

**Determinants of adoption and adaptation of sustainable agricultural practices by small
coffee farmers in Luya, Amazonas – Peru**

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Abstract

Despite the benefits of Sustainable Agricultural Practices (SAPs) their use rate among smallholder farmers is still low in developing countries like Peru. This study sought to examine the factors that determine the adoption of SAPs and their intensity at the smallholder household level in four coffee producer districts of Luya, Amazonas – Peru, based on cross-sectional data obtained from 145 sampled households, six coffee farmer interviews, and three expert interviews. The study results showed that coffee farmers adopted SAPs according to distinct factors that determine or influence their uptake; those factors could be farm(er)-related, sustainable practice attributes, and exogenous factors. While it is true that there was no strict pattern in farmers' profiles, especially in terms of socioeconomic characteristics, to explain the adoption of SAPs.

Moreover, drawing on the logistic regression technique, the marginal effects of the key factors that determine the adoption of SAPs were obtained, the number of people of working age living in the household, educational attainment, number of assets, coffee yield, coffee price, farm investment, sustainable practices attributes, certification, farmer knowledge about sustainable practices, access to extension services, performance expectancy, and facilitating conditions. The main barriers to the adoption of bundled sustainable practices are the scarce labour availability during peak season, smallholders' low economic level and lack of access to agricultural credit.

These suggest that to improve sustainable practices adoption rates, it should be increased farmers' knowledge about sustainable practices' attributes through demonstration facilities and offer facilitating conditions like information, demand-driven research, seeking attributes that producers are interested in, access to a platform of coordinated extension and advisory services and input accessibility. To overcome the barriers, it is needed to enhance the accessibility to agricultural credit for farm investment and improvement of the work system to lower production costs through saving in labour force.

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Chapter 1: Introduction

In the realm of smallholder farming, activities take place within intricate socio-ecological systems, where farmers navigate in a complex socio-political and environmental limiting circumstances. Under ongoing climate change conditions, that disproportionately affect farmers, making smallholders particularly susceptible to its impacts (Robiglio *et al.*, 2017; Pörtner *et al.*, 2022), added to multiple non-climatic factors such as socio-economic and environmental pressures, the vulnerability of smallholder agriculture is evident (Morton, 2007). In response to these threats emerged sustainable agriculture which is highly related and is crucial for achieving the United Nations' sustainable development goals (van Noordwijk *et al.*, 2018; World Bank, CIAT, and CATIE, 2015) and is considered imperative for resilience in the context of climatic variability (Lamichhane *et al.*, 2020). However, there is conflicting evidence about the factors that affect adoption or adaptation of sustainable practices in developing countries like Peru, hence till now no clear policies address this subject.

Coffee is the principal exportation crop in the Amazonas region in northern Peru (Salas López *et al.*, 2020), the local economy hinges on this particularly important crop for remote areas (Espinoza *et al.*, 2022; World Bank, CIAT, and CATIE, 2014) since coffee as a commodity can be produced and traded despite the distance. Coffee production in Amazonas and in general in Peru faces many challenges like pests and diseases and low yields (Minagri, 2018), which combined with the ongoing global change make the coffee value chain unsustainable which negatively impact rural people's livelihoods. In the academic literature it is widely recognised that sustainable agricultural practices in the coffee sector are crucial to cope with unpredictable events. These practices have an enormous potential to increase coffee yields while enhancing farm resilience (Kassie *et al.*, 2013; Zeweld *et al.*, 2017; Bro *et al.*, 2019) and stabilise the continuance of ecosystem services with economic farmer's goals (Altieri, 2002). However, despite the multiple benefits that sustainable practices promise, there are still low adoption or adaptation rates around Peru (World Bank, CIAT, and CATIE, 2014). The reasons for the low levels of adoption are still unknown. These reasons, according to prior research, varies in each context (Knowler and Bradshaw, 2007; de Graaff *et al.*, 2008). Lately, Peruvian government through development projects has been promoting the voluntary adoption of sustainable practices (Posthumus, Gardebroek and Ruben, 2010), without much success. This research aims to determine the barriers and drivers of small coffee farmers' adoption and adaptation of sustainable practices.

The Amazonas region of Peru is divided into seven provinces. Luya is one of them with 23 districts from which Pisuquia, Ocallí, Ocúmal, and Camporredondo are the primary coffee producers. According to National Agricultural Census (National Institute of Statistics e Informatics - INEI, 2012), most are small coffee farmers with less than 5 hectares of coffee crop area. Smallholder farmers' livelihoods in these districts rely on coffee cultivation for cash income. That is why the importance of this crop for the local economy and landscape management.

The literature review shows that in Peru, there is still scarce research on the adoption or adaptation of sustainable agricultural practices. This suggests that a more comprehensive investigation is required into ways to motivate smallholder farmers to adopt agricultural practices and technologies (Rosário *et al.*, 2022). This research helps to understand and deepen this important topic. In particular, this study seeks to examine the following research questions: What are the main factors influencing small farmers' adoption of sustainable agricultural technologies in Amazonas, Peru, as a strategy for rural development?

Chapter 2: Review of literature

There is no consensus in the definition of sustainable agriculture, according to Food and Agricultural Organization (FAO) 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*” (FAO, 2016, p. 12). It is widely accepted that sustainable agriculture plays a crucial role in enhancing economic and environmental outcomes, along with promoting human well-being (Nguyen and Drakou, 2021). Research demonstrates that compared to conventional land use, sustainable land use systems are beneficial for farmers, sustainability, and climate (van Noordwijk *et al.*, 2018).

However, past research has yielded contradictory findings concerning the factors influencing the adoption of SAPs, depending on the specific types and geographical locations of agricultural innovation, making generalisations difficult and confirming that farmers’ decision-making processes are heterogeneous. Innovative sustainable land-use systems like sustainable agriculture share several similarities with recent technologies. Both necessitates a shift in behaviour and initial investments in both knowledge and equipment, with an element of uncertainty regarding future returns (Chouinard *et al.*, 2008).

Regarding adoption, refers to the decision to use or not use such a practice, it is a learning process that follows different steps from getting aware of any innovation to its full-scale sustained use (Pannell *et al.*, 2006). In small-scale agriculture, the consistent uptake of combined sustainable methods varies, influenced by a range of internal and external factors that shape the individual success of adoption (Kassie *et al.*, 2013; Kudama, Wana and Dangia, 2021).

During the adoption process, there may be drivers and barriers that boost or impede its usage. Moser and Ekstrom (2010) suggest that barriers emerge due to the interactive relationship between individuals, the surrounding environment, and the relevant system. Nowak (1992) claimed that the adoption of sustainable agricultural practices by farmers is hindered by two primary factors, either individually or in combination: lack of willingness and financial constraints. Technologies that are economically viable and have broader suitability would be more readily and extensively disseminated compared to technologies that are cost-ineffective and have limited relevance.

An examination indicates that most perceived "barriers" have logical foundations and can be grouped into the following categories: contradictory information; risk; expenses associated with implementation and initial investment; intellectual investment; reduced adaptability; complexity; and incompatibility with other elements of farm management, as well as farm and personal-related goals (Vanclay and Lawrence, 1994).

In the international context, more recent studies have looked at socioeconomic and psychological factors, such as perceptions and attitudes, to explain adoption behaviour (Pierrette Coulibaly *et al.*, 2021; Li *et al.*, 2023) that improves economic analysis of farmer decision-making. In addition, Rosário *et al.* (2022) recommended adding more variables like farmers' knowledge to study the uptake of agricultural innovations. Numerous reviews suggest that enhancing the efficiency of interventions could be achieved by considering the interplay between cognitive, social, and dispositional factors that impact the decision-making of producers (Dessart, Barreiro and Van, 2019).

Concerning Peru, on her research in the Piura region on the adoption of organic farming, (Alvarado Barbarán, 2014) found that credit access, conservation techniques use, technical assistance access, propensity to innovate, income, and land-tenure status significantly increase adoption. Further, Rodriguez (2020) analysed data from the National Agricultural Survey found that education level, farmer age, number of family members of working age, altitude of the cropping area, and organisation belonging positively influenced the adoption of coffee farm technologies. (Cancino, Rubiños and Vargas, 2022) reported that social capital like associations or native communities does indeed promote resource conservation, however for that it is needed organisation' trust and adherence to the rules.

Coffee farmers persistently deal with different issues. One of them is that market liberalisation and integration have exposed farmers to elastic coffee prices (Tucker, Eakin and Castellanos, 2010), another big challenge is pests and diseases which are getting worse with climate variability. Moreover, the intensification of agricultural output and the substantial worldwide need for food has endangered the fundamental components of production and resulted in a rise in the application of artificial substances like fertilizers and pesticides, along with a significant impact on the environment and global biodiversity. Common methods of intensification in coffee cultivation include the elimination of shade trees, enhanced use of agrochemicals, higher planting densities of coffee shrubs, and the introduction of new coffee varieties (Perfecto and Vandermeer, 2015).

Study Frameworks

There have been many attempts to study and promote the adoption of agricultural innovations since the middle of the last century. Pannell *et al.* (2006) presented a sequential framework for technology adoption at farm levels, comprising six distinct stages: awareness of the problem or opportunity, non-trial evaluation, trial evaluation, adoption, review and modification, and non-adoption or disadoption". After that, for the review and modification stage, it was suggested: full adoption, partial adoption, alternating adoption, and opportunistic adoption (Pannell and Claassen, 2020) and highlighted that each practice has its own unique adoption story.

