PERCEPTIONS OF CLIMATE VARIABILITY AND THE USE OF PURCHASED FARM INPUTS AMONG COFFEE FARMERS IN THE CATTLE CORRIDOR OF CENTRAL UGANDA

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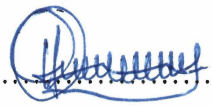
DECLARATION

I Mbabazi Harriet confidently declare that the work presented in this thesis is original, uniquely prepared by me as a result of my research and has not been submitted by anybody to this university or others.

Signature:  Date: 10/01/2024

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APPROVAL

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DEDICATION

I dedicate this thesis to the Almighty God, my beloved parents (Mr. Mulwana Steven and Mrs. Nanyimba Florence) and my supervisors (Dr. Stephen Wamala Kalule and Dr. Peter Omara).

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LIST OF ACRONYMS AND ABBREVIATIONS

ATET	Average Treatment Effect for the Treated
ATT	Average Treatment Effect for the Treated
GUREC	Gulu University Research Ethic Committee
ICO	International Coffee Organisation
IRR	Incident Rate Ratio
KGs	Kilograms
LLM	local linear matching
NN	Nearest-neighbor matching
PDM	Parish Development Model
PRM	Poisson Regression model
PSM	Propensity Score Matching
RUFORUM	Regional University Forum for Capacity Building in Agriculture
SACCOS	Savings and Credit Cooperatives Societies
SOPs	Standard Operating Procedures
SPSS	Statistical Package for Social Sciences
STATA	Statistics and Data
UCDA	Uganda Coffee Development Authority
UGX	Uganda Shillings
VSLA	Village Savings and Loan Associations
ZIP	Zero Inflated Poisson Regression Model

ABSTRACT

The negative effects of climate variability among smallholder coffee farmers in Uganda are worsening, especially in the cattle corridor, threatening the sustainability of coffee production. While there is increased use of farm inputs amongst coffee farmers, the linkage of such inputs use with farmer perception of climate variability is not well understood. This study assessed coffee farmer perceptions on temporal changes in climate variabilities, determined the relationship between use of purchased inputs and perceived crop-climate effects, and analyzed farmer perceptions on climate variability influencing the use of purchased farm inputs. A cross-sectional study design was employed to collect data from 272 randomly selected households from Luwero and Nakasongola districts using a semi-structured questionnaire. Data was analyzed using descriptive statistics and regression models (probit, propensity score matching, and zero-inflated poisson). The study results indicate a perceived general increase in climate variabilities, notably, low rainfall and short rainfall duration, high temperatures during the dry season, and seasonal dry spells in recent years. The study also reveals that farmers perceive a general increase in crop-climate effects, notably, worsening coffee harvests, increased pest incidences, low-weight coffee cherries, and coffee cherries with unfilled beans. The study further established that the use of purchased inputs, such as fertilizers, pesticides, herbicides, and manure, has generally increased in the study area in recent years. Farmers who use purchased inputs perceived a significant reduction in incidences of low coffee harvests, pest infestation, less coffee flowering, low-weight coffee cherries, and drying of coffee leaves. Results of the zero-inflated poisson regression revealed that changes in low and high rainfall amounts, seasonal dry spells, access to extension on climate and crop husbandry, access to credit, age, sex, coffee output, labour, shade trees, water harvesting, and mulching drive decisions to use purchased inputs. From these results, it can be concluded that incidences of climate variabilities and crop-climate effects are worsening and cause increased use of purchased farm inputs, which ultimately places a cost burden on a farmer. Therefore, the study recommends that farmers should be offered insurance schemes for climate-related crop losses. Also, access to climate variability adaptation and weather information by coffee farmers should be accurate and timely to facilitate informed decision-making on implementing climate-resilient programs.

Keywords: *Purchased inputs, perception, climate variability, smallholder farmers, climate effects*.

CHAPTER ONE: INTRODUCTION

1.1 Background to the study

Climate variability is a worldwide environmental threat that affects agricultural productivity (Lemi & Hailu, 2019)**.** It has been reported to negatively impact yields for many crops, as well as the quality of farm output (Bunn *et al*., 2015). For coffee, yield losses attributable to climate variability may rise to a level as high as 50% of the long-term average yields (Adhikari *et al*., 2020; Bunn *et al*., 2019). The situation is even worse for smallholder farmers, who largely depend on rainfall to cultivate crops (Cohn *et al*., 2017). Given the limited capital and capacity to invest, majority of the smallholder farmers find difficulties in responding to changing climatic conditions (Pham *et al*., 2019). Often, these farmers are neither equipped with facilities for irrigation in case of extreme hot temperatures and prolonged season dry spells nor have the ability to purchase farm inputs such as fertilizers and pesticides as a way of boosting crop vigour during adverse climatic conditions. Uganda remains one of the countries most vulnerable to climate variability because its agriculture is almost entirely rain-fed and is marked by seasonality (Mubiru *et al*., 2018; Radeny *et al*., 2019). Climate variability effects in Uganda's coffee-producing areas are reportedly worse in the cattle corridor (Nanfuka *et al*., 2020).

