understanding different coffee management systems' economic and environmental benefits is as important as recognizing opportunities to reconcile them (Jezeer, Verweij, Santos, & Boot, 2017). There is the first evidence from certified and non-certified coffee farmers exploring interactions between environmental and economic factors. Ibanez and Blackman (2016) find that eco-certified coffee in Colombia is linked to improving environmental outcomes yet do not identify clear economic benefits. Vanderhaegen et al. (2018) investigate the effect of double-certification among coffee producers in Uganda. They find that either it improves farm incomes or biodiversity yet fails to eradicate the tradeoff between economic and environmental outcomes. Haggar, Soto, Casanoves, and de Melo Virginio (2017) investigate the effect of sustainability certification schemes on coffee producers in Nicaragua. The authors find that the investigated certification schemes positively affect the environmental characteristics of coffee production, provide economic benefits to most farmers, and may contribute to mitigating environmental-economic tradeoffs.

We aim to contribute to this scarce evidence by investigating the relationship of sustainability certification with environmental and economic outcomes and the potential tradeoffs between these dimensions. We go beyond a narrow focus on yields and agricultural income by including total household income and food security as more general economic welfare outcomes. Our study is implemented among coffee smallholder farmers in three agro-ecological regions of Rwanda. The regions differ in terms of their agro-ecological suitability for coffee production, that is, the extent to which soil and climatic conditions match the requirements of coffee plants. This is relevant as coffee is highly susceptible to changes in climatic conditions. Increases in temperature and changes in precipitation patterns will affect coffee yields and quality and be particularly severe in regions less suitable for coffee production (Bunn, Läderach, Jimenez, Montagnon, & Schilling, 2015).

Thus, the objective of this study is threefold. First, we analyze the economic and environmental outcomes associated with Rainforest Alliance Certification. Second, we evaluate potential tradeoffs between these outcomes. Finally, as the effects of certification are likely to differ depending on regional climate, we investigate whether economic-environmental outcomes and tradeoffs associated with certification differ across three agro-ecological regions. The paper proceeds as follows. Section two provides background on the study context and develops a conceptual framework for the study. Section three describes the survey approach and the econometric framework. Descriptive and econometric results are then presented in section four. Section five discusses the results in more detail, and section six concludes.

BACKGROUND

Study context

Coffee represents, besides tea, Rwanda's major export crop and is increasingly recognized as a high-quality product (Food and Agricultural Organization, 2021). Around 400,000 smallholder farm families rely on coffee production, farming about 42,000 ha of coffee plantations (National Agricultural and Export Board, NAEB, 2019). Although the sector has experienced growth since the civil war in 1994, productivity still is among the lowest in East Africa (International Coffee Organization, 2015). Low coffee yields result from different environmental and farm management challenges: Pests and diseases limit crop productivity, and adoption levels of good agronomic practices such as weeding, pruning, fertilizers, and soil erosion control are low (Ngango & Kim, 2019). Coffee farmers face several challenges, including poor soil fertility and insufficient access to fertilizers, old and less productive coffee trees, low prices compared to competing crops, and pests and diseases reducing production by as much as 50% per year at the farm level (AgriLogic, 2018). Commercial input use among coffee producers is very low, and most labor used in coffee production is manual. At the same time, coffee production represents a primary source of cash income for purchasing household goods and food (Ortega et al., 2019).

Coffee is harvested in Rwanda between March and July. After picking the ripe coffee cherries, they need to be processed into parchment coffee before export. In Rwanda, coffee is either fully washed in wet mills, so-called Coffee Washing Stations (CWS), where farmers deliver their coffee, or semi-washed at the farm level and then traded via intermediaries (Macchiavello & Morjaria, 2018). Fully-washed coffee is of higher and more consistent quality and is associated with price premia in international markets (Blouin & Macchiavello, 2017). Therefore, Rwanda's government aims to increase the share of fully-washed coffee, and the number of CWS has been continuously increasing since 2002 (AgriLogic, 2018). Besides processing coffee, CWS also provide extension and support to farmers within their operational area. Since 2014, an increasing share of Rwandan coffee production has been certified under voluntary sustainability standards. Besides FairTrade and Organic, Rainforest Alliance represents the most prevalent scheme[1] (AgriLogic, 2018), with an estimated certified production of 5590 metric tons of coffee in 2020 (Alliance, 2021). Certified coffee is wet-processed and marketed by certified CWS.

Conceptual framework

Rainforest Alliances' mission is to conserve biodiversity and at the same time ensure sustainable livelihoods for farmers. The program includes criteria covering environmental and economic farm aspects that support strategies to improve farming practices, management systems, and farmers' knowledge (Rainforest Alliance, 2017). The conceptual framework, depicted in Figure 1, visualizes the expected relationships between Rainforest Alliance Certification, biodiversity-related and good agricultural practices, and coffee-related and household-level welfare outcomes.

The certification scheme requires the uptake of good agricultural practices and biodiversity-related measures. An improved uptake in these practices can thus be directly linked to Rainforest Alliance Certification, as the adoption of the practices is part of the certification scheme. The standard promotes exchanging synthetic with organic fertilizers and integrates shade trees as part of its continuous improvement system (Rainforest Alliance, 2017). Shade trees are associated with positive effects on the microclimate and contribute to tree species diversity (Souza et al., 2012) and soil fertility (Youkhana & Idol, 2009). Other environmental benefits derived from shaded coffee systems are biodiversity conservation, carbon sequestration, and soil erosion control (Cerdán, Rebolledo, Soto, Rapidel, & Sinclair, 2012). Integrated Pest Management (IPM), part of the good agricultural practices promoted by Rainforest Alliance, focuses on reducing pesticide use, for example, applying biological control measures and precision farming. Previous studies have found that IPM techniques can indeed reduce pesticide use and increase crop yields (Pretty & Pervez Bharucha, 2015) as well as protect soil, water, wildlife, and beneficial insects (Rezaei, Safa, Damalas, & Ganjkhanloo, 2019).

