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Determinants of adoption of sustainable agricultural practices by small-scale coffee farmers in amazonas, Peru

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ABSTRACT
This study seeks to examine the factors affecting the adoption of SAPs and their intensity of use at the smallholder household level in four coffee producer districts of Luya, Amazonas, Peru, based on cross-sectional survey data obtained from 145 sampled households, six coffee farmer interviews, and three expert interviews. Despite the benefits of Sustainable Agricultural Practices (SAPs), their use rate among small-scale farmers is still low in developing countries like Peru. The results showed that coffee farmers adopted different SAPs according to several factors that determine their adoption; those factors can be farm(er)-related, sustainable practices' attributes, and communication and extension. Moreover, drawing on the logistic regression technique (logit), the marginal effects of the critical factors that significantly determine the adoption of SAPs were obtained. The logit results evidenced that coffee farmers' decision to adopt SAPs was influenced by the number of people of working age living in the household for cover crop and composting, farmland slope for living or dead barriers, coffee yield and educational attainment for fertilization, and number of assets and facilitating conditions for wastewater treatment. The main problems are the lack of workers for integrated pest management, the focus on making money on farms for agroforestry, and people's fears about taking risks with cover crops. The findings provide actionable insights for policymakers and development practitioners aiming to foster sustainable farming practices in similar contexts.

Contribution/Originality: This study contributes to the literature by providing empirical evidence on the determinants of sustainable agricultural practice adoption among small-scale coffee farmers. The findings not only fill a knowledge gap in a geographically under-researched area but also provide insights for policymakers and practitioners aiming to foster sustainable farming practices.

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1. INTRODUCTION
There is no consensus on the definition of sustainable agriculture; however, its principles are improving efficiency in the use of resources; conserving, protecting, and enhancing natural ecosystems; protecting and improving rural livelihoods and social well-being; enhancing the resilience of people, communities, and ecosystems; and promoting good governance of both natural and human systems (Food and Agricultural Organization of the

United Nations, 2016). Moreover, it is widely accepted that sustainable agriculture plays a crucial role in enhancing economic and environmental outcomes, as well as promoting human well-being. Research demonstrates that compared to conventional land use, sustainable land use systems are beneficial for farmers, sustainability, and climate (Van Noordwijk et al., 2018).

Smallholder farming, on the other hand, takes place in a complex socio-ecological system, and farmers have to deal with a lot of social, political, and environmental problems. Moreover, the ongoing climate change conditions disproportionately affect farmers, making smallholders particularly susceptible to its impacts (Robiglio et al., 2017). In addition to multiple non-climatic factors, such as socio-economic and environmental pressures, the vulnerability of smallholder agriculture is evident.

In response to these threats has emerged sustainable agriculture, which is highly related and crucial for achieving the United Nations' sustainable development goals (Van Noordwijk et al., 2018; World Bank; CIAT; CATIE, 2015) and is considered imperative for resilience in the context of climatic variability (Lamichhane, Miller, Hadjikakou, & Bryan, 2020). However, there is conflicting evidence about the factors that affect the adoption or adaptation of sustainable practices in developing countries like Peru, where there is still scarce research on the issue of sustainable agricultural practices. This suggests that a more comprehensive investigation is required into ways to motivate smallholder farmers to adopt better agricultural practices and technologies (Rosário, Madureira, Marques, & Silva, 2022). In Peru, Barbarán (2014) in her research about the adoption of organic farming in the northern Piura region, found that credit access, use of conservation techniques, access to technical assistance, propensity to innovate, income, and land-tenure status significantly increased the adoption. In the Amazonas region of northern Peru, coffee is the principal cash crop (Robiglio et al., 2017) therefore, the local economy hinges on this particularly important crop for remote areas (Chavez Espinoza, Morante Dávila, Cueva Vega, Cruz Caro, & Chavez Espinoza, 2022; World Bank; CIAT; CATIE, 2015) since coffee as a commodity can be kept and traded despite far distances. Coffee production in Amazonas and, in general, in Peru faces many challenges like pests and diseases and low yields, which, joined with the ongoing global change, make the coffee value chain unsustainable, impacting rural people's livelihoods. In the academic literature, it is widely recognized that sustainable agricultural practices in the coffee sector are crucial to coping with unpredictable events. These practices have the potential to increase coffee yields while enhancing farm resilience (Bro, Clay, Ortega, & Lopez, 2019; Zeweld, Van Huylenbroeck, Tesfay, & Speelman, 2017) and balance the maintenance of ecosystem services with economic farmers' goals. However, despite the multiple benefits that sustainable practices promise, there are still low adoption and adaptation rates around Peru (World Bank; CIAT; CATIE, 2015). The reasons for the low levels of adoption are still unknown because most of the research has been focused on developing and applying technology packages for yield improvement. This research aims to determine the drivers and barriers to small coffee farmers' adoption or adaptation of sustainable practices, which, according to prior research, varies in each agroecosystem (Lamichhane, Hadjikakou, Miller, & Bryan, 2022). In particular, this study seeks to examine the main factors influencing small-scale farmers' adoption of sustainable agricultural technologies in Amazonas, Peru, as a strategy for rural development.

2. METHODOLOGY

2.1. Study Area

The research reported upon here comes from a study area located in northern Peru (Figure 1), specifically in four districts of Luya province in a warm, dry, or cold, dry climate (Robiglio et al., 2017).

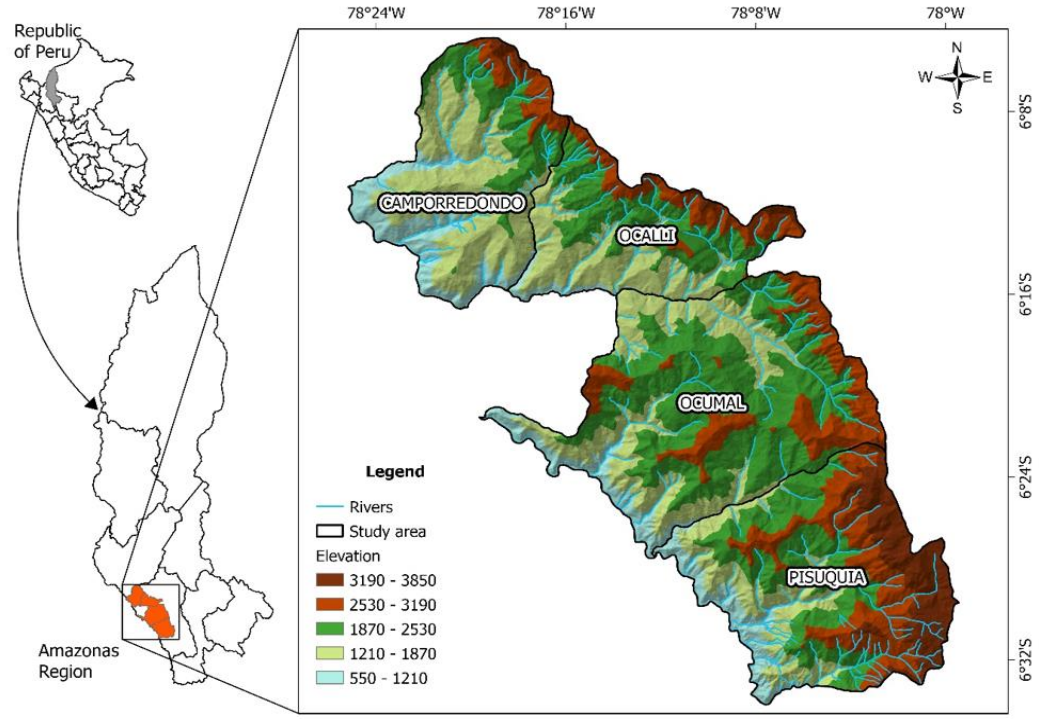

Figure 1. Geographical location of the study area.