Climate variabilities are commonly manifested as late on-set and/ or early cessation of rainfall (Mubiru *et al*., 2018). This tends to create a very prolonged seasonal dry spell. Further, sometimes the dry and wet seasons present with extreme high temperatures which farmers may experience as hot days. Such dry and hot environmental conditions cause excess evapotranspiration to the coffee crop translating into poor yields (Adhikari *et al*., 2020). At times, precipitation within a rainy season may fall below the long-term average of normal rains and ultimately, causing water stress to the crop. Even worse, during a normal rainy season, some dry spells may occasionally occur,

causing uncertainty to the farmers. Even when unusually high rainfall amounts are received, coffee growers may experience unprecedented outreach of pests as well as emergence of weeds (Wagner *et al*., 2021). Overall, such climate variabilities are translated into negative impacts on crops including coffee.

Commonly, shifts in rainfall patterns and adverse temperature conditions may bring negative crop-climate effects. Owing to excessively dry and hot temperatures, some coffee growers may experience unusual drying of crop leaves and tree branches. Furthermore, coffee flowering may vary from the usual interval of flowering and ripening of coffee fruits (DaMatta & Ramalho, 2006; DaMatta *et al*., 2018). Even worse, coffee flowers may prematurely drop more than the expected average. That aside, high temperatures may result into shorter fruit filling periods with a negative impact on the expected yields as well as bean quality i.e., size and weight (Mbwambo *et al*., 2022). These poor coffee yields in terms of quantity and quality have substantial threats to food security and livelihoods especially among smallholder farmers who constitute the highest percentage of the coffee sector.

On account of negative crop-climate effects, coffee farmers attempt to combat the adverse climatic conditions through two lines of approaches. First, very often, coffee growers respond by pursuing crop husbandry practices that reduce the impact of dry conditions on the crop. These practices include planting and/or maintaining shade trees in crops, providing the crop with organic manures, notably, decomposed animal dung and compost manure whose properties are important for not only supplying nutrients to the crop but also water retention. Also, some farmers undertake mulching, which creates cool conditions around the crop while conserving soil moisture. Other husbandry practices include planting drought-tolerant varieties, intercropping coffee with bananas, irrigation, and digging trenches for water harvesting while controlling soil erosion (Kajembe *et*

al., 2016; Pham *et al*., 2019; Asegid, 2020; Mbwambo *et al*., 2021). A second approach to dealing with dry conditions in coffee is the use of purchased farm inputs, notably soil (granular) fertilizers and nitrogenous foliar fertilizers. The action of these fertilizers on the crop is rooted in boosting plant vigour, which is useful in combating unfavourable environmental conditions (Kumari *et al*., 2022). Yet again, changing climatic conditions cause outbreaks of pests, which compel farmers to buy more agrochemicals to fight off such pests. Whether a farmer chooses husbandry practices, purchases inputs, or both to deal with climate risks, may depend in part on their perceptions of climate variability. The implication is that, any farmer response strategy comes with an increased cost burden. However, studies that investigate the impact of climate variability on the use of purchased inputs along with farm practices are scanty necessitating the current study. Understanding the relationship between climate variability and the use of purchased farm inputs is insightful for designing adaptive response strategies to changing climate so as to guarantee sustainable coffee production.

1.2 Problem statement

Climate variability causes profound losses in coffee yield, which may account for up to 50% of the total projected farm output (Bunn *et al*., 2019). Climate variabilities commonly present as extreme temperatures, prolonged dry spells, strong winds, erratic rainfall, and others (Pham *et al*., 2019). For instance, higher temperatures and reduced cloud cover cause an increase in the water needs of the coffee crop and subsequent water stress (Zhao & Dai, 2017). The impacts of climate variability are even worse in areas that tend to have prolonged dry spells, such as those in the cattle corridor (Alex *et al*., 2013; Nanfuka *et al*., 2020)**.** Such negative impacts may manifest as crop failure, irregular flowering, low-weight coffee beans, increased pests, and others (Bunn *et al*., 2019).

Several empirical studies (Mugagga, 2017; Mulinde *et al*., 2019; Atube *et al*., 2022; Makate & Makate, 2022; Jawo *et al*., 2023) have examined farmers' perceptions of climate variability and response actions. These studies report that farmers use different response options, including purchased farm inputs against the perceived climate shocks. For instance, Mulinde *et al*. (2019), with no empirical analysis, links increasing use of inorganic fertilizers and agrochemicals in central and eastern Uganda to changing climate. Reportedly, farmers' perceptions of climate variability can influence their response to climate shocks (Maddison, 2007). However, such farmer responses are relative and location-specific (Mbwambo *et al*., 2021) and might vary with respect to coffee growers. Despite the extensive literature available on farmer perceptions and changing climatic conditions, the direct linkage between perceptions on climate variabilities and the use of purchased farm inputs is not well understood. Therefore, this study sought to build on the available literature by analyzing the linkage between perceptions on crop-climate effects and climate variabilities and the use of purchased farm inputs among coffee growers.

1.3 Objectives

1.3.1 General objective

To examine the relationship between smallholder farmers' perceptions of climate variabilities in coffee production and the use of farm inputs in the cattle corridor of central Uganda.

1.3.2 Specific objectives

- To assess farmer perceptions on temporal changes in climate variabilities
- To determine the relationship between use of purchased farm inputs and perceived crop-climate effects
- To determine the influence of perceived climate variability on use of purchased inputs in coffee production

1.4 Research questions

1. What are the farmers' perceptions on temporal changes in climate variabilities?
2. What is the relationship between the use of purchased farm inputs and perceived crop-climate effects?
3. What is the influence of perceived climate variabilities on the use of purchased inputs in coffee production?