In the United States, Han and Niles (2023) using a Latent Class Analysis (LCA) approach identified five types of adopters: non-adopters, previous adopters, conservative new adopters, innovative new adopters, and early adopters. Lately, research has indicated that not only physical factors but also attitude, facilitating conditions, and risk expectations are critical factors in the adoption of sustainable land use systems, as they have a substantial impact on behaviour (Lemken, Spiller and von Meyer-Höfer, 2017).

There are many frameworks for agricultural practices adoption analysis. However, there is still a need in the field for a comprehensive approach that is readily available and illustrates the intricate, evolving, and multifaceted aspects of adopting sustainable agriculture (Han and Niles, 2023) in developing countries. This research is going to draw upon the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh *et al.* (2003) and expanded by the framework proposed by Dwivedi *et al.*, (2019), which added other factors such as risk expectations and attitudes.

The UTAUT model demonstrates its comprehensive nature by positing that the constructs of performance expectancy, effort expectancy, social influence, and facilitating conditions play a role in shaping the behavioural intention to adopt an innovation. Consequently, the behavioural intention and facilitating conditions impact the actual usage behaviour of the innovation. Originally designed and validated for the information technology domain, the UTAUT model's cohesive framework renders it applicable for investigating the adoption of various other technologies (Venkatesh *et al.*, 2003). UTAUT as a unified theory fits and can be applied to the adoption of sustainable practices (Trozzo, Munsell and Chamberlain, 2014)

For the UTAUT approach performance expectancy is defined as *"the degree to which an individual believes that using the system will help him or her to attain gains in job performance"* (Venkatesh *et al.*, 2003, p. 447). Then, effort expectancy has to do with perceived ease of use and is defined as the degree of ease associated with the use of the system. It was found that technology attributes (i.e., performance expectancy and effort expectancy) have direct effects on attitude and behavioural intention (Dwivedi *et al.*, 2019)

Past research has examined another contributing factor influencing behavioural intention, which is knowledge. Knowledge is seen as a measurable variable representing farmers' comprehension of the behaviour they are expected to adopt. A study conducted by Nyang'au *et al.* (2021) shows that knowledge is one of the determinants that influence the adoption of climate-smart-agricultural practices (CSA) in Kenya along with other factors like farmers' perceptions and attitudes. Whereas in Indonesia farmers' knowledge has exerted the most significant impact on farmers' inclination to embrace the certification geographical indication (Laksono *et al.*, 2022), and in India, most individuals who possess advanced understanding tend to adopt SAPs at a moderate to elevated degree (Ashrit and Thakur, 2021).

Behavioural intention (BI) refers to the possibility that a person may engage in certain behaviours in the future under certain conditions and to do something (Venkatesh et al., 2003). BI alludes to the moral decisions that individuals make about their future actions, serving as a link that connects their attitudes, perceptions, influences, and group activities (Buyinza et al., 2020).

Social influence is like subjective norms and represents the influence of reference groups or peers, its effect is significant when the use of technology is prescribed (Venkatesh *et al.*, 2003) for instance in farmers under any sustainable certification scheme. As the social norm increases, so does the intention to embrace sustainable agricultural practices (Nguyen and Drakou, 2021).

Facilitating conditions is designated as "*the degree to which an individual believes that an organisation's and technical infrastructure exists to support the use of the system*" (Venkatesh *et al.*, 2003, p. 453). Besides, owing to agriculture being exposed to multiple risks from natural disasters, market changes, and other shocks, risk expectations are important to consider for decision-making (Dessart, Barreiro and Van, 2019).

Lastly, attitude, meaning an individual's mentality towards in this case performing sustainable agricultural practices being evaluated positively or negatively, has been widely acknowledged to influence the intention to implement water and soil conservation measures (Wauters *et al.*, 2010; Faridi, Kavooosi-Kalashami and Bilali, 2020). Attitude together with knowledge and perceptions symbolise intrinsic motivations.

Farmer characteristics

Farmer head gender could play a role in this theme, it was found that female farmers' attitudes were more positive toward agricultural sustainability. Age is another factor thought to affect adoption; in general, younger individuals with advanced levels of education tend to embrace green technologies more readily. Education may also influence adoption, according to Ruzzante, Labarta and Bilton (2021), it might be due to farmers with more education being more willing to innovate.

Previous research has also emphasised that economic considerations like family resource endowments play a significant role in the acceptance and implementation of SAPs (McCarthy and Shurmann, 2014).

Small farmers tend to embrace a blend of compatible technologies to address multiple challenges in agricultural production, rather than opting for just one at a time. Furthermore, many studies applying multivariate probit found that the use of conservation farming strategies is interconnected (Ngaiwi *et al.*, 2023) and others also found that farmers adopt Climate-Smart Agriculture practices as complements and substitutes.

Farm characteristics

Land tenure rights can encourage the uptake of natural resources management practices; it was observed that their impact is most pronounced when it comes to embracing strategies that have extended planning periods, like erosion control methods. It was found that land tenure stability had a positive impact on farmers' adoption intensity of SAPs in China.

Farm size was also found to positively correlate with the adoption of many agricultural technologies (Ruzzante, Labarta and Bilton, 2021). Parcel's slope and quality as reported by Arellanes and Lee (2003). Distance to market, as stated by Mujeyi, Mudhara and Mutenje (2020), is often related to the use of productive practices since challenging road accessibility, a common issue in numerous tropical areas, can markedly rise expenses and impact the choices made in terms of productivity (Chavez and Perz, 2012).

SAPs' attributes

According to many earlier authors, the most effective approach to encourage the adoption of conservation practices is to ensure their economic viability and profitability (Cary and Wilkinson, 1997). However, there are also important considerations like the perceived practice characteristics such as relative advantage, compatibility, and complexity (Pannell *et al.*, 2006) that in the UTAUT model are described as performance expectancy and effort expectancy. Relative advantage refers to the perceived net benefit if the farmer adopts it. Compatibility with the production system and with existing beliefs and values. Complexity may increase the level of intensity needed for ongoing management (Pannell *et al.*, 2006). Each practice has its attributes or disadvantages according to the context. Some advantages and costs of some environmentally friendly practices are not visible making it difficult to perceive its benefits and a long payback period can diminish its attributes and further use.

External factors

Adoption or adaptation strategies are also shaped by opportunities available to farmers and the constraints they face. Communication, training, and technical guidance are important determinants directly affecting farmers' green production behaviours. Farmers will embrace the technology or practice solely if they are aware of its presence and proficient in its successful utilisation. Access to extension services improves farmers' understanding and uptake of CSA practices, as they become aware of shifts in climate and weather conditions (Nyang'au *et al.*, 2021). By contrast, a study showed that non-adoption or disadoption is higher when there is a decrease in farm labour.

In Peru, by the late 80s, with changes in the international context and modifications to the domestic regulatory framework, a crisis in the public sector emerged. This crisis was characterised by budgetary constraints, leading to significant reductions in services, particularly agricultural extension services. As a result, the inclusion of new actors such as NGOs and private companies as providers of extension services became relevant (Alvarado Barbarán, 2014).

Access to credit is a highly relevant factor in agriculture (Minagri, 2018). Agricultural credit has the potential to have a favourable impact on adoption.

Organisation membership can be used as a proxy of social capital. Which is a useful source for accessing information, obtaining credit, and exchanging price information. Belonging to an agricultural group can also enhance knowledge and stimulate adoption through information sharing between peers according to their organisation interests (Burlig and Stevens, 2021).

Sustainable agricultural practices in coffee production

As stated earlier, it is difficult to define what practices are sustainable owing to the broad sense that they encompass and the debate that involves different worldviews from a variety of stakeholders, however, some principles help guide the practical understanding of these techniques. The principles are as follows: integrated management, dynamic balance, regenerative design, and social development principles (Trigo, Marta-Costa and Frago, 2021). It is worth mentioning that, in this study, due attention is given to sustainable farm management and environmental practices that are considered key to poverty reduction in Peru. For this research, it was considered appropriate to explain the implementation of the following practices:

Cover crops. – Involves growing or allowing herbaceous non-aggressive species, they are creeping plants and do not grow too high. In the study area, some of these plants grow naturally like *Oplismenus* sp. and *Callisia* sp. others need to be planted i.e., *Centrocema* sp., *Mucuna* sp., and *Canavalia* sp. Permanent cover soil significantly reduces runoff and wind erosion, and if it is leguminous, adds nitrogen to the soil (Bro *et al.*, 2019). Moreover, soil cover moderates soil temperature, helps controlling weeds, and holds humidity for longer. Owing that many farms in Luya are in sloped lands, addressing erosion problems are relevant.

Coffee agroforestry. – Landscape management in which collectable trees or shrubs are cultivated among or around coffee crops to maintain soil fertility and conserve moisture. Arabica coffee is a shade-tolerant species and shadow prevents them from excessive sunshine irradiation and suppress weeds at the same time. Additionally, under extreme weather events shade trees protect plants from heavy precipitations, intense winds, and even landslides (Perfecto and Vandermeer, 2015). Shade trees store carbon dioxide (CO₂), contributing to combat climate change, and are recommended as a climate-smart practice, because they provide diversified farmer livelihoods, on-farm biodiversity refuge, and microclimate regulation (World Bank, CIAT and CATIE, 2015).