Located on the right bank of the Marañon River, these soils are classified as cambisols according to FAO's World Reference Base. This rural area is comprised of small-scale arabica coffee farmers who have a high dependency on rain-fed agriculture; the mean annual rainfall varies between 126 to 885 mm, and the temperature from 6°C to 29°C. The rainfall pattern is lately irregular and unreliable, thus affecting farmers' crop activities. The climatic and topographical conditions make this zone one of the most important coffee producers in Amazonas (Robiglio et al., 2017).

2.2. Questionnaire Development

The questionnaire was developed based on existing literature (Venkatesh, Morris, Davis, & Davis, 2003). The topic comprised farmers' socio-demographics, including gender, household size, age, experience, transportation means, income sources, and financial status. After that, it was considered farm characteristics such as size, fertility, slope, ownership, yield, management challenges, distance from household to input and output markets, and livestock keeping; then, it was asked for access to credit and input availability. The middle part of the questionnaire contained the characteristics of sustainable practices and farmers' knowledge, performance expectancy, effort expectancy, social influence, attitudes, behavioral intentions, and sustainable practices already implemented. In the last part, it was queried about access to communication and extension services. It is worth noting that the middle part of the questionnaire included statements operationalizing different dimensions of the latent variable of the research model, which could not be observed directly (Otter & Deutsch, 2023).

Indicators for independent predictor variables were measured using summated Likert scales from 1 to 5; for dependent variables, a binomial yes-no response was used to refer to the implementation of sustainable practices in their plots. It was hypothesized that a wide array of factors are significant determinants to consider for smallholders' adoption of Sustainable Agricultural Practices (SAPs). Table 1 displays the specific variables and definitions.

Table 1. Independent variables.

Variables	Definition	Expected sign
Farmer characteristics		
Gender	Gender of the household head	±
Age	Age of the household head	-
Household size	N° of working-age adults	+
Educational level	Years of formal schooling (HH head)	+
Farming experience	Farming experience of the household head	+
Economic status	Farmer's view of his/Her economic status	±
Farm characteristics		
Farm size	Coffee farm size in hectares	±
Soil fertility	Farmer's soil fertility rate	+
Land slope	Average land slope	-
Land ownership	Land tenure status (1 = Titled, 0 = Otherwise)	+
Coffee yield	Coffee output in quintals (56 kg) per hectare	+
Farm assets	N° of farm assets	+
Plot market distance	Distance from plot to input market (Minutes)	-
Credit eligibility	Farmer is eligible for a loan	+
Credit use	Farmers used agricultural credit	+
Coffee price	The current coffee price in PEN per quintal of 56 kg	+
Labor force availability	Availability of labor force	+
Inputs availability	Availability of farm inputs	+
Certification	Farm under any certification scheme	+
SAPs attributes		
Relative advantage	Perceived superiority to the practice that it supersedes	+
Compatibility	Perceived compatibility with their production system	+
Complexity	Perceived complexity	-
Communication and extension		
Access to communication means	N° of means of communication that it has access to	+
Access to extension services	N° of times farmers got training, technical assistance, or field demonstration	+
Visited sustainable farm	Whether farmers have visited a sustainable farm	+
Access to weather information	Whether farmers have access to weather information	+
Access to market information	Whether farmers have access to market information	+
Organization belonging	Farmer belongs to any organization	+

2.3. Sample

To begin with, the population of interest for this study is made up of 4025 small-scale coffee farmers located in four districts, selected due to their high potential for coffee production in Luya; those districts are Pisuquia, Ocallí, Ocúmal, and Camporredondo (MIDAGRI, 2023).

For the sample number, the following formulae were used:

$$n = \frac{Z^2 * p * q * N}{E^2(N-1) + Z^2 * p * q}$$

n: Sample.
N: Population is 4025.
Z: Is Z score for 95% of confidence level equal to 1.96.
E: Margin of error equals to 8% (0.08).

$$n = \frac{1.96^2 x 0.5 x 0.5 x 4025}{0.08^2(4024) + 1.96^2 x 0.5 x 0.5}$$

n= 144.7 which rounds to n= 145.

2.4. Sampling

The participants were selected using a multi-stage sampling approach. In the first stage, simple random sampling was used to select 20 villages within the four districts. Using simple random techniques, the second stage selected six to seven participants from each village. Along with the willingness to participate, the characteristics they had to meet were to be aged 18 years or older and oversee a small coffee farm in any of the districts of Pisuquia, Ocallí, Ocúmal, and Camporredondo in Luya province, Amazonas region, Peru.

2.5. Survey

Firstly, a presurvey was conducted in each district. Based on the feedback during this pre-test, the questions were ensured to be unambiguous and understandable by the respondents. After that, the instrument was revised, and some items were reordered to enhance the survey's flow. Moreover, Cronbach's alpha was used to ensure instrument reliability, where a threshold of 0.6 was accepted (Taber, 2018).

The survey was performed face-to-face using paper and pencil. It was carried out by two enumerators familiar with the farming system and local language, from the 16th of June to the 11th of July 2023. It took 40 to 50 minutes to complete each survey. In total, it was applied to 145 questionnaires. All participants were informed of the research purpose and asked for their voluntary participation; farmers were also informed to leave at any time during the interview process for distinct reasons; however, that problem did not come across, and as a result, the response rate was 100%.

2.6. Interviews with Farmers and Experts

To deepen the research question, six interviews were conducted with farmers in the four districts after completing their survey, allowing for a broader understanding of relevant aspects of the topic.

Additionally, three semi-structured face-to-face interviews were conducted with experts from academia, government, and the private sector to gather information and insights about the adoption of sustainable practices. Prior to this, their voluntary participation was requested via email.

2.7. Ethical Considerations

The Ethics Committee of the University of East Anglia in the United Kingdom granted ethical approval number ETH2223-1774 (Appendix 1) to conduct the research and collect data from respondents.

2.8. Data Analysis

For data analysis, it used descriptive statistics and a binary logistic regression model to identify the determinants of SAP adoption. The logistic regression model is a widely employed technique when the interest is the impact of various explanatory variables on the response variable, like adoption-related research. This model is used to explain a categorical variable called Y, which has two possible values: 0 representing non-adoption and 1 representing adoption (Cary & Wilkinson, 1997; Hosmer, Lemeshow, & Sturdivant, 2013). The model's purpose is to compute the probability of Y being 1 and to ascertain how the explanatory variables X {x1,…,xn} exert an impact on Y. X constitutes a collection of explanatory variables that combine various sets of factors. In this investigation, these categories encompass farm(er) characteristics, SAPs' attributes, and communication and extension services.