1.5 Conceptual framework

Farm inputs have the ability to enhance crop vigour and ensure survival under adverse climatic conditions. This explains why farm input use has been listed by several scholars as an adaptation strategy to climate change and variability (Mulinde *et al*., 2019; Atube *et al*., 2021; Makate & Makate, 2022). However, since perceptions affect the farmer choice of climate-resilient adoption strategies (Deressa *et al.*, 2011), it is expected that they will also influence the utilization of purchased farm inputs. Figure 1.1 below portrays the conceptual framework constructed based on the assumption that farmer perceptions of climate variability influence the utilization of purchased inputs in coffee production.

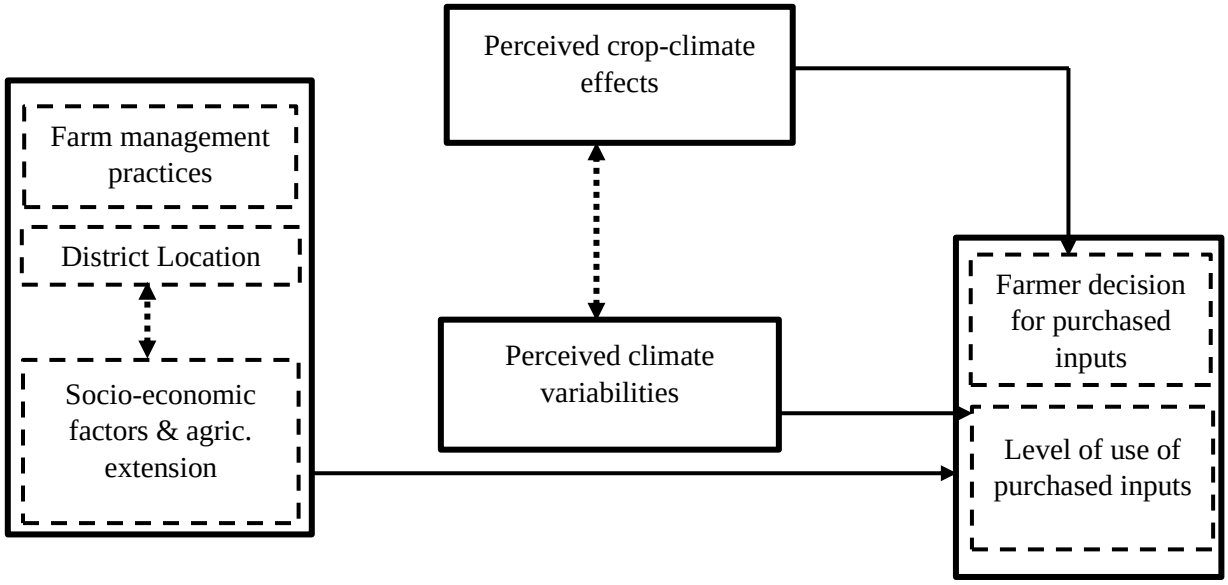


Figure 1.1: The Conceptual framework of the study (Authors' conceptualization)

This framework indicates that perceived climate variabilities such as low and high rainfall amounts, prolonged and short dry spells etc. may have direct implications on the level of use of purchased farm inputs (e.g., fertilizers, herbicides, pesticides, manure). Also, perceived crop-climate effects such as low yields, less flowering, and pest infestation could potentially influence farmers' decisions on the utilization of purchased farm inputs. The interaction of these independent variables may also affect the decision to use and level of use of purchased inputs. In this framework, farm management practices, district location, socioeconomic factors and agriculture extension are treated as control variables.

1.6 Scope of the study

This study considers both geographical and contextual scopes. In terms of geographical scope, this study was limited to Luwero and Nakasongola districts of Central Uganda, focusing only on coffee farmers. Contextually, information on climate variability and inputs used in coffee production were captured.

1.7 Justification of the study

Coffee is a very sensitive crop to climate variability and therefore productive within a narrow range of mean temperatures (ICO, 2014; Bunn *et al*., 2015; DaMatta *et al*., 2018; Asegid, 2020). The threat to coffee production due to shifts in temperature and precipitation patterns is increasing, with likely negative effects on coffee yields (Bunn *et al*., 2015; DaMatta, 2018). For instance, prolonged dry spell has been associated with excessive flower abortions, low-weight coffee cherries, and small coffee beans. This compels coffee growers to implement practices that ensure crop vigour and survival under adverse climatic conditions, such as the use of purchased inputs. It should be noted that farmers' use of these inputs as a response to climate variability effects may depend on their perceptions. According to Mbwambo *et al*., 2021, perceived climate risks by

farmers influence their decisions to undertake measures (including the use of farm inputs) against adverse climatic conditions. Therefore, a study to build on the available literature on input use and farmers' perception of climate variability in coffee production was crucial. The study findings provide an important guide for policymakers, the government, and development partners to design localized programs and estimate budgets for subsidizing coffee farm inputs aimed at mitigating climate risks. Finally, the study's findings and recommendations provide a basis for further studies.