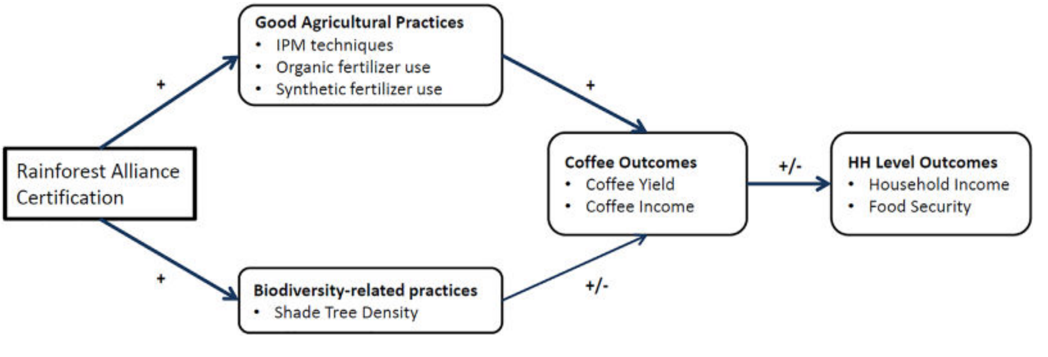

FIGURE 1 Hypothesized relationship between Rainforest Alliance Certification and outcome variables

The adoption of good agricultural practices, such as IPM techniques and organic fertilizers, is expected to be reflected in higher levels of agricultural productivity and accordingly coffee yields (Pretty & Pervez Bharucha, 2015; Rahn et al., 2018). Higher coffee yields are expected to translate into increased coffee income if the additional revenues exceed additional costs. Nevertheless, tradeoffs might exist between biodiversity-related practices and coffee-related outcomes (yield, coffee income). Previous research has shown that shade trees are typically associated with reduced coffee yields (Rahn et al., 2018), which might also lead to decreased coffee income, at least in the short run.

At the same time, coffee and household-related outcomes are likely to be influenced by other aspects linked to certification. For example, the implementation of a farm management plan as required by Rainforest Alliance might affect farmers' overall managerial skills and thus influence outcome variables. We specifically investigate the connection between economic outcomes and the adoption of good agricultural practices, as they are tied to improved environmental effects of coffee production.

Whether farm households can improve their overall wellbeing depends on the extent to which changes in coffee outcomes translate into household-level outcomes. Higher coffee income is expected to lead to higher total household income, which can be used to purchase food (Schleifer & Sun, 2020) and increase household-level food security. Under certain conditions, despite higher cash income from coffee, improvements in household-level outcomes may not be observed. For instance, if labor reallocation occurs in the certification process, reducing off-farm income streams, overall household income may decline (Vellema, Buritica Casanova, Gonzalez, & D'Haese, 2015). Similarly, if additional cash income from coffee is spent on non-food items, household-level food security may not improve (Anderman, Remans, Wood, DeRosa, & DeFries, 2014).

MATERIAL AND METHODS

Data collection

Household-level survey data were collected in four districts of Rwanda between October and December 2019. Districts were purposefully chosen to represent three climatic zones that differ in their suitability for coffee production. Bugesera is part of the "East-Rwandan dry and hot lowland zone", characterized by a savanna climate and is least suitable for coffee production. Huye is located in the "Temperate zone of the central highlands" and is more suitable for coffee production than Bugesera. Altitude and precipitation are higher than in Bugesera, and temperature swings are less pronounced than those in the eastern lowlands. Karongi and Rutsiro represent the climate of Lake Kivu Rift Valley, the area most suitable for coffee production. The land-lake-wind circulation creates a distinct regional climate system and high evaporation rates prevailing on Lake Kivu.

To construct our sample, we proceeded in two steps. First, we selected Coffee Washing stations (CWS) processing Rainforest Alliance-certified coffee in the three regions from a list of CWS obtained from the Rwandan Agricultural Board. We then matched each certified CWS with a non-certified CWS located in the same district and being similar in terms of processing volume and form of ownership (privately or cooperatively owned). In a second step, complete lists of certified and non-certified farmers were compiled by the selected CWS and with the help of randomly selected lead farmers. Based on the lists, we collected a stratified random sample of

202 certified and 286 non-certified farmers. 188 interviews were conducted in Bugesera (87/101 certified/non-certified), 161 in Huye (60/101 certified/non-certified), and 135 in the Lake Kivu Region (55/84 certified/non-certified). A standardized questionnaire was used to obtain information on household demographics, coffee production and marketing, crop production other than coffee, input use on the plot level, and certification.

By sampling farmers via CWS, we limit our sample to those coffee farmers that deliver at least part of their coffee to a CWS and implicitly exclude farmers who process all of their coffee on their farm. As discussed in Chapter 2.1, Rainforest Alliance-certified coffee produced in Rwanda is wet-processed by certified CWS. We, therefore, opted to choose both certified and non-certified farmers selling to CWS in order to ensure comparability, for example, in terms of coffee quality, processing method, and access to services that CWS typically provides.