The coefficients of the logit regression model, estimated by maximum likelihood methods and exponentiated coefficients [exp (B)] or odds ratios, were calculated using Statistical Package for the Social Sciences [SPSS 29] (Inc., Chicago, IL, United States). Several explanatory variables Xi strongly influenced the adoption or non-adoption of SAPs. Some were related to farmer characteristics, e.g., household number, and farm characteristics, e.g., land slope. The independent variables were initially checked for multicollinearity using the SPSS stepwise procedure of "collinearity diagnostics". The variable distance to the output market was withdrawn owing to collinearity with the distance to the input market.

To select relevant variables for the model, contingency table analysis was used for categorical variables and univariable analysis was applied for continuous variables (Hosmer et al., 2013). Model fit statistics were acceptable; the Hosmer and Lemeshow test statistic for the goodness of fit was not significant ($p > 0.05$), indicating a good model

fit (Hosmer et al., 2013). The Nagelkerke r2 was always greater than 0.1 indicating that the covariates explain a certain amount of variance in the dependent variable.

3. RESULTS

3.1. Descriptive Level

Of the respondents' households (n = 145), about 59% used the contour planting technique, and 39% applied sustainable fertilization practices and cultural control for pest management. However, only 15% of them used permanent soil cover as a soil conservation practice (see Table 2).

Table 2. Main sustainable agricultural practices adopted by the sampled farmers.

Dependent variables	Descriptions	Mean	Std. deviation	Percentage
Permanent soil cover	Dummy (1 if yes, 0 otherwise)	0.15	0.36	15%
Agroforestry	Dummy (1 if yes, 0 otherwise)	0.44	0.50	44%
Contour planting	Dummy (1 if yes, 0 otherwise)	0.59	0.49	59%
Living or dead barriers	Dummy (1 if yes, 0 otherwise)	0.43	0.50	43%
Composting	Dummy (1 if yes, 0 otherwise)	0.24	0.43	24%
Fertilization	Dummy (1 if yes, 0 otherwise)	0.39	0.49	39%
Integrated pest management	Dummy (1 if yes, 0 otherwise)	0.39	0.49	39%
Wastewater treatment	Dummy (1 if yes, 0 otherwise)	0.38	0.49	38%

The intensity of SAP adoption ranges from zero to eight; only seven farmers in the sample had not adopted any SAP. The mean number of SAPs adopted is three. Twelve percent adopted only one SAP, while about 25% of producers adopted two SAPs. Additionally, the majority 69% of the sample adopted 2–4 SAPs. Finally, about 7% of farm households used six, and 1% adopted 7 SAPs considered for this study in the data set.

Out of the total sample, over half of the smallholders (53.1%) belong to an organization; most of them (85.7%) are members of any farmers' association (45.5%), 10.4% belong to an agricultural cooperative, while only 3.9% of the organized farmers are members of any private company.

Regarding certifications, 11% of farmers reported producing under the organic certification scheme (Org); however, some farmers reported double (8.3%) or triple certification (1.4%) such as organic, Fairtrade (FT), and Rainforest Alliance (RA) (see Figure 2). This sums up to 22.8% of certified coffee farmers.

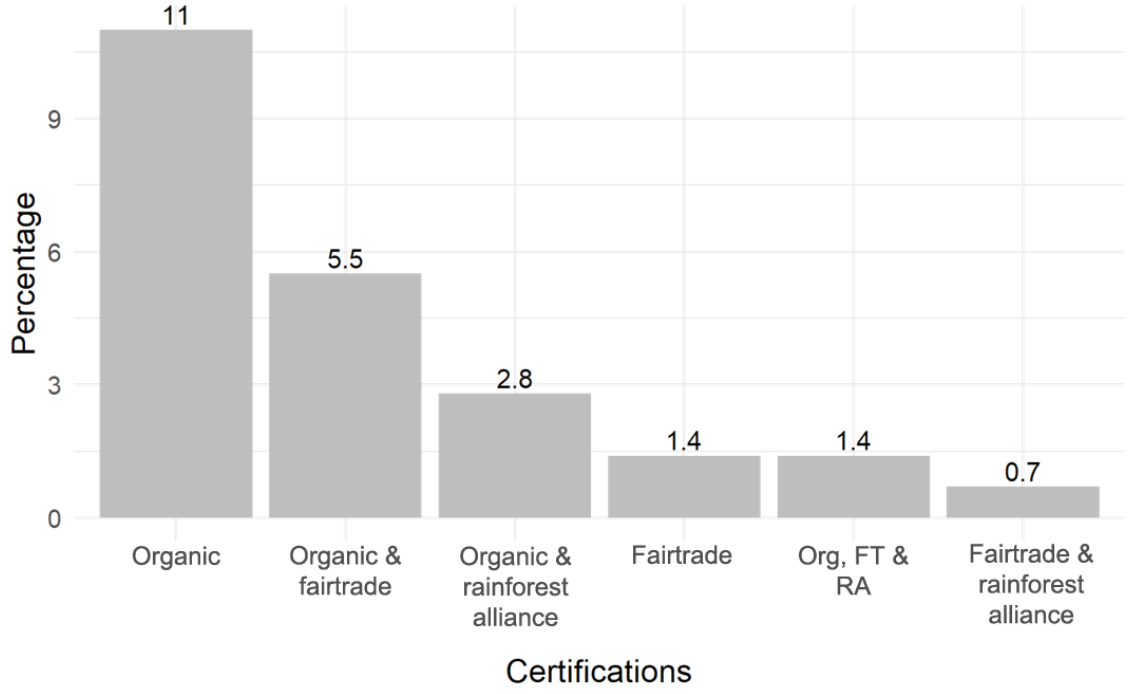

Figure 2. Coffee farmers under certification schemes.

Regarding access to extension services during the last year (2022-2023), 59.7% attended at least one training activity or received technical assistance. Of these, 40.5% reported having received both training and technical assistance, while only 2.4% of coffee producers reported participating in field demonstrations (Figure 3).