Contour planting. – Planting in rows with directions contrary to the main slope is a recommended practice that prevents soil erosion, which helps make better use of fertilisers and improve farm activities management as well.

Living or dead barriers. – or retention barriers, living barriers are strips with bushes, crops, hedgerows, or strips of cutting grass (Bro *et al.*, 2019), whereas the common dead barriers are ordering tree pruning branches, coffee stems or blocks horizontally against the slope to prevent soil erosion. Soil erosion control practices are considered as measure number 47 of the National Plan for Adaptation to Climate Change of Peru (Ministry of Environment, 2022)

Composting. - Is a process of decomposing organic materials such as coffee berry pulp, food waste, animal dung, etc. Preparation and application of compost improve coffee yields, serve as a soil amendment (soil organic carbon enhancing), and reduces fertiliser application through nutrient cycling. Coffee pulp composted is a source of nutrients, that could reach 1.61% of nitrogen, 0.51% of phosphorus, and 4.28% of potassium, moreover, a good composting process largely reduces greenhouse gas emissions (San Martin Ruiz, Reiser and Kranert, 2021; Parodi *et al.*, 2022)

Fertiliser use. – For sustained crop production in the long term, all the nutrients removed by the harvest (macro and micronutrients), should be returned to the system through fertilisation to avoid soil fertility depletion. Prudent use of chemical fertilisers is also considered a sustainable practice in Africa by Kassie *et al.* (2013) and by the National Plan for Adaptation to Climate Change of Peru, measure number 46 (Ministry of Environment, 2022).

Integrated pest management (IPM). – Is an ecosystem approach, where chemical control is utilised as the last resort for pest control, before that it is applied other preventive controls like cultural control, biological control, and ethological in the case of insect pests like coffee borer (Oliva *et al.*, 2020). This approach was strongly promoted since 2013 to control coffee leaf rust outbreak through training to producers' committees and delivery of control kits, nowadays, the National Agricultural Health Service oversees pest monitoring, does training through field schools and gives technical assistance, other government agencies also promote IPM through business plans and productivity enhancement projects.

Coffee processing wastewater treatment. – In the coffee cherries process, it is used to float the vain fruits, and in the wet process for washing up the mucilage after fermentation. A fermentation by-product is honey water of coffee that contains high organic matter and therefore needs filtration treatment before pouring it into water bodies to prevent environmental pollution (Torres-Valenzuela *et al.*, 2019). For that, it is often recommended to dig a pit and put a layer of gravel and one layer of sand as a filter mechanism.

Chapter 3: Description of methods

It is an observational cross-sectional explicative study aimed at examining the determinants of multiple Sustainable Agricultural Practices adoption among small coffee farmers in Luya, Amazonas, Peru, through primary data gathered by field survey and reinforced with interviews with producers and experts. Alternatives to overcome the barriers identified and strengthen the factors that foster the use of better practices will be discussed at the end.

Questionnaire development

The questionnaire was developed based on existing literature which included farmer's socio-demographics, including gender, household size, age, experience, transportation means, income sources, and financial status. After that are farm characteristics such as size, fertility, slope, ownership, yield, management challenges, distance from plot to input and output markets, and livestock keeping, then it was asked for access to credit and inputs availability. The mid part of the questionnaire contained the characteristics of sustainable practices and farmers' knowledge, performance expectancy, effort expectancy, social pressure, attitudes, behavioural intentions, and sustainable practices already implemented. In the last part, it was queried about communication and extension services access. The mid part of the questionnaire included statements operationalizing in different dimensions the latent variable of the research model which could not be observed directly, it was adapted from the questionnaire used by Otter and Deutsch (2023)

Indicators for independent predictor variables were measured using summated Likert scales from 1 to 5, and for dependent variables, it was used an ordinal 5 points scale ranging from not practised to full-scale practised, referred to the implementation of sustainable practices in their plots, then the dependent variable was converted into dummy dichotomous variables. It was hypothesised that a wide array of factors are significant determinants to consider for smallholders' adoption of Sustainable Agricultural Practices (SAPs). The specific variables and definitions are shown in Table 1.

Table 1. Independent variables and its expected influence

Variable	Definition	Expected sign
Farmer characteristics		
Gender	Gender of the household head	±
Age	Age of the household head	-
Household size	N° of adults of working age	+
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	Farmers' soil fertility rate	+
Land slope	Average land slope	-
Land ownership	Land-tenure status (1 = titled, 0 = otherwise)	+
Coffee yield	Coffee output in quintals per hectare	+
Farm assets	N° of farm assets	+
Plot input distance	Travel time to market for agricultural inputs (minutes)	-
Plot market distance	Distance from plot to output market (minutes)	-
Livestock keeping	Livestock ownership	+
Credit eligibility	Farmer is eligible for a loan	+
Credit use	Farmers used agricultural credit	+
Coffee price	Current coffee price in PEN per quintal	+
Labour force availability	Availability of labour 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 access	+
Access to extension services	N° of times farmers got training, technical assistance, or field demonstration	+
Visit to 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	+
Organisation belonging	Farmer belongs to any organisation	+

Sample

Firstly, the population of interest for this study is made up of 4025 small coffee farmers located in four districts, selected due to its high potential for coffee production in Luya, those districts are Pisuquia, Ocallí, Ocúmal and Camporredondo (MIDAGRI, 2023)

For the sample number, it was used the following formulae:

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

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)

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

$$n = 144.7 \text{ round } n = 145$$

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. In the second stage, six to seven participants in each village were chosen using simple random techniques. 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. Although the sample may not be representative of all the provinces, it can represent the major coffee farming systems in it.

Study area

The research reported upon here comes from a study area located in northern Peru, specifically in four districts of Luya province in a warm dry or cold dry climate (Robiglio *et al.*, 2017) situated in the Marañon river basin, those soils are classified as cambisols according to FAO. This rural area is comprised of small arabica coffee farmers who have a high dependency on rain-fed agriculture, the mean annual rainfall varies between 126 to 885mm, and the temperature from 6°C to 29°C. The rainfall pattern is sometimes irregular and unreliable, thus affecting farmers' cropping activities. The climatic and topographical conditions make this zone one of the most important coffee producers in Amazonas (Robiglio *et al.*, 2017). Those districts are connected by an unpaved road.

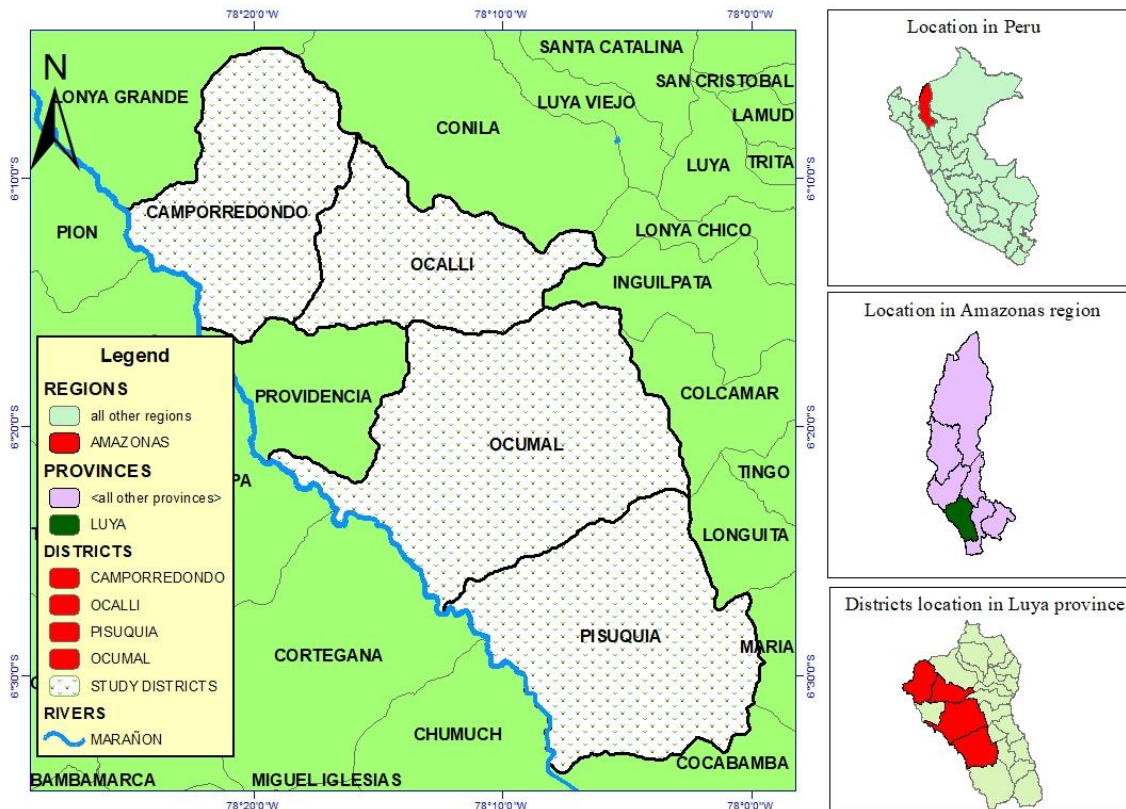


Figure 1. The study area made up of four districts of Luya province, Amazonas region in northern Peru

Survey

Firstly, a pre-survey was conducted on four coffee farmers (one in each district), based on the feedback during this pre-test it was ensured that the questions were unambiguous and understandable by the respondents; moreover, Cronbach alpha was used to ensure survey reliability where a threshold of 0.6 was accepted. After that, it was revised, and some items were reordered to enhance clarity of the instrument. Then, the final questionnaire was printed.