Econometric framework

To assess the association of Rainforest Alliance Certification with environmental and economic outcomes, we need to compare certified farmers to a suitable counterfactual. Given that certification is a choice variable and typically influenced by a range of observable and unobservable farmer characteristics (Meemken et al., 2021), certified and non-certified farmers are likely to differ systematically. As these characteristics likely correlate with the outcomes of interest, estimates will be biased due to self-selection into certification. To reduce selection bias, we apply inverse probability weighted regression adjustment (IPWRA; Wooldridge, 2010). The approach consists of two stages, wherein the first stage, inverse probability weights (IPW) are derived from the decision to obtain certification. In the second stage, the regression adjustment (RA) method is used to model outcomes.

In the first stage, IPW are estimated based on the probability of obtaining certification or the propensity score. For this purpose, the propensity score as defined by Rosenbaum and Rubin (1983) is calculated using a range of observable characteristics:

$$\boldsymbol{p}(\boldsymbol{X}) = \mathbf{Pr}(\boldsymbol{T_i} = \mathbf{1}|\boldsymbol{X}) = \boldsymbol{F}\{\boldsymbol{h}(\boldsymbol{X})\} = \boldsymbol{E}(\boldsymbol{T_i}|\boldsymbol{X}) \tag{1}$$

where X is a multi-dimensional vector of covariates and F{.} a cumulative distribution function. Based on the estimated propensity score $p\hat{}$, IPW are calculated as $\frac{1}{p^\wedge}$ for treated households, and $\frac{1}{1-p^\wedge}$ for non-treated households. Each observation is thus weighted by the inverse probability of receiving the treatment level it received.

The RA method fits separate linear regression models for certified and non-certified farmers. Covariate-specific outcomes are then predicted for each subject under each certification status. We obtain the average difference between predicted outcomes for certified farmers ($ADPO^C$) under certification and hypothetical non-certification (Hörner & Wollni, 2021). The predicted outcome for certified farmers under hypothetical non-certification takes the specific characteristics of certified farmers into account and can be interpreted as an estimation of the outcome certified farmers would have achieved if they were not certified (given their characteristics). The method thus takes differences in characteristics between certified and non-certified farmers into account, when constructing a hypothetical counterfactual against which certified farmers are compared. Combining the RA method with the IPW, the IPWRA estimator can be expressed as (Manda, Gardebroek, Kuntashula, & Alene, 2018):

$$\boldsymbol{ADPO^C}_{\boldsymbol{IPWRA}} = \boldsymbol{n_C^{-1}} \sum\nolimits_{\boldsymbol{i=1}}^{\boldsymbol{n}} \boldsymbol{T_i}[\boldsymbol{r_A}(\boldsymbol{X},\boldsymbol{\delta_C}) - \boldsymbol{r_n}(\boldsymbol{X},\boldsymbol{\delta_n})] \tag{2}$$

where n_c is the number of certified farmers and $ri(X)$ describes the weighted regression models for certified (C) and non-certified (N) coffee farmers with covariates X and estimated parameters.

δ_C^* and δ_N^*, which are obtained from the weighted regression procedure.

An important underlying assumption of the IPWRA method is the overlap assumption, requiring that, conditional on covariates, each farmer has a positive probability of obtaining certification. This is to ensure that each certified household can be matched with a non-certified household of similar characteristics. If the overlap assumption is violated, estimators are overly sensitive to model specifications. To meet this condition, we set a tolerance level between $p = 0.001$ and $p = 0.999$ for the estimated probability of certification. Furthermore, it should be noted that IPWRA seeks to reduce selection bias by conditioning on observed covariates. This implies that estimates are vulnerable to systematic bias in unobserved characteristics. Although controlling for a broad set of observable covariates may help reduce selection bias resulting from unobserved heterogeneity (Imbens & Wooldridge, 2009), our results should be interpreted as associations rather than causal effects.

Empirical specification

Based on the conceptual framework, we assess the association of Rainforest Alliance Certification with environmental and good agricultural practices and economic outcomes, both coffee-related and at the household level. We include binary indicators as to the first set of indicators about whether farmers apply organic fertilizer and integrated pest management. In addition, we measure the number of IPM practices applied. In the context of good agricultural practices, we also use the amount of synthetic fertilizer applied to the coffee plantation as an indicator, as Rainforest Alliance discourages the overuse of synthetic fertilizers. Finally, concerning biodiversity-related practices, we include a binary indicator of whether the farmer integrates shade trees in the coffee plantation and the number of shade trees per hectare.

Regarding the second set of indicators, coffee-related economic outcomes include coffee yields, measured per hectare and year, and coffee income, which equals coffee revenues minus variable costs incurred in coffee production per hectare. We further consider total household income and household-level food security to assess whether potential increases in coffee income translate into better economic outcomes at the household level. Total household income includes income generated from coffee and other crops produced on-farm valued at market price, livestock production, off-farm activities, and private transfers, subtracting the costs incurred by the household.

We use the Household Food Insecurity and Access Scale (HFIAS) to measure food insecurity, comprising nine recall questions covering different food insecurity-related events in the past 30 days. If the respondent experienced a given situation, a follow-up "frequency-of-occurrence" question is asked (rarely, sometimes, or often). Thus, questions can be scored 0–3, so the total HFIAS ranges from 0 to 27. A higher score then indicates a higher degree of food insecurity (Coates, Swindale, & Bilinsky, 2007). Table 1 provides a descriptive overview of the outcome variables and the covariates included in the econometric models.