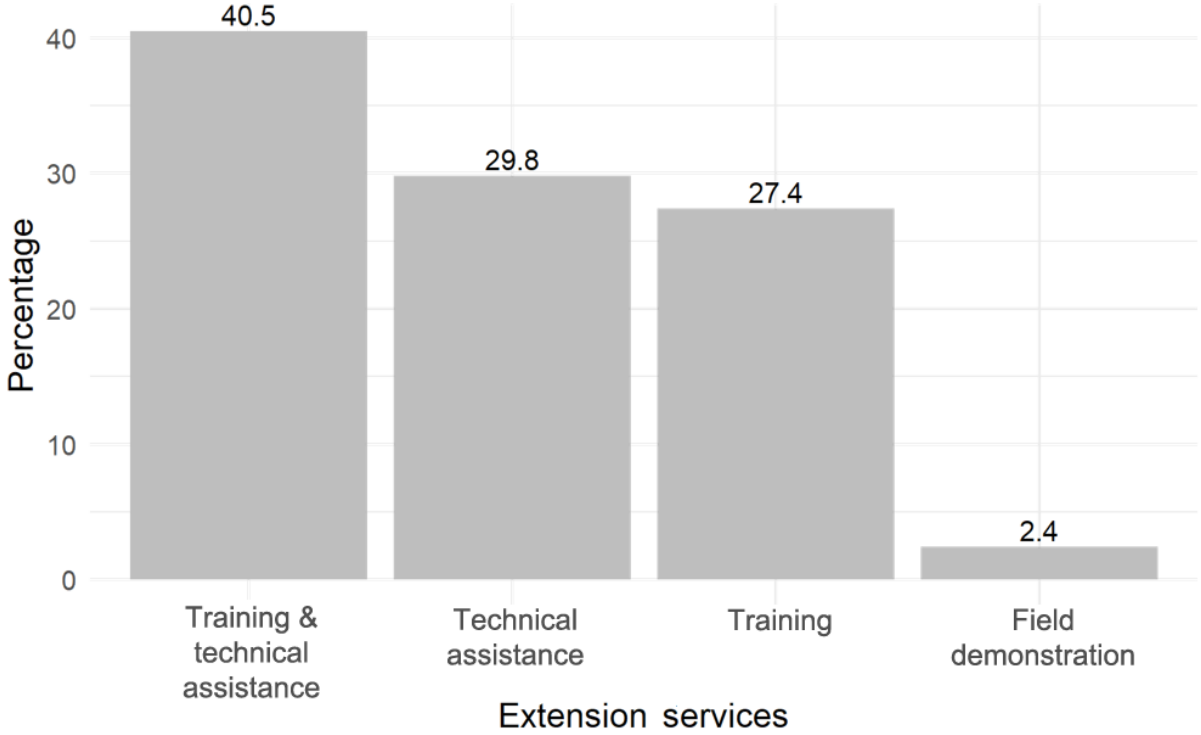

Figure 3. Percentage of farmers who accessed extension services.

The entities that delivered extension services were categorized as public and private. Figure 4 shows that private organizations, such as farmers' associations, agricultural cooperatives, and coffee companies, provided extension services to over 59% of farmers. In contrast, public entities like agricultural agencies and the National Service of Agrarian Health (SENASA) together reached around 24.1% of the farmers who received extension services. Respondents did not mention the National Institute of Agricultural Innovation (INIA) or the Agricultural Rural Productive Development Program (AGRORURAL). Finally, respondents only once mentioned the Social Development Cooperation Fund (Foncodes), which does not focus solely on coffee.

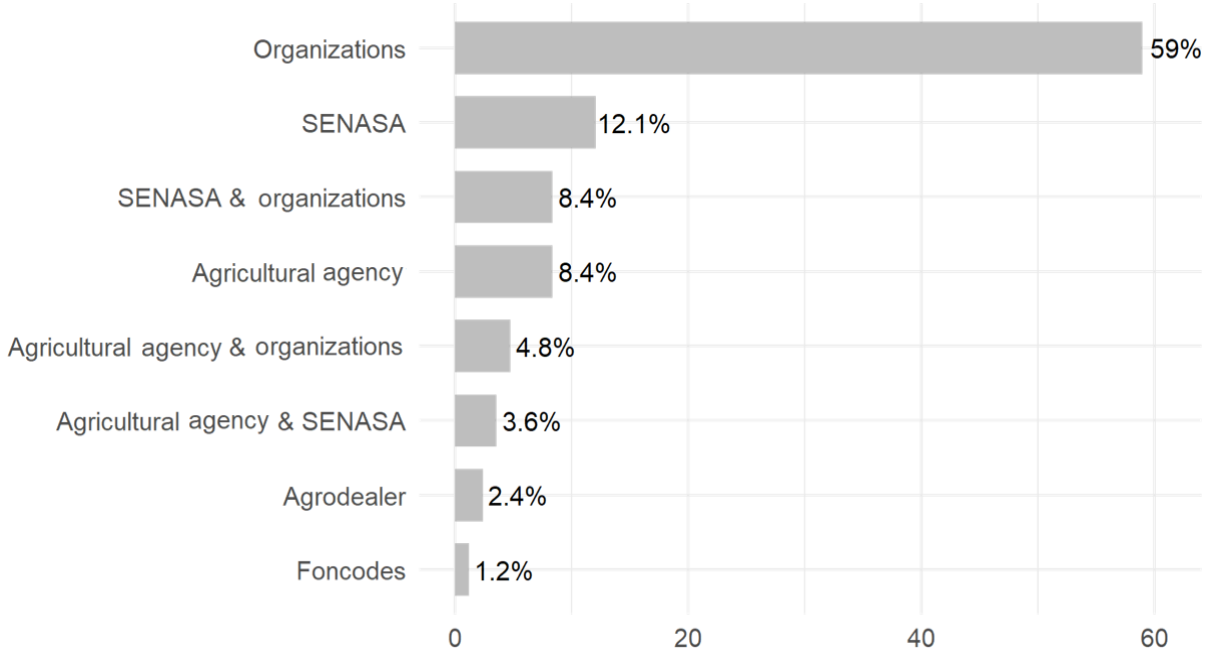

Figure 4. Entities that delivered extension services.

3.2. Statistics of the Independent Variables

The covariates included in the logit model involved household-specific characteristics, economic situations, farmers' perceptions about their farm plots, and communication and extension. Among the household characteristics, there was a mean of 2.5 individuals of working age per household. Whereas the average years of coffee farming experience in the study area was revealed to be approximately 21 years. In addition, the average distance from the furthest plot to the market was 68 travel minutes, traveling either on a bridle path or by car according to the mobility

used by the producer. Also, the percentage of households owning livestock was 62%; this farm animals included bull or cow, pig, or poultry.

Regarding farm-specific characteristics, the study revealed that about 27% of farmers rated their farm as having good soil fertility, and only 2% rated it as poor. Nearly one-third (31.7%) said that the average slope is steep, and 14.5% reported farming coffee on flat land. Concerning land tenure rights, over one-third (35.8%) of surveyed households reported having property titles, while the majority of them did not receive this document. The vast majority (96.6%) have a coffee pulper for the individual pulping process. However, only 23% and 31% reported owning a sundrier and storage facility for coffee, respectively.

When asked about the challenges they face concerning coffee management, they reported pests and diseases (mainly coffee berry borer, coffee leaf rust, and ants) as the main problem, followed by drought and low coffee prices. Seventy-five percent of respondents noticed a change in their working environment and reported weather variation that affects coffee uniform ripening, which is similar to the findings of Jezeer, Verweij, Boot, Junginger, and Santos (2019) in the neighboring San Martin region. Another important topic is credit; 47.6% said that they are loan eligible, but hardly 15% used any loan for agricultural purposes in the last three years.

Concerning factor market, 40% considered that they rarely find a labor force for coffee work, whereas 27.6% and 22.1% considered that they sometimes and often find workers, respectively. When it comes to input availability, 26.2% reported that they rarely find inputs, especially when they seek organic inputs like island guano (guano de isla), while 29% and 35% sometimes and often find inputs like fertilizers and pest control products.