CHAPTER TWO: LITERATURE REVIEW

2.1 Overview of coffee production sector in Uganda

Coffee is one of the most important globally cultivated crops with substantial contribution to the livelihoods of millions of smallholder farmers worldwide (Pham *et al.* 2019). It ranks as the second most traded commodity following crude oil and provides employment for over 100 million people (Asegid, 2020). Over 70% of the world's coffee is grown by smallholder farmers in Africa, Asia and the Americas, and for many of them, coffee is their main source of income (Cohn *et al*., 2017). Uganda remains East Africa's leading coffee producer and ranks second in Africa (Davis *et al*., 2022). According to UCDA (2021), "Nearly 42% of farming households grow some coffee and coffee has contributed on average 20-30% to the country's foreign exchange earnings over the past 20 years". The country's coffee sector is made up of *C. arabica* and *C. canephora* (UCDA, 2015). *C. canephora* (Robusta coffee) makes up 85% of the total annual production. It is cultivated in Uganda's central, eastern, western, and southeastern regions, whereas *C. arabica* is grown in the elevated areas along the slopes of Mount Elgon and Rwenzori (UCDA, 2015). Unfortunately, coffee production in Uganda is presently limited by the negative impacts of climate variability (UCDA, 2017; Bunn *et al*., 2019), hence in absence of effective climate-resilient options, the economic viability of coffee cultivation in Uganda would be compromised in many areas (Bunn *et al*., 2019).

2.2 Climate variabilities and changing climate

Ali (2018) described climate variability as short-term or seasonal/multi-seasonal variations in climate. Globally, it is one of the biggest threats to the realization of sustainable development goals (Chisale *et al*., 2021). According to Amikuzuno and Donkoh (2012), the impact of climate variability is manifested through changes in agro-ecological conditions and climatic factors,

particularly precipitation and temperature. Chisale *et al*. (2021) mentioned that unreliable rainfall is the major trigger for severe climatic conditions such as dry spells and floods. Additionally, Gay *et al*. (2006) and Bunn *et al*. (2015) stressed that extreme temperatures and drought stress are major threats to coffee production both at present and in the coming years. Literature by Lemma and Megersa (2021) states that "global temperature has been rising by nearly 1°C and is expected to rise to 2.5°C at optimum and 4.5 °C at worst scenarios". Consequently, agro-climatic indicators, particularly those closely associated with temperature, such as the rise in the length of the growing period (Eshetu *et al*., 2021), are continuously changing.

Studies investigating climate variabilities and changing climate have reported results at varying depths in different localities. For instance, using regression models, Chisale *et al*. (2021) reported a perceived increase in key climate events i.e; high temperatures, erratic rainfall, and droughts in Malawi. In Tanzania, a logistic analysis of farmers' perceptions and meteorological data indicated reduced rainfall amounts and a rise in temperature (Mbwambo *et al*., 2021). In various coffee landscapes of Uganda, Mulinde *et al*. (2019) identified key perceived climate risks as change in rainy seasons, prolonged drought, floods, hailstorms, and landslides. Relatedly, Mubiru *et al*. (2018) described climate risks observed in their findings as "erratic rainfall onset and cessation (which were either early or late), poor seasonal distribution of rainfall and decreased rainfall", and temperature changes. The authors further observed an overall rise in average maximum temperature, declining and stable trends in terms of average annual rainfall in their two study districts. What's obvious from these studies is that incidences of climatic events, i.e., prolonged dry spells and rainfall variations, are becoming more frequent and intense. These are projected to majorly affect the incomes of smallholders, who rely entirely on rain-fed agriculture, resulting in increased poverty levels, hunger and malnutrition (Ali, 2018). A synthesis of these previous studies

however confirms that the perceived intensity and kind of climate variabilities may differ from one location to another, and this is likely to affect how farmers respond to them locally.

Additionally, studies also suggest that socio-economic characteristics which may be location specific, affect farmers' perceptions of climate variabilities. For instance, Deressa *et al*. (2011) in Ethiopia mentioned that household head's age, knowledge of changing climate, wealth, agro-ecological contexts, and social capital influenced the perceptions of farmers with regards to climate variability. Yet Mbwambo *et al*. (2021) reported experience in farming, level of education, size of the farm, and accessibility to extension as some of the factors associated with the perceptions of farmers of variability in climate, in Tanzania. These studies collectively suggest that socioeconomic factors may influence how farmers perceive climate variabilities in a given location. Considering the above, this study sought to analyze how coffee growers in the study area perceive the variations in climatic events between the two time periods.

2.3 Crop-climate effects

Researchers relate crop-climate effects to the impact that climate variabilities have on the actual output (Bunn *et al*., 2015; Craparo *et al*., 2015; Buyinza, 2017). For coffee, this can be viewed in terms of the size and weight of the bean, bean defects (e.g., damages by insects, mouldy beans, broken beans etc.), and low yields. For instance, Pham *et al*. (2019) argued that the quality and yield of coffee declines significantly outside the ideal temperature range. Craparo (2017) also mentioned that because coffee is very susceptible to temperature fluctuations, yields are expected to continue declining under future climate projections. Regarding bean defects, Kath *et al*., (2021) investigated how variations in rainfall and temperature affect coffee bean characteristics and found out that reduced precipitation in the late cropping seasons was related to reduced bean sizes. These authors also added that insect-damaged and mouldy beans correlated with "changing climate

during the early and late growing seasons". Apparently, hot regimes reportedly increase coffee bean defects, alter their biochemical makeup, and negatively affect the quality of the beverage (Bote, 2016).