TABLE 1 Descriptive statistics of variables used in the analysis

	Full sample		Bugesera		Huye		Lake Kivu	
	Not certified	Certified	Not certified	Certified	Not certified	Certified	Not certified	Certified
Good agricultural and biodiversity-related practices								
Use of org. fertilizer	0.692 (0.462)	0.782 (0.414)	0.574 (0.497)	0.736 (0.444)	0.733 (0.445)	0.75 (0.437)	0.786 (0.413)	0.891 (0.315)
Synth.fert used kg/ha	265.8 (219.2)	234.6 (204.6)	272.1 (229.4)	204.3 (206.5)	283.7 (222.5)	289.6 (231.9)	236.5 (201.5)	222.8 (155.4)
Use of IPM	0.888 (0.32)	0.951 (0.218)	0.900 (0.300)	1 (0)	0.792 (0.41)	0.917 (0.279)	0.988 (0.11)	0.909 (0.29)
# of IPM techniques	1.8 (1.1)	2.4 (1.2)	1.7 (0.96)	2.4 (0.91)	1.8 (1.5)	2.5 (1.6)	1.9 (0.86)	2.2 (1.3)
Use of shade trees	0.682 (0.47)	0.792 (0.41)	0.634 (0.48)	0.747 (0.44)	0.753 (0.43)	0.917 (0.279)	0.655 (0.478)	0.73 (0.45)
# Shade trees per ha	134.1 (150.4)	146.9 (143.5)	125.3 (151.9)	138.2 (154.8)	144.6 (147.5)	188.5 (136.6)	131.9 (152.9)	115.2 (122.4)
Coffee-related and household-level economic outcomes								
Yield in kg (cherries)	4778.6 (3773.4)	4638.1 (3523.9)	4756.8 (3772.9)	4732.3 (3540.3)	4670 (3557.5)	4008.1 (3401.4)	4935.2 (4056.3)	5176.5 (3587.7)
Coffee income In 1000 RwF/ha	374.1 (784.9)	316.4 (710.5)	394.2 (779.2)	324.2 (743.5)	418.6 (700.1)	190.4 (693.7)	296.5 (885. 8)	441.5 (662.5)
Hh income in 1000 RwF/ha	886.2 (1037.1)	776.0 (940.4)	981.9 (1006.3)	826.3 (995.7)	980.4 (1061.1)	669.9 (913.6)	657.9 (1020.8)	812.3 (884.9)
Food insecurity (HFIAS)	9.4 (7.2)	8.3 (6.8)	9.2 (6.8)	7.95 (6.2)	10.3 (7.4)	8.2 (7.3)	8.6 (7.2)	8.9 (7.3)
Control variables								
HH size	5.0 (1.8)	5.1 (1.8)	4.6 (1.8)	4.7 (1.5)	5.2 (1.8)	5.2 (1.8)	5.2 (2.1)	5.3 (2.2)

TABLE 1 (Continued)

	Full sample		Bugesera		Huye		Lake Kivu	
	Not certified	Certified	Not certified	Certified	Not certified	Certified	Not certified	Certified
Age of the household head	47.9 (13.1)	51.3 (13.1)	46.1 (12.9)	56.1 (12.4)	48.4 (12.2)	47.2 (12.8)	49.6 (14.0)	48.2 (12.1)
Years of formal education	4.3 (2.8)	3.9 (2.9)	3.8 (2.9)	3.4 (2.8)	4.3 (2.7)	4.5 (2.9)	4.9 (2.6)	4.3 (2.9)
HH Type[1]	0.33 (0.47)	0.26 (0.44)	0.416 (0.49)	0.22 (0.42)	0.32 (0.47)	0.28 (0.45)	0.24 (0.43)	0.31 (0.47)
Farm size in ha	0.23 (0.17)	0.26 (0.19)	0.19 (0.153)	0.25 (0.19)	0.24 (0.17)	0.24 (0.16)	0.28 (0.20)	0.27 (0.24)
Coffee area in ha	0.09 (0.07)	0.11 (0.11)	0.07 (0.077)	0.09 (0.09)	0.09 (0.06)	0.13 (0.11)	0.09 (0.08)	0.11 (0.12)
Exp. in coffee prod. (Years)	38.6 (38.8)	43.7 (39.3)	39.4 (34.2)	56.5 (41.8)	32.7 (34.3)	34.4 (28.9)	44.6 (47.5)	33.7 (39.8)
Time to nearest CWS	47.5 (36.3)	46.7 (34.5)	37.6 (29.2)	35.3 (30.7)	58.9 (40.4)	61.6 (29.8)	45.8 (35.3)	48.5 (38.6)
Form of ownership of CWS[2]	0.66 (0.48)	0.56 (0.49)	0.931 (0.255)	0.76 (0.431)	0.58 (0.495)	0.33 (0.475)	0.42 (0.49)	0.509 (0.505)

Note: (1) 0 = Male Headed, 1 = Female headed; (2) 0 = Cooperatively owned, 1 = privately owned; Standard error in parentheses.
Abbreviations: CWS, Coffee washing station; HH, household.

RESULTS

In the following two sections, we present results from the IPWRA estimations. The last section explores potential tradeoffs between the use of biodiversity-related practices and economic outcomes. Results in Tables 2 and 3 below report the predicted outcomes for certified farmers under hypothetical non-certification which can be considered the counterfactual. In addition, we report the $ADPO^{C}{}_{IPWRA}$, which indicates the average difference between predicted outcomes for certified farmers under certification and hypothetical non-certification and can be interpreted as the change in the respective outcome associated with Rainforest Alliance Certification. We show both *p*-values and sharpened q-values, the latter being more robust in the context of multiple hypotheses testing (Anderson, 2008).