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. Each survey took 40 to 50 minutes to be fully completed. In total, it was applied to 145 surveys. All participants were informed of the research purpose and asked for their voluntary participation. Farmers were also informed to leave anytime during the interview process for distinct reasons, however, that problem did not come across and as a result, the response rate was 100%.

Interview with farmers

Six interviews were carried out with farmers in the four districts after completing their survey to deepen the research questions, two in Camporredondo, two in Pisuquia, one in Ocúmal and one in Ocallí.

Interview with experts

It was carried out semi-structured face-to-face interviews with three experts from the academia, government, and private sector to gather information and insights about the research topic. Previously, it was asked for their voluntary participation by email.

Ethical considerations

Ethical approval number ETH2223-1774 (Appendix 1) to conduct research and collect data from respondents was obtained from the University of East Anglia. Additionally, in collecting data from respondents, survey and interview consent was sought first.

Sample description

The vast majority of household heads were male (89.7%) which is different to the National Agricultural Survey (ENA) that reports 55.7% of male farmers. They were primarily smallholders with an average coffee plantation area of 2.29 ha, like the finding of Espinoza *et al.*, (2022) for Amazonas. The farmer's average age is 49 years, with a mean of 7 years of education. Regarding orientation, 73.7% are profit oriented and 26.2% are subsistence farmers that use primarily familiar labour force.

Table 2. Principal sample characteristics

Variable	Definition	Frequency	Proportion (%)	ENA 2022
Gender	Male	130	89.7%	55.7%
	Female	15	10.3%	44.3%
Age	19 - 30 years	12	8.3%	20.2%
	21 - 40 years	32	22.1%	23.2%
	41 - 50 years	33	22.8%	23.6%
	51 - 60 years	37	25.5%	14.3%
	Older than 60 years	31	21.4%	18.2%
Educational level	Primary school and below	84	57.9%	57.8%
	Secondary school (including incomplete)	52	35.9%	34.4%
	Technical degree	4	2.8%	5.9%
	University degree	5	3.4%	1.8%
Coffee farming experience	2 - 10 years	38	26.2%	-
	11 - 20 years	51	35.2%	-
	21 - 30 years	30	20.7%	-
	More than 30 years	26	17.9%	-
Orientation	Subsistence	38	26.2%	-
	Profit	107	73.7%	-

Chapter 4: Analysis and discussion

It followed several steps to analyse the data, coding, compiled, tabulated, and cleaning the row data, it used descriptive and regression techniques. The descriptive involves the use of the Likert scale to understand farmers' knowledge about SAPs. Logistic regression was used to estimate the drivers of the adoption of SAPs and their interrelationships. Employing the logit model, therefore, allows us to estimate the determinants of adoption and correlations among SAPs simultaneously.

Binary logistic regression model

Binary logistic regression was used to identify the determinants of SAPs 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 (Li *et al.*, 2023). This model is utilised to elucidate a categorical variable denoted as Y , which can assume two discrete values: 0 representing non-adoption and 1 representing adoption (Cary and Wilkinson, 1997; Hosmer *et al.*, 2013). The model's purpose is to compute the probability of Y being 1 and to ascertain how the explanatory variables $X \{x_1, \dots, x_n\}$ exert an impact on Y . X constitutes a collection of explanatory variables that combine various sets of factors. In this investigation, these categories encompass farmer characteristics, farm characteristics, SAPs' attributes, and perceptions concerning external contextual factors.

For the i th smallholder, Z_i is an indirect utility function derived from the decision to adopt a SAP, which is a linear function of the explanatory variables (X):

$$Z_{i1} = X_i \beta_1 \text{ (SAP adopted)}$$

$$Z_{i0} = X_i \beta_0 \text{ (SAP not adopted)}$$

With $X_i = \{X_1, \dots, X_n\}$ where X_i is the vector of explanatory variables of the i th farmer, and β is the vector of parameters to be estimated.

A farmer's decision to adopt is specified as $Y=f(X, \varepsilon)$, where ε is an error term with a logistic distribution.

$$Y_i = \begin{cases} 1 & \text{if } Z_{i1} > Z_{i0} \\ 0 & \text{if } Z_{i1} \leq Z_{i0} \end{cases}$$

Frequencies of adoption ($Y=1$) are of interest and non-adoption ($Y=0$) for different values of X , and we examine whether these frequencies vary significantly according to X . It was examined the likelihood $P(Y=1 | x)$ and $P(Y=0 | x)$ whose distribution function is given as:

$$P_i(Y_i = 1) = \frac{e^{z_i}}{1+e^{z_i}} \text{ for } Z_i = X_i \beta \text{ and } -\infty < Z_i < +\infty$$

Where P_i is the probability of the i th farmer's decision to adopt, and Y_i is the dependent variable representing adoption {1 if an adopter, 0 if a non-adopter}.

The coefficients of the logit regression model, estimated by maximum likelihood methods and odds ratios, were calculated using SPSS software version 29. Several explanatory

variables X_i strongly influenced the adoption or non-adoption of SAPs. Some of them were related to farmer characteristics: household number, and farm characteristics. The independent variables were initially checked for multicollinearity using the SPSS procedure of “collinearity diagnostics”. The variable distance to the output market was withdrawn owing to collinearity with the distance to the input market.

For selecting relevant variables for the model it was used contingency table analysis for categorical variables and univariable analysis for continuous (Hosmer *et al.*, 2013). Model fit statistics were acceptable. The Hosmer and Lemeshow test statistic for goodness of fit was not significant ($p > 0.05$), which indicates a good model fit (Hosmer *et al.*, 2013). The Nagelkerke r^2 was always greater than 0.1 indicating that the covariates explain a certain amount of variance in the dependent variable.

Descriptive analysis of the results

Of the 145 sampled coffee farmers, about 39% used sustainable fertilisation practices, and the majority (52%) of the respondents practised cultural control for pest management. Additionally, 38% adopted wastewater treatment for honey waters from coffee processing and only 28% of them used soil conservation practices like permanent soil cover, agroforestry, contour planting, and living or dead barriers.

Table 3. Main sustainable agricultural practices adopted by the sampled farmers.

Dependent variables	Descriptions	Mean	Std. Deviation
Permanent soil cover (P)	Dummy (1 if yes, 0 otherwise)	0.15	0.36
Agroforestry (A)	Dummy (1 if yes, 0 otherwise)	0.44	0.50
Contour planting (S)	Dummy (1 if yes, 0 otherwise)	0.59	0.49
Living or dead barriers (B)	Dummy (1 if yes, 0 otherwise)	0.43	0.50
Composting (C)	Dummy (1 if yes, 0 otherwise)	0.24	0.43
Fertilization (F)	Dummy (1 if yes, 0 otherwise)	0.39	0.49
Integrated pest management (P)	Dummy (1 if yes, 0 otherwise)	0.39	0.49
Wastewater treatment (W)	Dummy (1 if yes, 0 otherwise)	0.38	0.49

Source: own data

The intensity of SAP adoption is shown in Table 4. Adoption of SAPs ranges from zero to eight, only seven farmers in the sample had not adopted any SAP. The mean number of SAPs adopted is three. From the table, 12.4% adopted only one SAP, while about 20.7% of producers adopted two SAPs. In addition, 2–4 SAPs were adopted by the majority (56.2%) of the total sample. Finally, about 4.8% of farm households used six, and 3.4% adopted 7 SAPs considered in this study in the data set.

Table 4. The intensity of SAP adoption

Intensity	Frequency	Percentage
0	11	7.6%
1	18	12.4%
2	30	20.7%
3	33	22.8%
4	22	15.2%
5	19	13.1%
6	7	4.8%
7	5	3.4%
8	0	0%
Total	145	100%
Average intensity	3.17	

Of the total sample, over half of smallholders (53.1%) belong to an organisation, most of them (85.7%) belong to any farmers' association (45.5%) while only 3.9% of the organised farmers are members of any private coffee company.

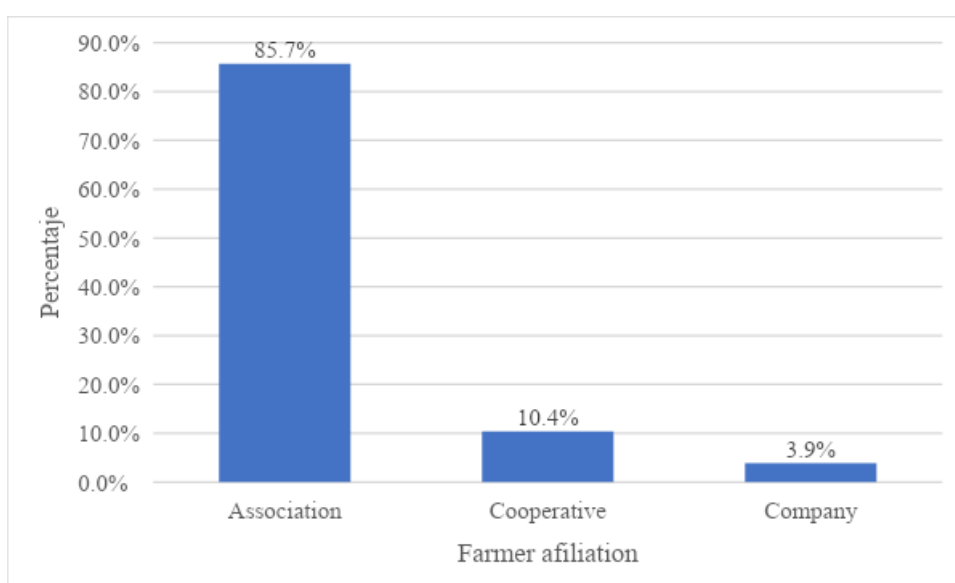


Figure 2. Farmers' organisation belonging

Of the total sample, 11% of farmers reported being farming under Organic certification scheme (Org), however, some farmers reported double (9%) or triple certification (1.4%) such as Organic, Fair Trade (FT), and Rainforest Alliance (RA). This sums up to 22.8% of certified coffee farmers.