3.3. Determinant Factors of Adoption

The resulting data set allows an examination of the adoption of various practices considered sustainable according to the literature. Following the approach of logistic regression, each dependent variable was transformed into a dummy, analyzed, and the results are shown in Table 3.

Table 3. Logistic regression results for significant determinants of sustainable practices adoption.

Variables	B	S.E.	Wald	D.F.	Signif	Exp(B)	Variables	B	S.E.	Wald	D.F.	Signif	Exp (B)
Cover crops							Composting						
Household number	0.46	0.21	4.96	1	0.026**	1.58	Household number	0.43	0.20	4.69	1	0.03**	1.53
Cover crop attributes	1.18	0.65	3.29	1	0.07*	3.25	Extension (Yes)	1.12	0.50	5.04	1	0.025*	3.07
Farmer knowledge	0.83	0.43	3.78	1	0.052*	2.30	Composting attributes	1.10	0.36	9.12	1	0.003*	2.99
Risk expectations	-0.92	0.31	9.10	1	0.003**	0.40	Facilitating conditions	0.84	0.38	4.84	1	0.028*	2.32
Fertilization													
Agroforestry							Farm investments (Yes)	1.165	0.524	4.949	1	0.026*	3.206
Farm orientation (Profit)	-2.55	1.02	6.24	1	0.012**	0.08	Credit use (No)			4.801	2	0.091*	
Agroforestry attributes	2.66	0.58	20.77	1	<0.001***	14.35	Credit use (To some extent)	1.159	0.973	1.42	1	0.233	3.188
Certification	3.03	1.45	4.36	1	0.037**	20.59	Credit use (Yes)	1.163	0.604	3.705	1	0.054	3.2
Facilitating conditions	1.24	0.54	5.37	1	0.021**	3.47	Coffee yield	0.041	0.015	7.475	1	0.006***	1.042
							Educational attainment	0.143	0.062	5.245	1	0.022**	1.154
Contour planting							Integrated pest management						
Economic situation (Extremely poor)			6.79	3	0.079*		Off-farm income	0.93	0.56	2.79	1	0.095*	2.541
Economic situation (Poor)	1.84	0.87	4.54	1	0.033	6.32	Labor availability (Rarely)			9.49	3	0.023**	
Economic situation (Average)	2.27	0.90	6.39	1	0.012	9.70	Labor availability (Sometimes)	-0.39	0.49	0.63	1	0.427	0.677
Economic situation (Not poor)	2.38	1.20	3.94	1	0.047	10.77	Labor availability (Often)	1.07	0.48	4.91	1	0.027	2.925
Farmer knowledge	0.45	0.25	3.33	1	0.068*	1.57	Labor availability (Always)	0.91	0.64	2.00	1	0.157	2.48
Performance expectancy	0.58	0.33	3.02	1	0.082*	1.78	Coffee price	0.01	0.00	9.08	1	0.003**	1.008
Living or dead barriers							Farmer knowledge	0.48	0.28	2.86	1	0.091*	1.614
Land slope (Flat)			5.11	2	0.078*		Wastewater treatment						
Land slope (Medium)	1.02	0.85	1.44	1	0.231	2.78	Number of assets	0.74	0.20	14.34	1	<0.001**	2.095
Land slope (Steep)	1.68	0.88	3.65	1	0.056	5.35	Coffee price	0.01	0.00	3.20	1	0.073*	1.006
Soil testing (Yes)	0.80	0.43	3.40	1	0.065*	2.22	Facilitating conditions	1.21	0.44	7.43	1	0.006**	3.358
Performance expectancy	0.94	0.34	7.51	1	0.06**	2.56	Extension (Yes)	0.95	0.47	4.10	1	0.043*	2.581

Note: ***,**,* indicates significance at 1%, 5%, and 10% level.

3.3.1. Cover Crop Adoption

A variable that significantly determined the adoption of permanent soil cover in coffee plantations was the number of people of working age living in the household (0.026**). Moreover, farmers who perceived that soil cover has good attributes in terms of relative advantage, compatibility, and less complexity, had 3 times more likelihood to adopt it (0.07*). Farmer's knowledge (0.052*) about soil cover's benefits influenced its actual use.

By contrast, risk expectations about the adoption of sustainable practices significantly prevent farmers from adopting cover crops (0.003***) by 60%.

3.3.2. Agroforestry Adoption

For coffee agroforestry adoption, results revealed that the good attributes of this practice are highly significant (<0.001***). For its use, moreover, farmers who consider that agroforestry is better than unshaded coffee, is compatible with their production system, and the management is not complex are highly probable to adopt it with an odds ratio of 14.35. Certification of the farm was related to shade-grown coffee (0.037**) with an odds ratio of 20.59.

Facilitating conditions or contextual factors (0.021**), that is, when the practice fits well with the farm's work structure, and the farmer has experience and equipment to handle SAPs, tends to use agroforestry (odds ratio [OR] = 3.47).

3.3.3. Adoption of Contour Planting

The results for practicing contour planting indicate that farmers' economic situations influence its adoption (p=0.079*). High-income farmers are more likely to adopt this practice (OR=10.77) compared to smallholders in harsh conditions. Additionally, farmers' knowledge plays a crucial role in its adoption (p=0.068*). Those who understand the benefits of contour planting for soil erosion control are more likely to use it (OR=1.57). Moreover, the performance expectancy of contour planting is another important factor considered by coffee growers when using it (p=0.082*).

3.3.4. Adoption of Living or Dead Barriers

According to the results, the factor of land slope influenced the adoption of living or dead barriers, which means that when the slope is steeper, farmers are more interested in adopting this practice, increasing the odds ratio 5 times (OR= 5.35) than in flat slope.

Coffee farmers' performance expectancy of sustainable practices had a significant impact on the adoption of this soil conservation practice (0.006**). Interestingly, soil testing is also related to the adoption of this soil conservation technique (0.065*) increasing the odds ratio of its current use more than two times (OR = 2.22).

3.3.5. Composting Adoption

For the good practice of preparing and applying compost, one of the factors that determined its adoption is the number of people of working age living in the household (0.020**). Moreover, access to extension services plays a significant role in compost use by smallholders (0.025*).

Facilitating conditions (0.028**), for instance, having tools or experience preparing compost, are significant push factors (OR = 2.32) for composting. Whereas the attributes of compost (<0.003***) have a highly positive impact on its adoption, whereby farmers who find good attributes in it are 3 times more likely to use this organic fertilizer (OR = 2.99).

3.3.6. Fertilization Adoption

The logit results revealed that prioritization of farm investment (0.026**) increases the odds ratio of fertilization by more than three times (OR=3.2). The use of credit also increases (0.054*) the adoption of fertilization (organic matter, macro, and micronutrients) three times (OR = 3.2) compared to farmers that do not use loans for agriculture purposes.

As such, coffee yield (<0.006**) is related to the adoption of fertilization. Moreover, the results also indicate that educational attainment determines the use of fertilizers (0.022**); for one additional year of schooling, the likelihood of fertilizing augments 15.4%.