Other researchers have related the effect to the actual appearance of the coffee crop in the garden, for example, damage caused by increased pest infestations and diseases, drying of the coffee trees and leaves, flower and fruit abortion, and premature ripening of coffee cherries (Mugagga, 2017; Pham *et al*., 2019; Mbwambo *et al*., 2022). According to these scholars, variations in climate directly affect coffee production by altering flowering and bean filling, and indirectly by decreasing or increasing disease and pest incidences i.e., the coffee berry borer and coffee leaf rust. In some cases, erratic rainfall may result in coffee trees blossoming at different times of the year, thereby prolonging the period of harvesting (Jassogne *et al*., 2013). After flowering, poor bean filling and premature ripening of coffee beans may occur due to increased temperatures and sunshine (Mugagga, 2017). This may result in cherries of low weight, which is characteristic of low coffee quality and quantity. The available literature clearly shows that changing climate leads to crop-climate effects, such as fruit abortion, reduction in cherry growth, elevated occurrences of bean defects, and premature ripening, resulting in low yields and poor-quality coffee (Craparo *et al*., 2015).

Finally, some researchers have analyzed these effects in terms of the suitability of coffee-growing areas. As indicated by Bianco (2020)**,** the rising average temperatures and prolonged droughts are likely to render areas previously productive for coffee-growing unproductive in the space of 50 years. Notably, Asegid (2020) predicted a 16% reduction in areas productive for coffee cultivation by 2050. However, research has also shown that presently less productive areas under coffee cultivation could potentially experience an increase in productivity under changing climate (Bunn

et al., 2015; Magrach & Ghazoul, 2015). From this literature analysis, it is clear that climate effects are increasingly impacting the productivity and sustainability of the coffee subsector with changing climate. This justifies the need for sustainable climate-resilient measures which may guarantee the continued receipt of income from coffee by smallholder farmers. According to the available literature, farmers use various strategies in response to severe climate impacts. For instance, Mbwambo *et al*. (2022) reported that coffee farmers use shade trees, mulches, cut-off drains, terraces, and irrigation as mitigation strategies. Other studies have also mentioned that farmers use inorganic fertilizers, pesticides, herbicides, etc., in response to climate-related impacts (Mulinde *et al*., 2019; Atube *et al*., 2021). The use of these practices has resulted in a significant positive change in productivity, increased revenue from coffee at the farm level, and regulation of coffee pests and diseases (Harelimana *et al*., 2022). However, the available literature fails to explain the effect of using purchased inputs on the level of change in the incidences of crop-climate effects which the current study addresses.

2.4 Linkage of climate variabilities with use of farm inputs

Farm inputs can be defined as materials or resources essential for the cultivation of crops. The use of inputs such as fertilizers, agrochemicals, etc., in coffee production may be triggered by farmers' perceptions of climate variabilities. Apparently, the inputs play a significant role in enhancing crop growth during adverse climatic conditions. The proponents of purchased farm input use (Makate & Makate, 2022) indicate that they are significant in building climate-resilient small-scale agro-systems. Studies indicate that in response to climate events, farmers use purchased inputs, such as improved coffee varieties, crop diversification, fertilizers, and pesticides (Lybbert & Sumner, 2012**;** Mugagga, 2017; Mulinde *et al*., 2019). Fertilizers, for instance, are said to prevent total crop failure under incidences of rainfall stress (Makate & Makate, 2022). Likewise, since climate variability is associated with increased pest and disease incidences (Lin, 2011), farmers are likely

to increase agrochemical use, such as pesticides, to minimize yield losses due to pest attacks. Research has also linked soil fertility enhancement and carbon sinks to the use of biochar and charcoal soil amendments (Lehmann *et al*., 2006)**.** In other cases, coffee farmers "plant drought-resistant crops to adapt to moisture stress" (Patt *et al*., 2005)**.** Overall, farmers employ several farm inputs to cushion their crops against climate risks. However, farmers' responses to these climate risks in terms of input use are location specific and depend on a number of factors **(**Mendelsohn & Wang, 2017). Such factors may include socio-economic attributes, practicing farm management techniques, and the way farmers perceive variations in climate. For instance, Atube *et al*. (2021) established that farm income and sex of household head had a positive association with the use of pesticides and fertilizers, in northern Uganda. Similarly, Mendelsohn and Wang (2017) reported that a perceived enhancement in agricultural productivity due to climate variability may prompt farmers to increase input use intensity and may do otherwise when productivity decreases. In other words, farmers may be triggered to increase agricultural input use if changes in climate support increase in growth of the net revenue. Regarding perceptions, Makate and Makate (2022) in Malawi discovered that exposure to extreme shocks such as drought stimulated purchase of farm inputs (i.e., agrochemicals, fertilizers, labour, and seeds). For farm management practices, planting shade trees, for instance, may reduce coffee pests and disease incidence i.e., white stem borers and leaf rust (Ayalew, 2018), thereby decreasing the need for agrochemical use as a climate-resilient strategy. The current research builds on the already available literature by studying the influence of perceived changes in different climate variabilities, use of farm management practices, and socioeconomic factors on utilization of various purchased agricultural inputs.

CHAPTER THREE: METHODOLOGY

3.1 Description of the study area

The research was carried out in two neighboring districts within the cattle corridor of central Uganda namely: Luwero and Nakasongola (see Figure 3.1). The famous cattle corridor as an agro-ecological zone of stretches from the south-west through the central region to northeastern Uganda. In this zone, smallholder farmers practice mixed farming involving small-scale cultivation of crops along with rearing livestock. Among the common crops are cassava, sweet potatoes, maize, and beans. Some farmers that live in the outskirt areas of this cattle corridor also grow perennial crops including coffee and bananas. Overall, the farming community in this agroecological zone experiences a long dry spell, receives very low rainfall and tends to have extremely high temperatures (Stark, 2011). For Luwero, three quarters of the district is covered with savanna and soils are generally red sandy loam. Overall, Luwero district lies at an approximate altitude of between 1,082-1,372 meters high, and experiences high temperatures and rainfall of the modified equatorial climate type.