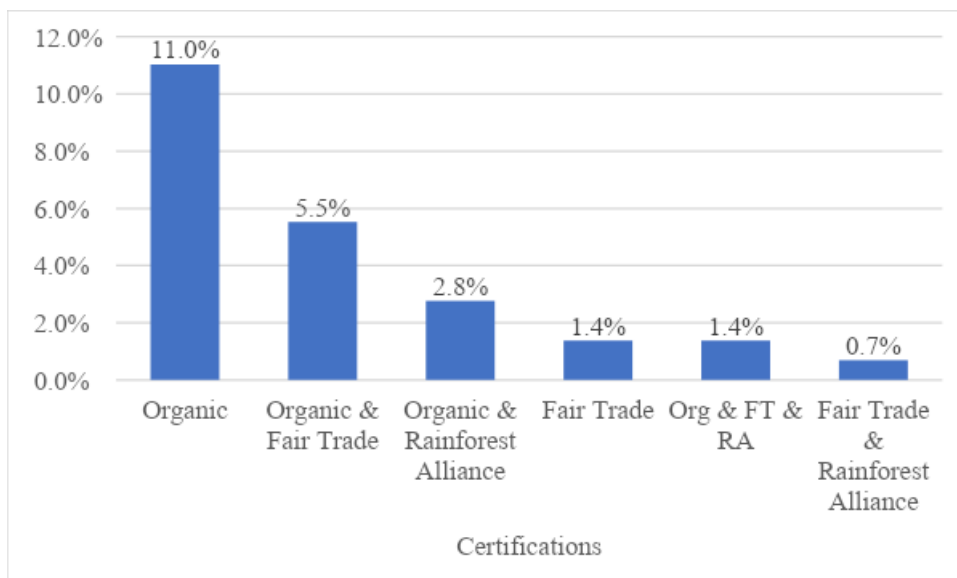


Figure 3. Coffee farmers under certification schemes

Regarding access to extension services during the last year, 59.7% attended at least one training activity or got a field visit, of them 40.5% reported that they had received training and technical assistance, while field demonstration was reported only by 2.4% of the producers that had access to extension services.

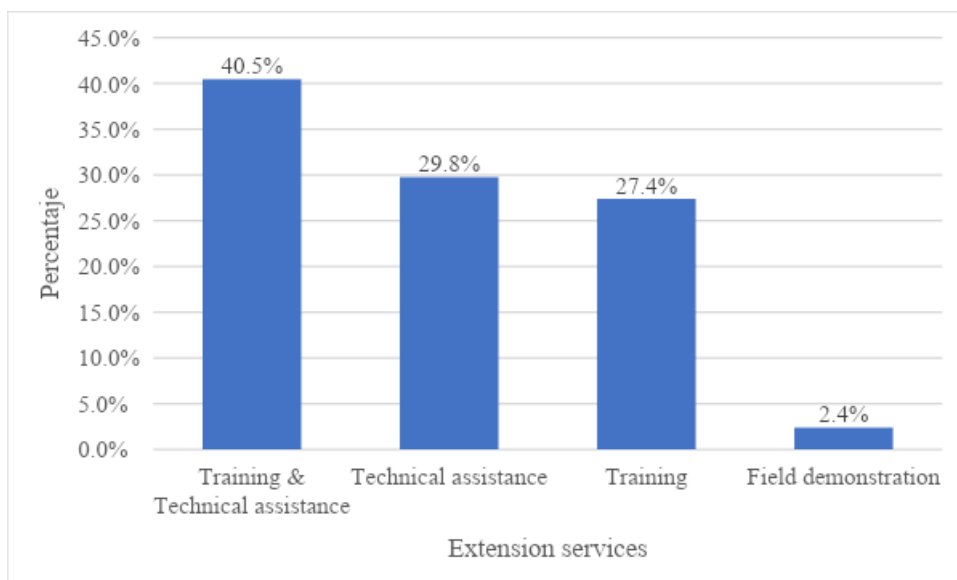


Figure 4. Types of extension services that coffee farmers accessed.

The entities that delivered extension services are sorted as public and private, in figure 5 it can be seen that private organisations such as farmers' associations, agricultural

cooperatives, and coffee companies provided extension services to more than 59% of farmers as compared to public entities like Agricultural Agencies, and the National Service of Agrarian Health (SENASA) joint reached around 24.1% of the farmers that got extension services, while the National Institute of Agricultural Innovation (INIA) nor the Agricultural Rural Productive Development Program (AGRORURAL) were mentioned by the respondents. Lastly, the Social Development Cooperation Fund (Foncodes) which not only focuses on coffee was mentioned only once.

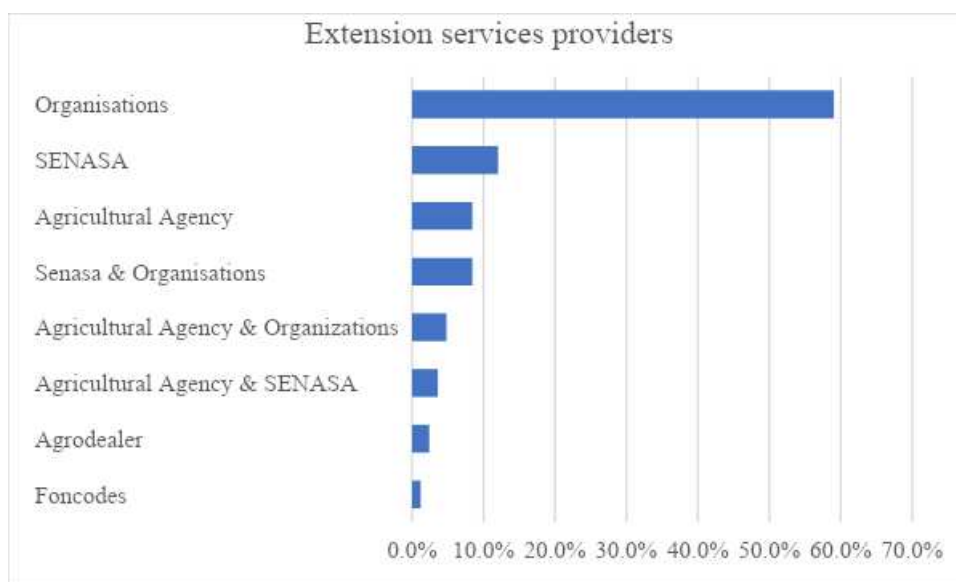


Figure 5. Entities that delivered extension services

Statistics of the independent variables

The covariates included in the logit model involved household-specific characteristics, economic situation, farmers' perceptions about their farm plots, and external factors. Table 2 reports the summary statistics of the independent variables, among the household characteristics there was a mean of 2.5 individuals of working age per household, giving an idea of labour force constraints. While 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 input market was 68 travel minutes, whereas the relevant output market was reported to be 64 minutes travelling 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%, these livestock 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 to farm coffee on flat land. Concerning land tenure rights, over one third (35.8%) of surveyed households reported having property title while most of them did not receive this document. The vast majority (96.6%) own a coffee pulper for the individual pulping process, however only 23% and 31% reported owning a sun drier 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 like the findings of Jezeer *et al.* (2019) in the neighbouring San Martin region. Another important topic is credit, 47.6% said that is loan eligible, but hardly 15% used any loan for agricultural purposes in the last three years.

Concerning the factor market, 40% considered that they rarely find a labour 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; while 29% and 35% sometimes and often find inputs like fertilisers and pest control products.

The resulting data set allows an examination of the adoption of various practices considered sustainable. Following the approach of logistic regression, each dependent variable was transformed into a dummy.