3.3.7. Integrated Pest Management Adoption

Off-farm income was found to benefit the adoption of integrated pest management (IPM) (p = 0.095*) increasing the likelihood by three times (OR=3.2). Moreover, scarce labor availability (0.023**) significantly hinders the adoption of IPM, whereas when the farmer often finds a labor force the odds ratio of applying IPM increases by 2,9 times.

Farmers that get better prices tend to apply integrated pest management (0.003***). In the same manner, farmer knowledge about pest control (0.091*) determines its use according to the results.

3.3.8. Wastewater Treatment Adoption

In this case, the number of farm assets was the most significant factor determining the adoption of coffee wastewater treatment (<0.001***). Smallholders getting better prices are more likely to invest in wastewater treatment facilities (0.073*). According to the study, another significant determinant is access to extension services (0.043**). Lastly, the results also suggest that facilitating conditions (0.006**) are determinant factors for water treatment adoption in the study area.

4. DISCUSSION

This study found that different factors determine or hinder coffee growers in Luya province's adoption of sustainable practices; these factors can be farm(er)-related, sustainable practices attributes, and associated with access to communication and extension services.

4.1. Variables that Determine the Adoption of SAPs

The number of people of working age living in the household determined the use of cover crop adoption and composting of coffee pulp; this result is in line with Kassie, Jaleta, Shiferaw, Mmbando, and Mekuria (2013) for the adoption of animal manure in Tanzania and with Antwi-Agyei and Amanor (2023) who found that larger households can allocate more time to labor-intensive practices like composting activities. The average number of people of working age living in the household is 2.5, which gives an idea of family labor constraints, which is why it is necessary to hire labor.

Good practices' attributes are determinants for the adoption of cover crops, agroforestry, and composting, which are in line with the findings of Arbuckle and Roesch-McNally (2015) for perceived benefits of cover crops; this finding is also consistent with Jezeer et al. (2019) who reported a trend in farmers using high-shade levels perceived lower risks due to coffee price volatility than farmers with medium shade in the neighboring San Martin region.

Farmer knowledge determines the adoption of cover crops, as reported by Slijper, Tensi, Ang, Ali, and van der Fels-Klerx (2023) in their study of Dutch arable farmers, and by Ashrit and Thakur (2021) who concluded that knowledgeable farmers in southern India adopted sustainable agricultural practices, such as better sowing methods. Farmer knowledge also determines the adoption of integrated pest management because this practice is knowledge-intensive, as indicated by Vásquez (2018) for coffee rust control in the nearby province of Rodríguez de Mendoza.

Coffee certification was related to the adoption of agroforestry owing to certification entities like Organic, Fairtrade, and Rainforest Alliance stimulating the use of on-farm biodiversity (Bro et al., 2019); this correlates with the findings of Saragih (2013) in Indonesia, where coffee trees were associated with certified coffee.

Moreover, facilitating conditions are significant determinants for the adoption of agroforestry, composting, and wastewater treatment. These findings are backed up by Otter and Deutsch (2023) in Germany and Sebuliba et al. (2023) in Uganda, who reported facilitating conditions as a significant factor that explains the preference of farmers to use shade trees in their coffee fields. Likewise, Bravo-Monroy, Potts, and Tzanopoulos (2016) in Colombia reported facilitating conditions as a factor for the adoption of organic farming that includes coffee wastewater treatment to meet certification requirements.

The economic situation was also significant. Farmers in a better financial status adopted contour planting more than farmers in poorer economic situations. This is in accordance with Benitez-Altuna, Trienekens, Materia, and Bijman (2021) who found that factors related to economic resources, trust, and training shape risk perception and barriers, thereby indirectly impacting the adoption of ecological intensification practices in Chile.

Performance expectancy influences the adoption of contour planting, as farmers anticipate that this practice will enhance coffee quality and productivity on their farms. This factor also determines the uptake of living or dead barriers in the study area.

Land slope determined the adoption of living or dead barriers in steeper soils due to soil erosion issues; this is in line with the findings of Posthumus, Gardebroek, and Ruben (2010) in southern Peru, which might be because farmers' perception of soil erosion increases with slope, while if they cannot perceive erosion, they are less likely to use soil erosion control practices (Arellanes & Lee, 2003).

Access to extension services influenced the adoption of composting and wastewater treatment as reported by Kudama, Wana, and Dangia (2021) for composting and by Bro et al. (2019) for organic certification that is linked to wastewater treatment. This finding is also in line with Antwi-Agyei and Amanor (2023) and Eshetu, Johansson, Garedew, and Yisahak (2021) for water management and soil and water conservation, respectively.

Fertilization adoption positively correlated with coffee yield. Farmers who fertilize get better coffee yields, which allows them to earn more crop income and afford fertilizers.

Educational attainment was a determinant of the adoption of fertilization, which is consistent with the findings of Bro et al. (2019) in Nicaragua and Ehiakpor, Danso-Abbeam, and Mubashiru (2021) in Ghana, who used a multivariate probit model.

The availability of labor to hire determined the adoption of integrated pest management. This finding is consistent with Vásquez (2018) investigation of determinants of leaf rust control in coffee in the nearby province of Rodríguez de Mendoza.

The price of parchment coffee significantly influenced the application of integrated pest management and the installation of wastewater treatment facilities, possibly due to the cost-intensive nature of these practices.

Lastly, the number of assets was determinant for the installation of treatment for wastewater, which means that the use of the treatment of coffee wastewater is left until last. This might be because farmers do not see the direct benefit of this sustainable practice.

4.2. Barriers to Adoption of SAPs

The main barrier to the adoption of cover crops was risk expectations, as reported by Arbuckle and Roesch-McNally (2015) for the adoption of cover crops in the United States; however, in the study of Jezeer et al. (2019) perceived risks did not explain farmers' current shade and input strategies. Farmers who were focused on making money were the one who had the hardest time growing shaded coffee. They were also less likely to use agroforestry, which could be because they thought that coffee grown in direct sunlight would produce more beans (Guzmán Castillo, Orihuela, Vásquez-Lavín, & Arévalo López, 2024).

4.3. Variables that do not Influence Adoption

According to the results of this study, gender did not influence the adoption of any practice, as suggested by Doss and Morris (2000). Social influence of families and peers was not significant, as found by Sarkar et al. (2022) in Bangladesh, suggesting that individuals engaged in small-scale farming often disregard the impact of others' conduct on their actions (Buyinza, Nuberg, Muthuri, & Denton, 2020). Moreover, results show that economic situation is not a determinant for low-cost practices like living or dead barriers (Arellanes & Lee, 2003).

4.4. Discussion of the Interviews

Experts agree with the survey results, saying that the adoption of sustainable practices is affected by the number of family members working age, the level of education, the availability of extension services, the household income, the price of the coffee, the slope of the land, the size of the land, and the availability of labor.