On the other hand, Nakasongola district lies on the central plateau at a height of between 1000 and 1400. It is characterized by high temperatures, reaching a maximum of between 30 ℃ - 32 ℃. Nakasongola also tends to experience long seasonal dry spells whose duration may go up to 5 months. Like other numerous dry areas across the globe, the cattle corridor of Uganda is prone to climate variability and overall changing climate which negatively affects agricultural production. This motivated the current research to examine how farmer perception of climate variabilities is related to decisions to use purchased farm inputs in the context of smallholder coffee farming.

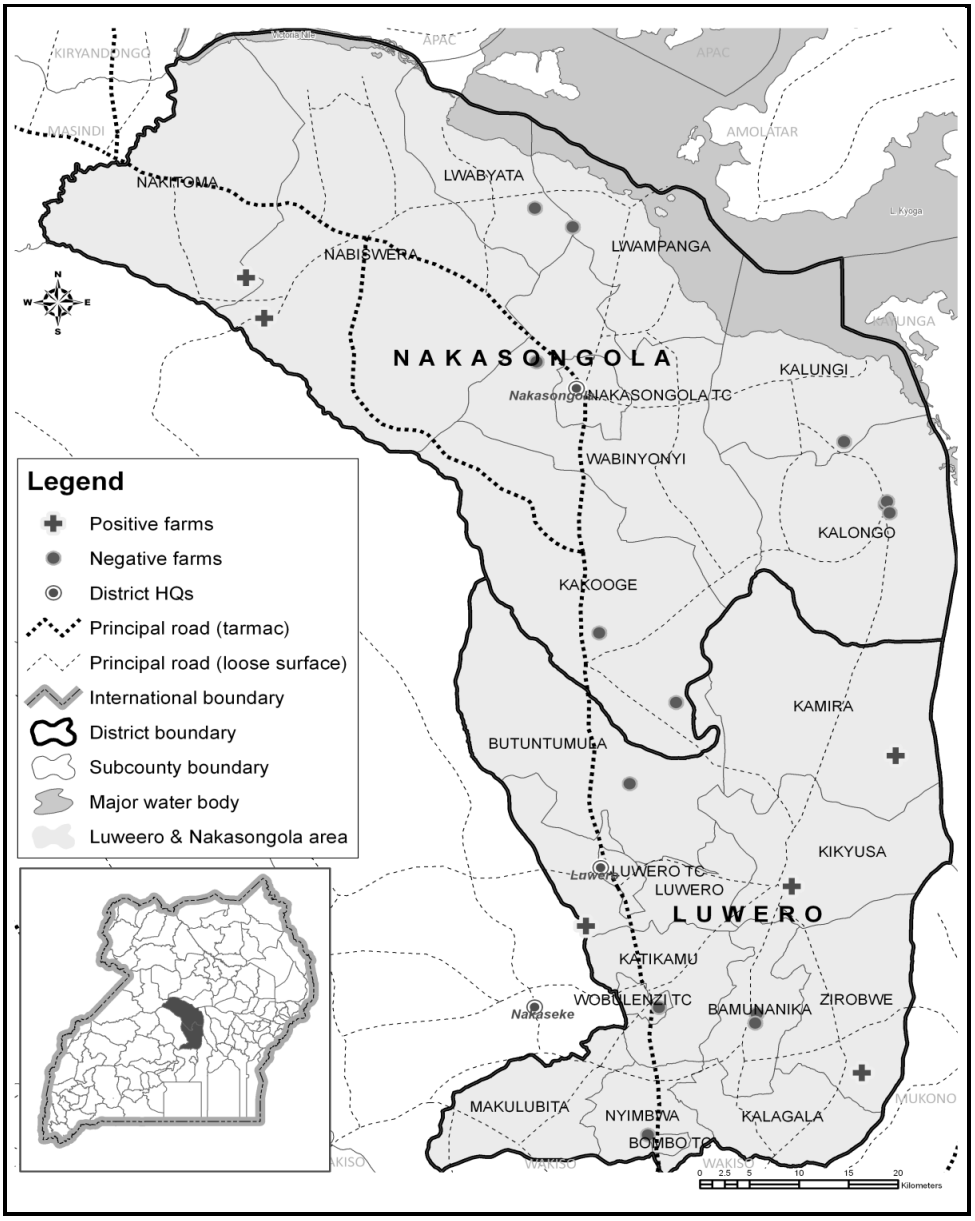


Figure 3.1: A map of Uganda showing study districts

Source: Adapted from Nizeyimana *et al*. (2013)

3.2 Study design

A cross-sectional survey, conducted between January 2023 and February 2023 was used to obtain quantitative data from coffee farming household heads. This research design was chosen because it is the most suitable for collection of a large dataset at a single point in time.

3.3 Sampling procedure

A multi-stage sampling procedure was employed to select districts, sub-counties, villages, and smallholder coffee growers. In the initial stage, two neighboring districts were considered based on their location in the cattle corridor of central Uganda and the level of coffee production. Secondly, one sub-county per district was selected namely, Kikyusa and Kakooge from Luwero and Nakasongola, respectively, based on the level of coffee production and vulnerability or proneness to adverse climatic conditions. Two parishes were selected from each sub-county, namely, Kyampogola and Kibengo from Kikyusa, and Kakooge and Kyeyindula from Kakooge. Six villages were then randomly selected from Kyampogola and five from Kibengo parish. Likewise, five villages were selected from Kakooge and four from Kyeyindula. Finally, a list of coffee growers was established from each village with the help of local leaders to constitute a sampling frame from which the respondents were randomly selected. Since Kikyusa sub-county in Luwero district has more coffee farmers, a larger proportion of the sample size was preferred from this sub-county. Thus, a final sample of 166 and 106 coffee farmers was obtained from Luwero and Nakasongola districts, respectively.