Table 5. Logistic regression results for significant determinants of Sustainable Practices adoption (***, **, * indicates significance at 1%, 5% and 10% levels)

VARIABLES	B	S.E.	Wald	DF	SIGNF	EXP(B)	VARIABLES	B	S.E.	Wald	DF	SIGNF	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
Agroforestry							Fertilisation						
Farm orientation (profit)	-2.55	1.02	6.24	1	0.012**	0.08	Farm investment (yes)	1.165	0.524	4.949	1	0.026**	3.206
Agroforestry attributes	2.66	0.58	20.77	1	<.001***	14.35	Credit use (no)			4.801	2	0.091*	
Certification	3.03	1.45	4.36	1	0.037**	20.59	Credit use (to some extent)	1.159	0.973	1.42	1	0.233	3.188
Facilitating conditions	1.24	0.54	5.37	1	0.021**	3.47	Credit use (yes)	1.163	0.604	3.705	1	0.054	3.2
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	Labour availability (rarely)			9.49	3	0.023**	
Economic situation (average)	2.27	0.90	6.39	1	0.012	9.70	Labour 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	Labour 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	Labour 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						
Land slope (flat)			5.11	2	0.078*		Farmer knowledge	0.48	0.28	2.86	1	0.091*	1.614
Land slope (medium)	1.02	0.85	1.44	1	0.231	2.78	Wastewater treatment						
Land slope (steep)	1.68	0.88	3.65	1	0.056	5.35	Number of assets	0.74	0.20	14.34	1	<.001***	2.095
Soil testing (yes)	0.80	0.43	3.40	1	0.065*	2.22	Coffee price	0.01	0.00	3.20	1	0.073*	1.006
Performance expectancy	0.94	0.34	7.51	1	0.006**	2.56	Facilitating conditions	1.21	0.44	7.43	1	0.006**	3.358
							Extension (yes)	0.95	0.47	4.10	1	0.043*	2.581

Cover crop adoption

A variable that significantly influenced the adoption of permanent soil cover in coffee plantations was the number of people of working age living in the household (0.026**) as found by Rodriguez (2020) for coffee technology adoption and by Bro *et al.* (2019) for field practices in Nicaragua. An interesting finding, in line with Arbuckle and Roesch-McNally (2015) is that farmers who perceived that soil cover has good attributes in terms of relative advantage, compatibility, and less complexity, have 3 times more likelihood to adopt it (0.07*). Farmer's knowledge (0.052*) about soil cover's benefits influenced its use as reported by Slijper *et al.* (2023) in their study of Dutch arable farmers.

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

Agroforestry adoption

For coffee agroforestry adoption, results revealed that the good attributes of this practice are highly significant (<0.001***) for its use, which can be considered as a factor that determines the adoption as found by Buyinza *et al.*, (2020a), farmers who consider that agroforestry is better than unshaded coffee, is compatible with their production system and the management is not complex are very probable to adopt it with an odds ratio of 14.35; this finding is also consistent with Jezeer *et al.* (2019) who reported a trend in farmers with high-shade levels perceived lower risks due to coffee price volatility than farmers with medium shade in the neighbour San Martin region. Certification was related to shade-grown coffee (0.037**), owing to certification bodies like Organic, Fair trade and Rainforest Alliance stimulate the use of on-farm biodiversity, this is in line with findings of Saragih (2013) in Indonesia.

Facilitating conditions or contextual factors (0.021**), when the practice fits well the farm's work structure, and the farmer has experience and equipment to handle SAPs, tend to use agroforestry (OR = 3.47), this finding is backed up by Sebuliba *et al.* (2022)' finding in Uganda who reported facilitating conditions as significant factor that explain the preference of farmers to use shade trees in their coffee fields.

Contour planting adoption

The result for practising contour planting showed that farmers' economic situation is a factor that influences its adoption (0.079*), while average farmers are more likely to adopt this practice (OR=9.7) in comparison to smallholders in extremely poor situations. Whereas it appears that farmer' knowledge is what determines its use (0.068*) where the comparative advantage (OR = 1.57) of applying contour planting is greater than individuals who do not realise its benefits for soil erosion control, this finding agrees with Ashrit and Thakur (2021) who reported that farmers who performed well in knowledge, adopted SAPs like better sowing methods in southern India. Performance expectancy also plays a role in the use of contour planting (0.082*) by small coffee farmers, that is farmers expect for practices to improve coffee quality and productivity in their farm.

Living or dead barriers adoption

According to the results, the factor 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, due to soil erosion issues that are in line with the findings of Posthumus, Gardebroek and Ruben, (2010) in southern Peru. This 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 and Lee, 2003).

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 of its current use more than two times (OR=2.22).

Moreover, results show that economic situation is not a determinant for low-cost practices like living or dead barriers (Arellanes and Lee, 2003).

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**) in agreement with Antwi-Agyei and Amanor (2023) which might be due to this practice being labour intensive and larger households can allocate more labour to composting activities. Meanwhile, it is more probable to adopt composting when the farmer considers his or her parcel's soil as poor (0.090*) than when the farmer rates soil fertility as good, these last have 31% less probabilities to use coffee pulp made compost. Similar result was reported by Arellanes and Lee (2003).

Facilitating conditions (0.028**) for instance having tools for or experience preparing compost are significant push factors (OR=2.32). Whereas composting attributes (<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 fertiliser (OR = 2.99); moreover, access to extension services play a significant role on compost use by smallholders.

Fertilisation adoption

The logit results revealed that prioritisation of farm investment (0.026**) increase the odds of fertilise by more than three times (OR=3.2). The use of credit also increases (0.054*) the adoption of fertilisation (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 due to farmers that fertilise get better coffee yields which allow them to get more income and afford fertilisers, moreover, the results also indicate that educational attainment influences fertiliser use (0.022**), for one additional year of schooling the likelihood to fertilise augments 15.4%, which is consistent with the findings of Bro *et al.*, (2019) in Nicaragua.

Integrated pest management adoption

Off-farm income was found to impact in the adoption of integrated pest management (0.026**) increasing the likelihood by three times (OR=3.2). Moreover, scarce labour availability (0.023**) significantly hinders the adoption of IPM whereas when the farmer often finds labour force the odds of applying IPM increases 2.9 times (OR=2.9) this factor is mentioned by Vasquez (2018) when investigating determinants of leaf rust control.

Farmers that get better prices tend to do integrated pest management (0.003***). In the same way, farmer knowledge about pest control (0.091*) determine its use according to the results because of this practice is knowledge intensive as found by Vasquez (2018) for coffee rust control in the near province of Rodriguez de Mendoza.

Wastewater treatment adoption

In this case, the number of farm assets was the most significant factor determining the adopting of coffee wastewater treatment (<0.001***), this might be because some farmers do not realise the benefits of this practice and they leave it for the end or postpone its installation. Smallholders getting better prices are more likely to invest in wastewater treatment (0.073*). Another determinant is access to extension services (0.043**) due to the fact that most of the organisations that deliver extension services are certified and this affiliation gives more likelihood to adopt this water treatment practice (Bro *et al.*, 2019). Lastly, results also suggest that facilitating conditions (0.006**) are determinants for water treatment adoption in the study area as found by Bravo-Monroy, Potts and Tzanopoulos (2016) in Colombia for organic farming adoption which includes coffee wastewater treatment to meet certification requirements.

Variables that do not influence adoption.

According to the results, in this study gender did not influence the adoption of any practice as suggested by Overfield and Fleming (2001), which could be because of low female respondents; age, neither was significant as found by Knowler and Bradshaw (2007) and Posthumus, Gardebroek and Ruben (2010) for soil conservation practices and contrary to the reported by Alvarado Barbarán (2014) for adoption of organic technologies. Agricultural credit was not found significant for soil erosion control techniques, it might be because many farmers commented that traditionally they are not used to working with loans and are afraid of debt, this was also found as a problem in the National Coffee Action Plan (Minagri, 2018), but also, according to the National Agricultural Census (INEI, 2012) is because cumbersome procedures, high interest rates, lack of collateral, among others.

Land-tenure rights (ownership) were not found significant owing to most farmers keeping a purchase-sale agreement which could make them feel to some extent secure in their properties, this contradicts what was reported by Rodriguez (2020) in another region. Social influence of familial and peers neither was 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 *et al.*, 2020b).

It also merits to mention that at the time when the survey was conducted coincided with lower and unfavourable coffee prices which as mentioned by Byerlee (1993) agricultural market trends affects producer's decisions and cause risk and innovation rejection. Some respondents chiefly in Pisuquia and Ocúmal commented that there are neighbours who are abandoning the countryside, which might be as a livelihood strategy (Landaverde *et al.*, 2022), this phenomenon have implications on labourers' availability and increased labour cost (Minagri, 2018). All the coffee is gathered by hand, which means that harvest shares the main costs. There is also growing pressure on water resources because coffee farmers depend on nearby streams and sometimes, where possible, they use water intended for human consumption to irrigate coffee as a coping measure during droughts (Moser and Ekstrom, 2010).

Farmer's interview results

Semi-structured interviews allow the interviewer to ask a predetermined set of questions. Data from the interviews assists in the interpretation of the quantitative results and provides qualitative insight into participants' perspectives.

What motivated or allowed you to implement sustainable practices?

A farmer interviewed who was Organic and Fair Trade certified said that cooperative extensionists motivated them to be ordered on his farm and improve coffee quality to achieve economic improvement. Another farmer mentioned that he has been accustomed to using shade trees on his farm since a long time ago "If I remove the shade, the coffee leaves will fall" and added that shade allows coffee to produce large fruits even though it takes

more time to ripen. It was also reported by another interviewee that climate change adaptation motivated him to use fertilisation and irrigation so that the plants could resist drought periods. While the following farmer replied that he knows that shaded coffee helps according to the land and location he said, “If the plantation is close to any water stream if you put shade there are going to be pests, but if the land is on the hillside, you should use shade.” Farmers recognised that coffee under shade reduces yield as reported by Collazos Silva (2018) however is traded off with less weeding requirement and better coffee fruit size.

What impeded you from implementing SAPs?