From the expert interviews, it could be noted that public and private actors show different interests and visions, as reported by the Ministry of Agriculture and Irrigation (Minagri, 2018), and hence different criteria for assessing enablers, barriers, and relevant sustainable techniques. Academia and government representatives were more considerate of environmental sustainability, recommending agroforestry, while private sector interviewees, with economic viability when advising coffee quality improvement, sought ways to make the work system more efficient for farmers to lower coffee production costs and thus save time for other diversifying activities.

Most of the farmers in this area are resource-constrained and might require financial incentives to carry out sustainable farming activities. According to many authors, financial incentives had the most compelling proof of increasing farmers' probabilities of adopting conservation practices (Read & Wainger, 2023). These incentives not only help with implementation costs but also attenuate the perceived risk of adoption. Some targeted incentives that could be used are buying agricultural equipment with government money, getting technical help, and using the services of agricultural cooperatives (Parodi, Villamonte-Cuneo, Loboguerrero, Martínez-Barón, & Vázquez-Rowe, 2022; Piñeiro et al., 2020). Regardless of the incentive type, according to reports, connecting programs to economic advantages is crucial to encourage farmers to embrace SAPs in the near future. In the long run, one of the most compelling incentives for farmers to adopt and consistently follow sustainable methods is the perceived positive results of such adoption on their farms or the environment (Piñeiro et al., 2020).

4.5. Study Limitations

The smallholder farmers who took part in our study were chosen through a stratified random sampling process to make sure that all four districts were represented. However, owing to resource limitations, we used a margin of error of 8%. Given that adoption and barriers are intricately linked to complex socio-ecological systems, caution should be exercised when attempting to generalize these findings to other regions.

5. CONCLUSIONS

The factors that determined the adoption of sustainable agricultural practices in the study area are the number of people of working age living in the household for cover crop and composting, farmland slope for living or dead barriers, coffee yield and educational attainment for fertilization, and number of assets and facilitating conditions for the use of wastewater treatment.

The main things that stop coffee farmers from using sustainable farming methods are a lack of labor during the busy season for things like cover crops and composting, fears about the risks of using cover crops, and a focus on making money for agroforestry.

The results suggest that to improve the adoption rates of sustainable practices, it must be increased farmers' knowledge about sustainable practices' benefits and attributes and offer facilitating conditions for their ready uptake. Moreover, demand-driven research is needed about features farmers seek in technologies, choice experiments for coffee farmers' preferences, or willingness to adopt, in order to improve the adoption of sustainable practices in the study area.

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Institutional Review Board Statement: The Ethical Committee of the University of East Anglia, United Kingdom has granted approval for this study on 22 May 2023 (Ref. No. ETH2223-1774).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Both authors contributed equally to the conception and design of the study. Both authors have read and agreed to the published version of the manuscript.

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APPENDIX

Appendix 1. Ethics-ETH2223-1774.

Ethics ETH2223-1774 : Mr Elen Guevara Fernandez

Date Created	18 Mar 2023
Date Submitted	02 Apr 2023 Date of last resubmission 02 May 2023
Date forwarded to committee	02 May 2023
Researcher	Mr Elen Guevara Fernandez
Category	PGT
Supervisor	Dr John Mcdonagh
Faculty	Faculty of Social Sciences
Current status	Approved

Ethics application Applicant and research team Principal Applicant
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Primary Supervisor
Name of Primary Supervisor
Dr John Mcdonagh
Primary Supervisor's school/department School of Global Development

Course/Programme Details
Provide the name of your course or programme of study.
MA Agriculture and Rural Development
If the project is to be undertaken as part of a module, provide the Module Title and Module Identifier.
Dissertation DEV-7056X
If the project is to be undertaken as part of a module, provide the name of the Module Leader.
Prof Ben D'Exelle

Project details
Project title
Determinants of adoption and adaptation of sustainable agricultural practices by small coffee farmers in Luya, Amazonas - Peru

Project start date
15 Jun 2023

Project end date
26 Sept 2023

Describe the scope and aims of the project in language understandable by a non-technical audience. Include any other relevant background which will allow the reviewers to contextualise the research.
This project's scope is to understand better the factors or drivers that influence the adoption, adaptation and implementation of sustainable agricultural practices by small coffee farmers in four districts of Luya province, Amazonas region, Peru.
This research aims to elucidate why most small coffee farmers still need to implement sustainable agricultural practices highly recommended by the government and private stakeholders.
This project will determine the most critical constraints and drivers to adopting and adapting sustainable practices.

Provide a brief explanation of the research design (e.g. interview, experimental, observational, survey), questions, methodology, and data gathered/analysis. If relevant, include what the participants will be expected to do/experience.
This research will apply a cross-sectional design through a survey and interview administration at one point in time to gather information from small coffee farmers and experts using a structured questionnaire and a semi-structured interviews. The questions consist of enumerator details, characteristics of the farmer, characteristics of the external environment, characteristics of the sustainable agricultural practices (SAPs), farmer's knowledge, perceptions and attitudes towards SAPs, communication and extension and lastly the implementation of SAPs.
The semi-structured interview is about experts' perceptions about adoption of SAPs in the coffee sector.

Detail how any adverse events arising in the course of the project will be reported in a timely manner.
Any unexpected adverse event will be reported to the Ethics monitor as far as I reach an internet connection

Will you also be applying for Health Research Authority approval (HRA)?
No

Indicate if you are applying for approval for an experiment to be conducted in the School of Economics' Laboratory for Economic and Decision Research (LEDR).
No

Is the project?:
none of the options listed

Does the project have external funding administered through the University's Research and Innovation Services (RIN)?
No

Will the research take place outside of the UK?
Yes

Will any part of the project be carried out under the auspices of an external organisation, or involve collaboration between institutions?
Yes

Do you require or have you already gained approval from an ethics review body external to UEA?
No

Does this new project relate to a project which already has ethics approval from UEA?
No

Research categories
Will the project include primary data collection involving human participants?
Yes

Will the project use secondary data involving human participants?
No

Will the project involve the use of live animals?
No

Will the project have the potential to affect the environment?
No

Will the project have the potential to affect culturally valuable, significant or sensitive objects or practices?
No

Will the project involve security sensitive research?
No

Human participants - selection and recruitment
How many Participant Groups are there who will receive tailored participant information?:
Two

Name of Participant Group 1.
Small coffee farmers

Name of Participant Group 2, if applicable.
Experts

How will the participants be selected/recruited?
The participants will be selected using cluster sampling in which the annexes of each district will be selected randomly. The only characteristic they have to meet is to be in charge of a small coffee farm in the districts of Pisuquia, Ocalli, Ocumal and Camporredondo in Luya province, Amazonas region, Peru.
From 4025 coffee farmers, 145 will be selected and surveyed; moreover, for experts interview, three of them will be selected from the academia, government and private coffee sector.

In terms of UEA participants only, will you be advertising the opportunity to take part in this project to?:
None of the above (i.e. UEA's Student Insight Review Group (SIRG) does not need to be informed)

What are the characteristics of the participants?
Inclusion criteria: be in charge of the management of a small coffee farm located in the districts of Pisuquia, Ocallí, Ocumal and Camporredondo
Exclusion criteria: Coffee farms bigger than 30 hectares of the coffee crop.