3.4 Sample size determination

According to Singh and Masuku (2014), we assume that half of farmers grow coffee which gives p=0.5 (maximum variability). Therefore, using Cochran's formula (Cochran, 1977) a representative sample size of the study was obtained as in equation (1).

$$n = \frac{Z^2 Pq}{e2} \qquad \text{.....} \quad (1)$$

Where n=sample size

z^2= confidence level at 95%

p= is the estimated proportion of coffee farmers' population

q= 1-p

e is the desired level of precision at 5%

$$n = \frac{(1.96)^2(0.5)(1-0.5)}{(0.05)^2} = 384.16 = 384$$

Response rate for the study was 70% (272). According to Baruch (1999), a response rate of 60 +/- 20 is acceptable to obtain valid results. Moreover, Mugenda and Mugenda (2013) stated that "when the study population is less than 10, 000, a sample size of between 10 and 30% is a good representation of the target population".

3.5 Data collection

Data was collected using a semi-structured questionnaire administered among coffee farmers through face-to-face interviews**.** The questionnaire was researcher-administered to ensure that research questions are well understood by the respondents. Also, this helped the research to gain deeper insights, especially on the perceptions of climate variability over the past 6 years. To test for suitability and reliability, a pre-test was done on 40 households within the area of study, to identify necessary improvements to the survey tool. The questionnaire involved three types of questions. First, the open-ended questions which captured on metric data such as quantity of season coffee harvests. Second, multiple choice questions which gave respondents options from which to select the answer. Third, rating scale questions enabled respondents to choose a number that best reflects their answer. The questions were administered to the household head since he/she was answerable for coffee growing in the household.

The questionnaire comprised of the following parts. The first part of the questionnaire captured data on the household socio-economic characteristics. These included: household size (number of family members), education level (years in formal school), marital status (single=1, married=2,

separated=3 & widow/widower=4), sex (Male=1& Female=0), farming experience (years), coffee farm size (acres), access to credit and extension services. The second part captured data on annual coffee production broken down in two seasons to enhance the accuracy of responses. Key data collected included seasonal dry coffee cherries harvest (kg), land allocated to coffee production (acres), farm inputs use in coffee production (frequency of use of foliar and granular fertilizers, manure, pesticides, etc.) and labour for different coffee related activities in man-hours. The third part of the questionnaire constituted farmer perceptions on climate variability risks in coffee production. The variables captured included low, short and high rainfall amounts, prolonged and short dry spells, strong winds, etc. In addition, data was collected on farmer perceptions on crop-climate effects. The variables included perceptions on experiencing drying of coffee leaves, less flowering, small size coffee beans, and low weight of dry coffee cherries. All these farmer perceptions were rated on 1-10 points scale (where 1=very low impact & 10 = very high impact). Lastly, data was also collected on land conservation and management practices, the variables included practice of mulching, intercropping, digging water harvesting trenches, planting shade trees, and others.

3.6 Data analysis

Data collected was entered by SPSS and analyzed using STATA 14.0 version. Descriptive statistics including proportions, means, frequencies, and standard deviations were used to characterize farmers based on socio-economic factors and perceptions on climate variabilities, crop-climate effects and use of inputs. T-tests were also conducted to check for significant differences between parameters. Regression analysis using probit, propensity score matching and zero inflated poisson models was conducted to answer study objectives (2& 3).

3.6.1 Farmer perceptions on temporal changes in climate variabilities and crop-climate effects

Prior to analyzing farmer perceptions, coffee growers in the cattle corridor were profiled based on their socio-economic characteristics using descriptive statistics. For purposes of comparing coffee growers in the two study districts i.e., Luwero and Nakasongola, an independent t-test was applied on continuous variables. The variables included age, farming experience, education level, land and others. In addition, a chi-square test was employed to examine the relationship between categorical independent variables i.e., sex, marital status, access to extension and credit services and the district of origin of the coffee growers.

On changing climate events, the paired t-test was used to compare farmer perceptions between two time-periods of 3 years each. The reason for the three-year time periods was to facilitate respondents' ability to recall information more easily. The time periods compared were as follows: Time period 1 ranged between 2017-2019 while and Time period 2 ranged between 2020- 2022. The climatic variables on which farmers' perceived changes were sought included rainfall duration during the rainy season, rainfall amounts during the rainy season, temperature levels during dry season, hot days during rainy season, prolonged dry spell, experiencing short dry spells, strong winds, intensity and frequency of hailstorms.

Similarly, paired t-tests were also applied to compare farmer perceptions on crop-climate effects between the two time periods explained above. The variables on crop-climate effects included drying of coffee crop leaves, coffee flower abortion, experiencing reduced coffee flowering, experiencing low coffee harvests, low-weight dry coffee cherries, unfilled coffee cherries, small size coffee beans, and pest incidence.