The interviewee reported that making compost is easy for him however it takes time, and they lack farm hands, because he is busy all day picking from sunup to sundown, then he ends up tired. The following producer stated that he is focused on productivity, so he has seen that unshaded coffee when well-fertilised produces very well. Another farmer revealed that he has bought the farm recently, so he lacks the means and is still learning about coffee production because he was a migrant from a non-coffee producer family. The last interviewee considered cover crops as weeds, and he thinks weeds get away the strength of the plants that is why he does not like soil cover plants instead he likes his farm well cleared.

Adaptations

One farmer reported that he has adapted his processing plant according to his circumstances (daily amount). Other interviewee had adapted fertiliser mixed with soil to prevent damage to seedlings and also reported that he had adapted an irrigation system that works using the syphon principle and does not require energy. Fertilisation and pruning according to the production cycle of the trees and renewing sprouts was another adaptation reported.

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 and Wainger, 2023), these incentives not only help with implementation costs but also attenuate the perceived risk of adoption. Market incentives are economic factors that either lower the cost and/or increase the benefits of adoption. Targeted incentives such as agricultural machinery purchase subsidies, technical guidance, and agricultural cooperative services might be taken into consideration (Piñeiro *et al.*, 2020; Parodi *et al.*, 2022). 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).

Expert interview results

What household characteristics do you think influence more on adopting sustainable agricultural practices?

Academia representative: educational level, members with secondary or higher education are more open to new practices, number of family members who support farm activities, and training of the household head or relatives.

Government representative: level of education of household head, family income from diverse sources for instance livestock or a second cash crop.

Private sector representative: The economic level is important for farmers' livelihoods as they try to get better prices to sustain their families as their priority and they are more likely to adopt sustainable practices if they are rewarded for instance with higher coffee prices.

What farm characteristics do you think influence adopting sustainable practices?

Academia: topography or relief is one factor that influences adoption and when there is less slope embracing sustainability is feasible, climate conditions, productive infrastructure, meaning the farm assets, and accessibility to resources.

Government: Relief or topography, climate characteristics, resource availability for investment, and land extension.

Private sector: physical access is fundamental, farms close to communication vias, or roads are easy for the management to bring fertilisers or labourers, water access is key to water seedlings and also for coffee wet processing, moreover, for association partners to get loans they need land title as collateral.

What external factors drive or constrain more from adopting sustainable practices?

Academia: Institutions Intervention, it is needed for a sound policy for rural intervention to prevent confusing farmers with different discourses, it is also stated by Robiglio *et al.* (2017) in their analysis. Institutional support to rural initiatives with programs or projects.

Economic instability impacts negatively on farmers' economy and investments through the raising of input prices. As reported by other researchers, intervention becomes a barrier when rarely linked or coordinated where for instance each farm adviser delivers according to his or her own criteria, rather than a concerted strategy.

Government: Policies, national, regional, or local development policies as stated in the National Coffee Action Plan that disjointly investment across all three levels of government does not allow for resource optimisation (Minagri, 2018). The government should support policies for sustainable development, and market availability due to farmers needing access to markets for their output (Robiglio *et al.*, 2017).

Private sector: Access to technical assistance, access to credit for investment, price volatility impact on crop planning, and access to inputs and tools for farming.

What economic factors do you consider that determine SAP adoption?

Academia: Economic diversification allows farmers to engage with sustainable practices.

Government: Technology prices must be accessible to farmers and the proximity to input markets is also fundamental, so farmers can get these technologies.

Private sector: Off-farm income or income diversification helps during the off-season, production costs management with a focus on lowering the production costs because it is difficult to know next year's prices, then farmers if they want to ensure their earnings, they need to reduce cost per kilogram of coffee, moreover, workforce availability for harvest.

What SAPs do you consider advisable to promote and adopt for small coffee farmers in the districts of Luya?

Academia: Agroforestry, soil conservation practices.

Government: Agroforestry is highly advisable, along with the promotion of circular production systems with animal husbandry so farmers can use manure as fertiliser. And no less important is water conservation for instance water seeding and harvesting.

Private sector: recommended improving coffee quality control to get better prices for farmers, yield improvement to get more money from sales, also advice to improve the work system so that the producer does not waste time owing to when is harvest-season they are time constrained. This is in line with Barham and Weber (2012) who found that boosting net cash returns for coffee farming households is primarily dependent on improving yields, as opposed to focusing on price premiums from certifications associated with sustainable practices.

The findings of this study are also supported by experts who mentioned that the number of family members of working age, educational attainment, extension services, economic level, coffee prices, land slope, access to resources like fertile soil, land size, and labour availability determine the adoption of sustainable practices.

Public and private actors show different interests and visions (Minagri, 2018), and hence different criteria for assessing enablers, barriers, and relevant techniques. It can be noticed that academia and government are more considerate of environmental sustainability recommending agroforestry while private sector interviewee, with economic viability when suggesting coffee quality improvement and making the work system more efficient for farmers to lower coffee production costs and save time for other activities.

Practical implications

Promoting and using environmentally sound practices in tropical agricultural landscapes is pressing. By encouraging innovation as a process rather than a result, it becomes feasible to tackle unique contextual requirements and boost farmers' ability to adapt to change.

Expanding these processes requires the engagement of providers offering innovation support services, thereby establishing a conducive setting for experimentation and innovation (Pircher *et al.*, 2022).

However, Peru lacks a reliable extension and advisory service system for providing technical support to rural producers (Landaverde *et al.*, 2022) in difficult regions like the Amazon that is renowned for its limited infrastructure (Chavez and Perz, 2012) which makes it difficult to reach distant producers in the most need.

Evidence suggests that engaging the services of a farm adviser increases the likelihood of adopting something new like shown in this study, composting, and coffee wastewater treatment. The provision of extension services enhances farmers' knowledge, abilities, and consciousness regarding innovative practices (Nyang'au *et al.*, 2021).

Following this line of thought, the agricultural sector should enhance and broaden its demonstration facilities linked to facilitated dialogue to effectively communicate the societal, economic, and environmental advantages of implementing sustainable farming practices (Parodi *et al.*, 2022) which can help evidencing SAPs' attributes that were found that determine its adoption for soil cover, agroforestry, and composting.

Soil testing is one of the foundations for good technical assistance and soil management, however in the study area only 22.1% of the farmers reported that have tested their soil, but not all of them use the result properly. Moreover, most of the farmers reported that the main challenge is pests and diseases and require training and advice on pest management or control, which is known that involves an integrated farm management and close monitoring and control, however as the results showed the National Service for Agricultural Health (SENASA) could not reach those farmers timely, neither other institution like National Institute of Agricultural Innovation (INIA).

From the survey results and interviews, it is suggested to smallholders that not only rely on coffee crops as main cash income and undertake other income-generating activities (economic diversification), agroforestry, alternative cash crops like avocado or small animal farming. These on-farm diversification activities might provide food for household and workers, sources of timber and derivatives, which will generate extra income (Krishnan, 2017) and reduce climate and low prices risks (World Bank, CIAT, and CATIE, 2015). For which it is needed facilitating conditions through political support measures for capacity building and local market's development.

Low rates of adoption show the need for participatory identification and analysis of intervention priorities where all actors involved in the value chain take decisions and the government acts as facilitator and has a promoter role. For that it is needed as an innovation platform to facilitate interaction among stakeholders. It should comprise at least two components: agricultural innovation support facility offering agricultural technology and inputs, and agricultural innovation support services to provide advisory services. In the Peruvian coffee sector, it has been created the National Executive Coffee Council in 2021, however, concrete actions have not yet been seen.

Sustainable and resilient farming is knowledge-intensive and demands location-specific knowledge (Šūmane *et al.*, 2018). This study's findings suggest pathways to increase the likelihood of the adoption of sustainable agriculture by strengthening access to extension services through an approach of constructive dialogues (Ingram and Morris, 2007), and foster knowledge integration and sharing among practitioners and other stakeholders across multiple levels. Adopting improved management solutions as a learning process requires ongoing orientation and information collection, supporting a network of adopters would facilitate practical knowledge exchange, allowing other farmers to observe improvements, and opening a two-way engagement for knowledge transfer. This suggests that funding and encouraging knowledge exchange activities is advisable, owing to farmers tend to rely on informal knowledge (Šūmane *et al.*, 2018).

It would appear that trust building is also needed, which includes wider social and organisational change, many smallholders do not join organisations due to risk aversion or bad past experiences. The principles of sustainable agriculture are guided by both values and what is commonly considered scientific understanding. In this way, trust is needed throughout the value chain, trusted farmers to lead farmer organisations, trusted individuals delivering technical assistance and getting information from farmers, and trusted traders paying fairer prices, in order to attain high quality (Krishnan, 2017), not only physically but also environmentally.

Compared to developed countries that have done research and analysed the benefits of sustainable practices adoption (Read and Wainger, 2023), still, little attention has been paid to this research area in Peru, academia and research institutes, especially INIA, should investigate, among many others, SAPs characteristics, compatibility, viability and profitability for small coffee farmers environment, then, carefully estimate the relative costs and benefits of different strategies at farm level, this might facilitate its confident promotion through incentives based on solid evidence. Further demand driven research is clearly needed about features that farmers seek in technologies, choice experiments for coffee farmers' preferences or willingness to adopt in order to produce customised recommendations. It requires the implementation of an articulated research system, as stated by the Minagri (2018) through their National Action Coffee Plan but not yet achieved.