Will the project require the cooperation of a gatekeeper for initial access to the individuals/groups to be recruited?
No

Is there any sense in which participants might be 'obliged' to participate?
No

Will the project involve vulnerable groups?
No

Will payment or any other incentive be made to any participant?
No

How and when will participants receive this material?
For the expert interview, an email will be sent to each of them explaining the research objectives and inviting them to participate voluntarily.

Include any other ethical considerations regarding participation.
Before surveying and interviewing, all participants will be explained the project research objectives and that all data will be managed anonymized and privately, after that, they will be asked for their voluntary decision to participate or not, clarifying that they can withdraw at any time and this decision will not affect them in any way.

Human participants - consent options
By which method(s) will consent to participate in the research be obtained?:
Participant Information Sheet and Consent Form Verbal

Human participants - information and consent Participant Information and Consent
Will opt out consent for participation in the research be used?
No

You can generate a Participant Information Text and Consent Form for this application by completing information in the Participant Information Text and Consent Form Generator tab. Alternatively you can upload your Participant Information Text and Participant Consent Form which you have already prepared. Confirm below:
Generate automated Participant Information Text and Consent Form.

When will participants receive the participant information and consent request?
The participant information and consent request will be given before starting the survey and interview. Furthermore, all the participants will have the chance to avoid answering any questions.

How will you record a participant's decision to take part in the research?
The decision will be recorded through a blank spot to be ticked after asking for opt-in consent. For written consent, it will be signed indicating that they have understood the information provided and they agree to participate.

Human participants - method
Which data collection methods will be used in the research?:
Interview
Anonymous questionnaire

If your research involves any of the methods (including Other) listed above, upload supporting materials.
How have your characteristics, or those of the participants influenced the design of the study or how the research is experienced by participants?
The characteristics of the participants reported in the National Agrarian Census 2012 and my experience in the coffee sector influenced the research design.

Will the project involve transcripts?
Yes

Select ONE option below:
By hand

If yes provide details.
Not applicable. I will do the transcripts myself.

Provide an explanation if you are not offering the participant the opportunity to review their transcripts.
I will send the expert interview transcripts from Spanish to English to each of their emails. However, offering transcripts to the farmers does not make sense because they will not be able to understand it.

Will you be capturing photographs or video footage (digital assets) of individuals taken for University business?
No

Is this research using visual/vocal methods where respondents may be identified?
No

Will it be necessary for participants to take part in the study without their knowledge and consent at the time?
No

Will deception or incomplete disclosure be used?
No

Will the participants be debriefed?
No

Will substances be administered to the participants?
No

Will involvement in the project result in, or the risk of, discomfort, physical harm, psychological harm or intrusive procedures?
No

Will the project involve prolonged or repetitive testing?
No

Will the project involve potentially sensitive topics?
No

Will the project involve elite interviews?
Yes

If yes, provide details.
This research includes interviews with three experts from academia, government and the private sector, who will be contacted and informed by email before the interview.

Will the project involve any incitement to, encouragement of, or participation, in an illegal act (by participant or researcher)?
No

Will the research involve an investigation of people engaged in or supporting activities that compromise computer security or other activities that may normally be considered harmful or unlawful?
No

Does the research involve members of the public in participatory research where they are actively involved in undertaking research tasks?
No

Does the research offer advice or guidance to people?
No

Is the research intended to benefit the participants, third parties or the local community?
Yes

Provide an explanation.
Indirectly, the results will likely guide further research or interventions in the districts involved.

What procedures are in place for monitoring the research with respect to ethical compliance? I will travel to the area of research for make sure to meet all the ethical issues and ensure data collection

Does the study involve the use of a clinical or non-clinical scale, questionnaire or inventory which has specific copyright permissions, reproduction or distribution restrictions or training requirements?
No

Health and safety - participants
Is there a possibility that the health and safety of any of the participants in this project including a support person (e.g. a care giver, school teaching assistant) may be in question? No

Health and safety - researcher(s)
Is there a possibility that the health and safety of any of the researcher(s) and that of any other people (as distinct from any participants) impacted by this project including research assistants/translators may be in question?
Yes

If yes, how have you addressed the health and safety concerns? Describe any safeguards included and relevant protocols.
There is a very low risk to work alone in these places and will be traveling with a sibling, we both have health insurance, and there is medical coverage in those places where I will be surveying and interviewing.
Regarding home interviews, given that I will first ask for consent I do not see any risk because the information I will be asking for is not sensitive.

Risk assessment
Are there hazards associated with undertaking this project where a formal risk assessment will be required?
No

Notes
I have filled out my risk assessment grid and submitted it with my dissertation proposal.

Research outside the UK
State the countries where research will be undertaken.
Peru

Has formal permission/a research permit been sought to conduct this research in the host overseas country?
No
If yes, describe the action you have taken and upload documentary evidence below. If no, explain why this is not necessary/appropriate.
For very short studies, it is not always appropriate to apply for formal clearance

Upload the approval correspondence where relevant.

Does the research comply with the relevant legal requirements of the host overseas country?
Yes

Provide details.
In Peru, for applying a survey, the legal requirement is to ask for informed consent, which this research is meeting.

If relevant, have you taken out travel and health insurance for the full period of the research?
Yes, Europ Assistance International Student Plan however I will apply for UEA insurance.

If relevant, have you reviewed the Foreign, Commonwealth and Development Office (FCDO) guidance and applied for a visa?
I reviewed the FCDO, and as I am Peruvian, I will enter Peru with my passport.

Work with external partners and collaborators
Provide details of the external organisation(s)/institution(s) involved with this project.
Not applicable

Has agreement to conduct research in, at or through another organisation/institution been obtained?
Not applicable

Upload the correspondence where relevant.

Does any external Co-applicant need to seek ethics approval in connection with this project?
No

Data management
Will the project involve any personal data (including pseudonymised data) not in the public domain?
No

Will any personal data be processed by another organisation(s)?
No

Will the project involve access to records of sensitive/confidential information?
No

Will the project involve access to confidential business data?
No

Will the project involve secure data that requires permission from the appropriate authorities before use?
No

Will you be using publicly available data from the internet for your study?
Yes

If yes, provide details about the publicly available data from the internet you will be using for your study.
I will use public data from the Peruvian government, statistics and census accessible to the public domain.
Will the research data in this study be deposited in a repository to allow it to be made available for scholarly and educational purposes?
Yes

Provide details.
University of East Anglia repository

Who will have access to the data during and after the project?
During and after the project: Supervisor

Where/how do you intend to store the data during and after the project?
I will store the data on UEA repository

How will you ensure the secure storage of the data during and after the project?
I will store on my onedrive account

How long will research data be stored after the study has ended?
Ten years

How long will research data be accessible after the study has ended?
Ten years

How are you intending to destroy the project data when it is no longer required?
Yes it will be programmed to be completeley deleted after ten years

Generate and upload files
PARTICIPANT INFORMATION TEXT AND CONSENT FORM

Upload the Participant Information Sheet and Consent Form. Enter Participant Group number and name.
Experts

Enter Participant Group number and name.
Small cofee farmers