Regarding the overlap assumption, which is necessary for IPWRA results to be valid, we identify no observation with a probability of certification below the minimum threshold of $\hat{p} = 0.001$ or above the maximum threshold of $\hat{p} = 0.999$. This suggests that we have sufficient overlap in our sample. Furthermore, after applying IPW, the sample should be balanced between certified and non-certified farmers. Over-identification tests indicate that the null hypothesis of balanced covariates cannot be rejected for any subsample. Test statistics for the entire sample are $X^2(10) = 7.6745$ with $p > X^2 = 0.6606$. For Bugesera, test statistics are $X^2(10) = 1.69652$ with $p > X^2 = 0.9982$; for Huye $X^2(10) = 7.16558$with $p > X^2 = 0.7097$; and for Lake Kivu $X^2(10) = 5.03991$ with $p > X^2 = 0.8885$. Probit model results on the certification decision that are used to derive IPW are presented in Table A1.

Management practices

Overall, Rainforest Alliance Certification is associated with a significant increase in the uptake of several environmentally friendly practices, including the use of organic fertilizers, the use, and number of IPM techniques, and shade trees (Table 2, *Full Sample*). This is despite the fact that good agricultural and environmentally-friendly practices are relatively widely adopted in the research area, for example, shade-grown coffee is common, with 68% of the non-certified farmers following this practice (cf. descriptive statistics in Table 1). Our IPWRA results suggest that certification is associated with a 7-percentage point increase in the likelihood of adopting organic fertilizer, a 6-percentage point increase in the likelihood of applying IPM techniques, and a 12-percentage point increase in the likelihood to maintain shade trees (Table 2). Furthermore, certification is associated with an average increase of 0.5 IPM techniques used. However, it should be noted that only the number of IPM techniques and the likelihood to maintain shade trees remain significant when correcting for multiple hypotheses testing. Finally, the amount of synthetic fertilizer applied to coffee is not significantly correlated with certification, neither positively nor negatively.

When regionally disaggregating the results, we find that these general findings are most strongly reflected in Bugesera. The uptake of organic fertilizer, for instance, is significantly associated with certification only in Bugesera. Bugesera is also the region where adoption levels of organic fertilizer among non-certified farmers are the lowest (cf. descriptive statistics in Table 1). In this region, which is less suitable for coffee production, certification is associated with a 14-percentage point increase in the likelihood to apply organic fertilizer. Similarly, the results on IPM are even more pronounced in Bugesera than in the full sample. Here, certification is associated with a 20-percentage point increase in the likelihood to adopt IPM and an

TABLE 2 Association of Rainforest Alliance Certification with good agricultural and biodiversity-related practices

	Non-certified PO		ADPO^C		*p*-value	Sharpened q-values
Full sample						
Use of organic fertilizer	0.712	(0.030)	0.07	(0.04)	0.101	0.315
Amount of synt. fertilizer per ha in kg	260.3	(15.1)	−25.6	(18.6)	0.169	0.433
Use of IPM techniques	0.89	(0.02)	0.06	(0.02)	0.022	0.153
# of IPM techniques	1.9	(0.09)	0.52	(0.12)	0.000	0.001
Use of shade trees	0.67	(0.03)	0.12	(0.04)	0.004	0.03
# Shade trees per ha	132.6	(9.5)	11.6	(13.6)	0.395	0.653
Bugesera						
Use of organic fertilizer	0.599	(0.06)	0.14	(0.07)	0.059	0.256
Amount of synt. fertilizer per ha in kg	185.6	(26.0)	18.7	(31.7)	0.556	0.812
Use of IPM techniques	0.799	(0.05)	0.20	(0.05)	0.000	0.001
# of IPM techniques	1.5	(0.17)	0.92	(20)	0.000	0.001
Use of shade trees	0.6	(0.05)	0.11	(0.07)	0.089	0.315
# Shade trees per ha	103.3	(15.0)	34.4	(21.3)	0.107	0.315
Huye						
Use of organic fertilizer	0.71	(0.07)	0.03	(0.09)	0.693	0.835
Amount of synt. fertilizer per ha in kg	301.7	(27.7)	−8.6	(37.8)	0.820	0.877
Use of IPM techniques	0.81	(0.05)	0.10	(0.06)	0.106	0.315
# of IPM techniques	1.8	(0.25)	0.66	(0.32)	0.041	0.197
Use of shade trees	0.82	(0.05)	0.09	(0.06)	0.139	0.386
# Shade trees per ha	148.9	(22.2)	36.3	(28.5)	0.203	0.433
Lake Kivu						
Use of organic fertilizer	0.80	(0.05)	0.09	(0.07)	0.218	0.433
Amount of synt. fertilizer per ha in kg	217.9	(27.8)	−0.29	(30.8)	0.992	0.938
Use of IPM techniques	0.996	(0.01)	−0.09	(0.04)	0.027	0.166
# of IPM techniques	1.9	(0.12)	0.39	(0.21)	0.067	0.27
Use of shade trees	0.65	(0.06)	0.08	(0.09)	0.337	0.599
# Shade trees per ha	124.3	(18.0)	−5.6	(24.3)	0.816	0.877

Note: Non-certified PO presents the potential outcome means for certified farms under hypothetical non-certification; ADPO^C stands for 'average difference in predicted outcomes' for certified farmers under certification and hypothetical non-certification; Standard deviation in parentheses.

average increase of 0.92 practices used. Finally, certification is associated with an 11-percentage point increase in the likelihood to maintain shade trees, which is in line with the findings from the full sample. Again, our results are only partly robust to correcting for multiple hypotheses testing, after which only the use of IPM techniques and the number of IPM techniques remain significant in Bugesera.