Equally important, information and communication technologies like mobile phones and internet access has an enormous potential for knowledge information and transfer, leading to a broader reach of the message owing to the fact that 90% of households are already using mobile phones. It also can reduce transaction costs (Minagri, 2018) and some risks for private investment.

World Bank, CIAT, and CATIE (2014) recommends post-harvest community infrastructure; tree crop rejuvenation and agroforestry as climate smart practices for Peruvian coffee, I agree with the promotion of tree crop rejuvenation to prevent excessive pests (which is the main problem in the study area), owing to avoid high humidity and fungus development and

reduce competition for nutrients (adaptation), and maintain yields (productivity), its adoption was not in the scope of this study, however should be studied.

Overall, for tailored policy, farmers' segmentation may be needed to differentiate the needs of distinct groups in designing effective and equitable policies and take advantage of smallholders' acceptance of policies and interventions. For instance, matching intervention types with adoption stages.

Chapter 5: Conclusions

- The factors that influenced the adoption of sustainable agricultural practices are the number of people of working age living in the household, educational attainment, number of assets, coffee yield, coffee price, farm investment, sustainable practices attributes, certification, farmer knowledge about sustainable practices, access to extension services, performance expectancy, and facilitating conditions.
- The main barriers to the adoption of bundled sustainable practices are the scarce labour availability during peak season, smallholders' low economic level, risk expectations, and lack of access to agricultural credit.
- The results suggest that to improve sustainable practices adoption rates, it should be increased farmers' knowledge about sustainable practices' economic and environmental attributes through demonstration facilities and offer facilitating conditions like timely information, demand-driven research seeking attributes that producers are interested in, access to a platform of coordinated extension and advisory services and input access. To overcome the barriers, it is needed to enhance the accessibility to agricultural credit for farm investment, use targeted incentives and improve the work system to lower production costs through saving in the labour force.

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Appendix 1

Ethics ETH2223-1774 : [REDACTED]

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	[REDACTED]
Category	PGT
Supervisor	Dr John McDonagh
Faculty	Faculty of Social Sciences
Current status	Approved

Ethics application

Applicant and research team

Principal Applicant

Name of Principal Applicant
Mr [REDACTED]
UEA account
[REDACTED]
School/Department
School of Global Development
Category
PGT

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 completely 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 coffee farmers

Appendix 2

Variables in the Equation for cover crop adoption									
		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 1 ^a	Household number	.457	.205	4.960	1	.026	1.580	1.056	2.363
	Cover crop attributes	1.178	.650	3.290	1	.070	3.248	.909	11.600
	Farmer knowledge	.834	.429	3.778	1	.052	2.303	.993	5.342
	Risk expectations	-.919	.305	9.097	1	.003	.399	.220	.725
	Constant	-6.101	3.008	4.114	1	.043	.002		

a. Variable(s) entered on step 1: Household number, S_CV_AT, FK1, RE_S.

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	27.131	4	<.001
	Block	27.131	4	<.001
	Model	27.131	4	<.001

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	96.318 ^a	.171	.298

a. Estimation terminated at iteration number 6 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	6.318	8	.612

Variables in the Equation for agroforestry adoption									
		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 1 ^a	Farm orientation (profit)	-2.547	1.020	6.240	1	.012	.078	.011	.578
	Agroforestry attributes	2.664	.584	20.769	1	<.001	14.350	4.564	45.119
	Certification	3.025	1.449	4.360	1	.037	20.590	1.204	352.178
	Facilitating conditions	1.244	.537	5.365	1	.021	3.470	1.211	9.942
	Constant	-7.114	2.800	6.454	1	.011	.001		

a. Variable(s) entered on step 1: Farm orientation, S_AF_A, CER01, FC_S.

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	53.558	4	<.001
	Block	53.558	4	<.001
	Model	53.558	4	<.001

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	69.891 ^a	.309	.539

a. Estimation terminated at iteration number 7 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	5.436	8	.710

Variables in the Equation for contour planting									
		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 1 ^a	Economic situation (extremely poor)			6.790	3	.079			
	Economic situation (poor)	1.844	.865	4.541	1	.033	6.321	1.159	34.466
	Economic situation (average)	2.272	.899	6.386	1	.012	9.699	1.665	56.491
	Economic situation (not poor)	2.377	1.198	3.936	1	.047	10.769	1.029	112.680
	Farmer knowledge	.452	.247	3.333	1	.068	1.571	.967	2.552
	Performance expectancy	.579	.333	3.019	1	.082	1.784	.929	3.427
	Constant	-5.245	1.712	9.387	1	.002	.005		
	a. Variable(s) entered on step 1: Economic situation, FK3, PE_S.								

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	16.497	5	.006
	Block	16.497	5	.006
	Model	16.497	5	.006

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	179.459 ^a	.108	.145
a. Estimation terminated at iteration number 4 because parameter estimates changed by less than .001.			

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	12.675	8	.124

Variables in the Equation for living or dead barriers adoption									
		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 1 ^a	Land slope (flat)			5.110	2	.078			
	Land slope (medium)	1.021	.852	1.436	1	.231	2.777	.522	14.765
	Terrain slope (steep)	1.678	.878	3.652	1	.056	5.354	.958	29.924
	Soil testing (yes)	.798	.432	3.403	1	.065	2.220	.951	5.182
	Performance expectancy	.941	.343	7.509	1	.006	2.563	1.307	5.025
	Constant	-5.183	1.582	10.731	1	.001	.006		

a. Variable(s) entered on step 1: Terrain slope, Soil testing, PE_S.

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	18.665	4	<.001
	Block	18.665	4	<.001
	Model	18.665	4	<.001

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	180.350 ^a	.121	.162

a. Estimation terminated at iteration number 4 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	4.106	7	.767

Variables in the Equation for composting adoption									
		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 1 ^a	Extension (yes)	1.122	.500	5.036	1	.025	3.071	1.153	8.183
	Household number	.425	.196	4.691	1	.030	1.529	1.041	2.245
	Composting attributes	1.096	.363	9.118	1	.003	2.993	1.469	6.097
	Facilitating conditions	.840	.382	4.836	1	.028	2.317	1.096	4.900
	Constant	-9.986	2.032	24.158	1	<.001	.000		
a. Variable(s) entered on step 1: Extension dic, Household number, S_CP_A, FC_S.									

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	32.912	4	<.001
	Block	32.912	4	<.001
	Model	32.912	4	<.001

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	127.360 ^a	.203	.304
a. Estimation terminated at iteration number 5 because parameter estimates changed by less than .001.			

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	8.253	8	.409

Variables in the Equation for fertilisation adoption									
		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 1 ^a	Farm investment (yes)	1.165	.524	4.949	1	.026	3.206	1.149	8.949
	Credit use (no)			4.801	2	.091			
	Credit use (to some extent)	1.159	.973	1.420	1	.233	3.188	.474	21.452
	Credit use (yes)	1.163	.604	3.705	1	.054	3.200	.979	10.456
	Coffee yield	.041	.015	7.475	1	.006	1.042	1.012	1.072
	Educational attainment	.143	.062	5.245	1	.022	1.154	1.021	1.303
	Constant	-3.001	.575	27.205	1	<.001	.050		
a. Variable(s) entered on step 1: Farm investment, Credit use, Coffee yield, Educational attainment.									

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	43.699	8	<.001
	Block	43.699	8	<.001
	Model	43.699	8	<.001

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	149.737 ^a	.260	.353
a. Estimation terminated at iteration number 5 because parameter estimates changed by less than .001.			

Variables in the Equation for Integrated Pest Management									
		B	S.E	Wal	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
				d				Lower	Upper
Step 1 ^a	Off-farm income	.932	.558	2.791	1	.095	2.541	.851	7.587
	Labour availability (rarely)			9.485	3	.023			
	Labour availability (sometimes)	-.390	.491	.632	1	.427	.677	.259	1.771
	Labour availability (often)	1.073	.484	4.909	1	.027	2.925	1.132	7.561
	Labour availability (always)	.908	.641	2.004	1	.157	2.480	.705	8.716
	Coffee price	.008	.003	9.081	1	.003	1.008	1.003	1.014
	FK6	.479	.283	2.859	1	.091	1.614	.927	2.811
	Constant	-6.655	1.941	11.756	1	<.001	.001		

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	25.684	6	<.001
	Block	25.684	6	<.001
	Model	25.684	6	<.001

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	167.752 ^a	.162	.220
a. Estimation terminated at iteration number 4 because parameter estimates changed by less than .001.			
Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	3.343	7	.852

Variables in the Equation for wastewater treatment									
		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 1 ^a	Number of assets	.740	.195	14.337	1	<.001	2.095	1.429	3.073
	Coffee price	.006	.003	3.204	1	.073	1.006	.999	1.012
	Market information (yes)	.824	.544	2.298	1	.130	2.279	.786	6.614
	Facilitating conditions	1.211	.444	7.432	1	.006	3.358	1.406	8.022
	Extension (yes)	.948	.468	4.096	1	.043	2.581	1.030	6.464
	Constant	-10.213	2.321	19.363	1	<.001	.000		

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	62.986	5	<.001
	Block	62.986	5	<.001
	Model	62.986	5	<.001

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	129.494 ^a	.352	.479
a. Estimation terminated at iteration number 5 because parameter estimates changed by less than .001.			

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	4.632	8	.796