TABLE 3 Association of Rainforest Alliance Certification with socio-economic outcomes

	Non-certified PO		ADPO^C		*p*-value	Sharpened q-values
Full sample						
Coffee yield in kg per ha	4532.8	(264.3)	127.1	(324.4)	0.695	0.835
Coffee income in 1000 RwF/ha	332.3	(53.3)	−5.4	(69.7)	0.938	0.938
Household income in 1000 RwF/ha	806.5	(70.5)	−20.8	(92.8)	0.822	0.877
Food insecurity (HFIAS)	9.1	(0.503)	−0.85	(0.68)	0.214	0.433
Bugesera						
Coffee yield in kg per ha	3964.2	(621.5)	767.5	(668.5)	0.251	0.455
Coffee income in 1000 RwF/ha	339.1	(92.7)	2.8	(114.8)	0.981	0.938
Household income in 1000 RwF/ha	770.9	(121.6)	96.4	(157.2)	0.540	0.81
Food insecurity (HFIAS)	7.2	(0.87)	0.81	(1.1)	0.437	0.695
Huye						
Coffee yield in kg per ha	4454.7	(522.5)	−313.7	(591.2)	0.596	0.835
Coffee income in 1000 RwF/ha	423.99	(96.8)	−208.4	(126.8)	0.098	0.315
Household income in 1000 RwF/ha	791.2	(123.8)	−139.5	(152.9)	0.362	0.629
Food insecurity (HFIAS)	9.76	(1.1)	−1.6	(1.4)	0.283	0.51
Lake Kivu						
Coffee yield in kg per ha	4723.9	(486.7)	388.8	(549.4)	0.487	0.749
Coffee income in 1000 RwF per ha	282.4	(90.5)	142.3	(124.3)	0.252	0.455
Household income in 1000 RwF per ha	737.5	(149.6)	83.9	(182.0)	0.645	0.835
Food insecurity (HFIAS)	8.9	(0.74)	0.03	(1.2)	0.980	0.938

Note: Non-certified PO presents the potential outcome means for certified farms under hypothetical non-certification; ADPO^C stands for 'average difference in predicted outcomes' for certified farmers under certification and hypothetical non-certification; Standard deviation in parentheses.

In Huye and the Lake Kivu region, results are mostly qualitatively in line with the general findings, that is, the average difference in predicted outcomes (ADPO^C)have the same signs as in the full sample, but they are not statistically significant. The only significant differences are observed in the context of IPM: In Huye, certified farmers tend to use more practices, whereas, in the Lake Kivu region, the likelihood of IPM adoption is lower among certified farmers. However, these two results turn insignificant when taking multiple hypotheses testing into account.

Economic outcomes

We do not find any significant association between Rainforest Alliance Certification and coffee-related economic outcomes in the full sample, that is, coffee yield and cash income from coffee. This is despite the fact that certified farmers seem to be more likely to apply organic fertilizers and IPM, as shown in the previous section. The uptake of good agricultural practices associated with certification is highest in Bugesera so we would expect the yield effects to be largest in this region. When looking at the regionally disaggregated results, we find that the ADPO^C, that is, the yield increase associated with certification, is most prominent in Bugesera but not statistically significant. Furthermore, despite these observed yield increases in Bugesera, this is not reflected in a similar increase in coffee income associated with certification. Increases in coffee income associated with certification are highest in the Lake Kivu region, the region best suited for coffee production, but also here, the $ADPO^C$ is not significant. In summary, we do not find significant associations between certification and coffee yields and coffee incomes in any of the three regions.

In the absence of significant changes in coffee-related outcomes, we are also less likely to find significant associations between certification and household-related welfare outcomes. This is confirmed in the full sample and the region-specific samples concerning household income. We find a significant association between certification and reduced food insecurity in the full sample. However, this result is not robust once we correct for multiple hypotheses testing and is also not significant in any of the three regions.

Environmental-economic interactions

To investigate potential tradeoffs between environmental and economic outcomes associated with certification, we explore bivariate correlations between the farmer-specific $ADPO^C$ for the number of shade trees per hectare, as an indicator for biodiversity-friendly farm management, and selected economic outcome variables. We chose to focus on the connection between shade trees and economic outcomes, as Rainforest Alliance is significantly associated with an increase in the cultivation of shade trees across the full sample. Furthermore, shade tree management has also been used in previous research to investigate economic-environmental trade-offs of certification (Haggar et al., 2017; Vanderhaegen et al., 2018). Figure 2 visualizes the relationships between the ADPO of tree density and the ADPO of coffee yield, coffee income, and household income, respectively.

In the full sample, we find slightly positive correlations between environmental and economic benefits associated with certification when considering the relationship between shade tree density and yield effects or coffee income. No strong connection is observable in the full sample between shade tree density and overall household income. Region-specific results are more pronounced, and we can observe some clear differences between the regions. In Huye and the Lake Kivu region, the two regions that are more suitable for coffee production, we observe a positive correlation between environmental and economic benefits associated with certification. In Bugesera, the climatic region least suitable for coffee production, the observed correlations between environmental and economic benefits are negative, indicating the existence of tradeoffs. While there is no strong relation between shade tree density and yield changes, increased shade tree density associated with certification is closely related to decreases in coffee income and household income in Bugesera.

DISCUSSION

Although the application of good agricultural practices is already quite common in Rwanda, we find an overall positive association between Rainforest Alliance Certification and the uptake of the management practices studied. Yet, the overall increase in the uptake of good agricultural practices does not translate into improved economic indicators among certified farmers. This is in line with findings by Ibanez and Blackman (2016), who find that sustainability certification

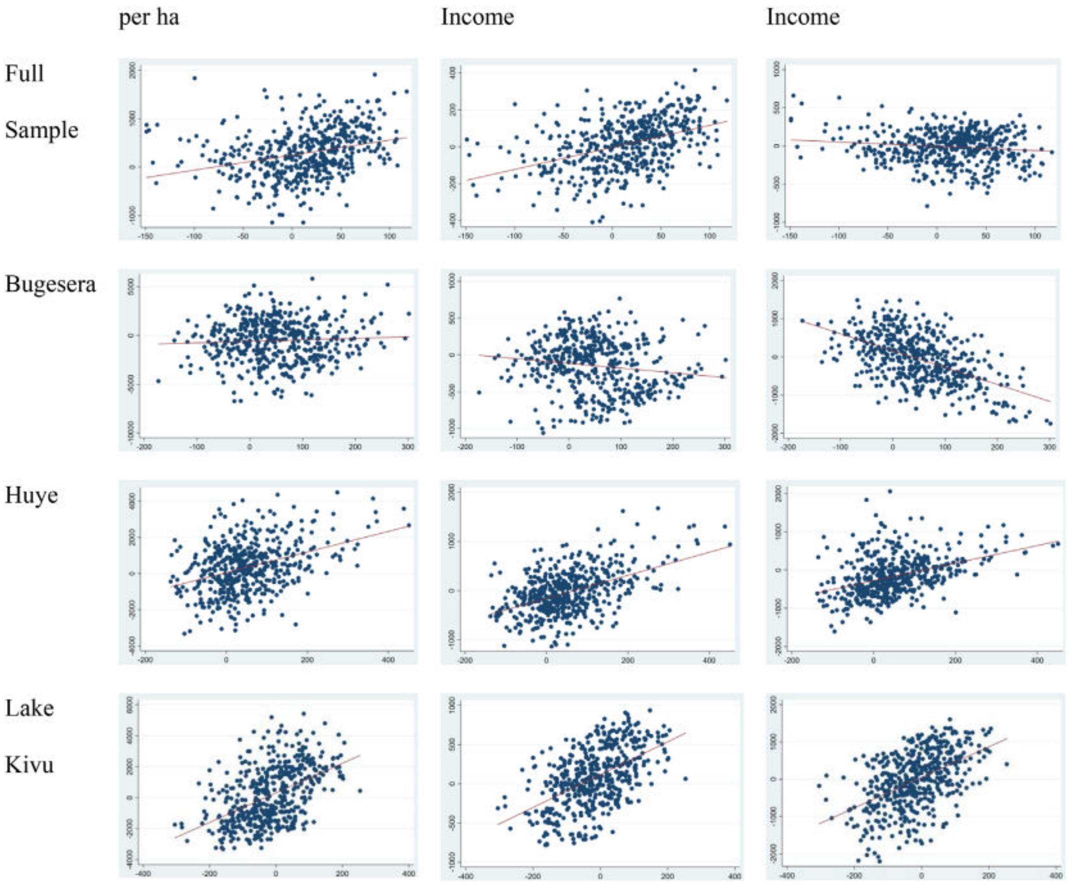

FIGURE 2 Correlations between farmer-level ADPO (changes associated with certification)

is associated with an increased uptake of environmentally friendly management practices, that is, an increased uptake in organic fertilizer, but did not identify any economic benefits. Similarly, Vanderhaegen et al. (2018) found that certification improves either economic outcomes such as productivity or environmental outcomes such as biodiversity, but not both at the same time.

Generally, our results indicate a stronger connection between Rainforest Alliance and changes in environmentally friendly practices in regions less suitable for coffee production, in our case in Bugesera. Although the use of environmentally friendly practices is generally common in our research area, we observe that in the regions more suitable for coffee production these practices are more prevalent among non-certified farmers than in Bugesera. Accordingly, initially, lower levels in Bugesera may be the reason why Rainforest Alliance is more strongly associated with an increase in the uptake of practices in this region. As the use of good agricultural practices is required to become Rainforest Alliance certified, the increase in adoption in areas with lower prior adoption rates is not surprising, but rather to be expected. At the same time, this shows that Rainforest Alliance is indeed able to attain changes in prevalent farm practices.

While there is a positive correlation between certification and the use of shade trees, we find no significant connection between certification and the number of shade trees.

Overall, the integration of shade trees is widely practiced among coffee farmers in our research area. Increased pressure on land has provided incentives to integrate trees with coffee in Rwanda. Farmers optimize farmland to produce essential goods such as fruits, firewood, and mulch, alongside coffee (Smith Dumont, Gassner, Agaba, Nansamba, & Sinclair, 2019), which is also common among Latin American coffee producers (Méndez, Bacon, Olson, Morris, & Shattuck, 2010). A limitation of our data is that we have no information on the planting date of the trees, and can therefore not trace how many trees were planted after certification. Nonetheless, certification may play an important role not only in providing incentives to plant new trees, but also to maintain existing shade trees, which may otherwise be progressively removed to increase the productive efficiency of the coffee plantation. Furthermore, cultivating shade trees is part of Rainforest Alliance's continuous improvement system. As certification is still relatively recent in Rwanda, and farmers have been certified only for a few years, the number of shade trees on certified farms might further increase.

In our study, we do not find significant associations between certification and (socio-)economic outcomes. While the adoption of good agricultural practices is directly within the control of the certification schemes, economic outcomes are only indirectly associated with Rainforest Alliance. Coffee and household incomes are also directly affected by external factors such as input and market prices or market demand. Overall, an insignificant association between certification and (socio-)economic outcomes is in line with previous studies on the economic benefits of coffee certification (DeFries et al., 2017). Improvements in economic outcomes can result from the application of good agricultural practices that can lead to yield increases and/or quality improvements. Yield increases and quality improvements are, however, long-term objectives, which may not have materialized in Rwanda yet. Furthermore, previous research has documented a positive association between Rainforest Alliance Certification and price premiums (Haggar et al., 2017; Rueda & Lambin, 2013), which can translate into income increases more directly. In Rwanda, the coffee sector is strongly regulated by the NAEB, which sets a floor price for coffee cherries. As a result, certified coffee might not be able to obtain price premiums high enough to translate into substantial income increases for certified farmers (yet). The fact that other studies report similar findings regarding the absence of significant effects of Rainforest Alliance Certification on coffee productivity and net income, such as Haggar et al. (2017) for Nicaragua, suggests that further research should specifically focus on economic effects in the long run.

Regarding synergies and tradeoffs, we observe different tendencies across regions. In Huye and the Lake Kivu region, shade tree density and income simultaneously rise under certification, pointing towards synergies between these outcomes. In Bugesera, we find some evidence for minor tradeoffs between outcome categories, as Rainforest Alliance is associated with either an increase in shade tree density or income. This is similar to Haggar et al. (2017), who find a weak but negative correlation of tree diversity with productivity and net income. In our study, we observe tradeoffs in Bugesera, the region that is less suitable for coffee production, suggesting that here increasing production costs associated with the uptake of management practices are not compensated by increases in yields or prices. On the other hand, in the favorable regions of Huye and Lake Kivu, the observed synergies between increases in shade tree density and income levels might be related to further improvements in coffee quality and farmers' ability to secure price premiums.

Overall, our results suggest that through the certification of good agricultural practices, Rainforest Alliance Certification might be effective in increasing the uptake of environmentally friendly management practices, particularly in regions where initial adoption levels are low. Yet, while in regions that have favorable conditions for coffee production, improvements in production practices seem to go hand in hand with economic benefits, this is less so the case in the region that is less favorable for coffee production. Thus, if certification is promoted in less favorable regions, particular effort needs to be placed on securing economic benefits for farmers, too. This said, our results should be treated with caution since the overall associations between certification and economic outcomes are weak in our sample, which may confound the interpretation of the observed synergies and tradeoffs.

CONCLUSIONS

This study investigates the relationship of Rainforest Alliance Certification with environmental and socio-economic outcomes of coffee farmers in Rwanda. Using household survey data from three agro-ecological regions, we explore potential tradeoffs between these dimensions. Since certified and non-certified farmers are likely to differ systematically, we employed IPWRA to reduce potential selection bias in our analysis. Our results indicate no significant associations between Rainforest Alliance Certification and socio-economic outcomes of coffee farming in Rwanda, but a positive association between certification and good agricultural practices. This finding may not be surprising, since the application of good agricultural practices is a requirement for certification, whereas the economic outcomes considered in this study depend on other external factors, including market demand, prices, and climate conditions. We find that the association between certification and adoption of good agricultural practices is particularly strong in the region least favorable for coffee production, indicating that under such circumstances Rainforest Alliance Certification could provide leverage in promoting more environmentally friendly coffee production practices. Caution is warranted, however, due to potential tradeoffs between environmental and economic benefits. While in the more favorable regions for coffee production, Rainforest Alliance Certification tends to be associated with increases in shade tree density and income at the same time, pointing towards synergies, in the less favorable region we find evidence for tradeoffs. To overcome some limitations of our data and further substantiate our findings, further research is needed that explicitly takes longer-term economic effects of certification into account to provide more comprehensive information on the economic viability of certification for smallholder farmers under different agro-ecological conditions.

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ENDNOTE

[1] Other schemes in Rwanda include Starbucks' C.A.F.E. Practices, Nespresso's AAA Sustainable Quality Program, and 4C Compliant Coffee (AgriLogic, 2018).

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APPENDIX A

TABLE A1 Probit regression on the certification decision to derive inverse probability weights

	Full sample	Bugesera	Huye	Lake Kivu
HH Size	0.002	0.023	0.07	0.04
Education of hh head	−0.02	−0.03	0.03	−0.05
hh type[1]	−0.29**	−0.899***	0.02	0.38
Age of the household head	−0.004	0.028**	−0.03**	−0.01
Farm size in ha	−0.004	1.3	−1.4	−0.74
Coffee area in ha	2.0 ***	−0.60	4.5***	2.2
Years of experience in coffee production	0.02***	0.02	0.04***	0.01
Time to nearest CWS	0.002	0.008***	−0.001	−0.004
Form of ownership of CWS[2]	−0.26**	−0.898***	−0.77***	0.22
N	488	188	161	139
LR chi2(9)	39.72	63.38	30.81	10.11
Prob > chi2	0.0000	0.0000	0.0003	0.3415
Log likelihood	−311.13086	−98.101296	−90.912967	−88.244123
Pseudo R2	0.0600	0.2442	0.1449	0.0542

Note: (1) 0 = Male Headed, 1 = Female headed; (2) 0 = Cooperatively owned, 1 = privately owned; Significacet levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Abbreviations: CWS, Coffee washing station; HH, household.