3.6.2 Determining the relationship between use of purchased farm inputs and perceived crop-climate effects

This study employed propensity score matching (PSM) technique to compare the users and non-users of purchased inputs in terms of their perception of crop-climate effects. PSM was used because it reduces selection bias since there was a lack of randomization among the users of purchased inputs in the study area. The first step in estimating the differences in perceptions of crop-climate effects between the two categories of coffee farmers was to estimate propensity scores. In order to obtain these propensity scores, a binary probit model (e.g., users 1 and non-users 0) was used, where the dependent variable is "using purchased inputs" and the independent variables are the determinants of farmers' decisions to use these inputs (Rosenbaum & Rubin, 1983). As such, the first stage probit regression model is specified as shown in equation (2).

$$Y_{i(0,1)} = \beta_o + \beta_i X_i + \beta_i Wi + \varepsilon_i \quad \text{----------(2)}$$

Where y=1 if the respondent is using purchased inputs

y=0 if respondent is not using purchased inputs

β_i represents the slope

X_i represents vectors of socio-economic factors namely, Age, extension services on climate variability, education, access to credit and land for coffee production, access to hired labour, type of coffee grown, household size, and sex.

Wi represents vectors of climate variabilities namely, perceived change in prolonged dry spell, perceived changes in seasonal dry spell, low rainfall amounts, high rainfall amounts and perceived changes in frequent hailstorms.

ε_i represents the error term

After estimation of the propensity scores, different matching approaches were tested to match each treatment unit (users) and the comparison unit (non-users). They included; nearest-neighbor (NN) matching, caliper and radius matching, stratification and interval matching, and kernel matching and local linear matching (LLM) (Khandker *et al*., 2010). For this study, the nearest-neighbor (NN) matching was adopted based on the data. The average treatment effect for the treated (ATT) was then estimated using PSM, as specified in equation (3) below.

$$^{\tau}ATT = E(\tau|D = 1) = E[\,Y(1)|D = 1] - E[Y(0)|D = 1\,] \quad \ldots\ldots\ldots\

3.6.3 Determining the influence of perceived climate variability on use of purchased farm inputs

This study postulated that the annual level of use of purchased farm inputs is a function of farmer perceptions on perceived change in climate variabilities. These climate variabilities included perceptions on seasonal low rainfall, perceptions on seasonal high rainfall, perceived change in seasonal dry spell, and perceived change in hot days during rainy season. In addition, farm practices that tend to impact the micro-climate for the coffee crop were also added. These included maintenance of shade trees, water harvesting practices, intercropping with cover crops and mulching. Further, socio-economic factors as control variables were added to the empirical model and these included: total labour, access to credit, sex, education level, age, coffee output, extension on climate variability and extension on crop husbandry. The dependent variable i.e., level of use of purchased inputs was captured as count data. One of the efficient models for analyzing count data is the standard Poisson regression model (PRM). However, the Zero inflated Poisson model (ZIP) was preferred to PRM for analysis because of presence of over dispersion in the Poisson regression model and to account for frequent zero-observations in the data (Mouatassim & Ezzahid, 2012). Therefore, the empirical model used in this study is as follows.

$$Y_i = \beta_o + \beta_i X_1 + \beta_i X_2 + \beta_i X_3 + \varepsilon_i \text{----------(4)}$$

Where; Y_i represents the number of counts on annual use of purchased farm inputs. The purchased farm inputs considered in the study included: foliar fertilizers, soil fertilizers, manure, pesticides and herbicides. Each of these inputs was regressed independently of the others for the same independent variables.

β_i represents the slope

X_1 is a vector containing climate variability events

X_2 is a vector containing socio-economic factors

X_3 is a vector containing land conservation practices

ε_i represents the error term

Table 3. 2:Apriori Signs for variables used in Zero inflated poisson regression model

Variables	Description of variable	Expected sign
Frequency of use of inputs (**dependent**)	Number of times of input application	+/-
Climate events		
Perceptions on seasonal low rainfall	Change in occurrence between two time periods	+/-
Perceptions on prolonged seasonal dry spell	Change in occurrence between two time periods	+/-
Perceptions on seasonal high rainfall	Change in occurrence between two time periods	+/-
Perceptions on hot days during rainy season	Change in occurrence between two time periods	+/-
Land conservation and management factors		
Maintenance of shade trees	Dummy for shade trees in coffee garden (1=Yes, 0=No)	+/-
Intercropping using cover crops	Dummy for cover crops in coffee garden (1=Yes, 0=No)	+/-
Mulching	Dummy for mulch in coffee garden (1=Yes, 0=No)	+/-
Digging water harvesting trenches	Dummy for water harvesting in coffee garden (1=Yes, 0=No)	+/-
Socio-economic factors		
Sex	Dummy for sex of the respondent (1=Male, 0=Female)	+/-
Education level	Years of formal education by household head	+/-
Age	Number of years of household head	+/-
Coffee output	Quantity of annual coffee output (kgs)	+/-
Labour	Total labour (hours)	
Access to credit	Dummy for access to credit services (1=Yes, 0=No)	+/-
Extension on climate variability	Dummy for access to climate extension (1=Yes, 0=No)	+/-
Extension on crop husbandry	Dummy for access of crop husbandry extension (1=Yes, 0=No)	+/-

3.7 Data quality control

3.7.1 Validity and reliability

The questionnaire was formulated in such a way that it answered all aspects of the research problem with maximum guidance from supervisors. It was then pre-tested on 40 households in a different parish of Kikyusa sub-county where the study was not conducted. Necessary

improvements in the questionnaire were made based on the pre-test experiences and results. This was to improve the reliability of the content. Well-trained research assistants were hired to collect field data from the respondents.

3.8 Ethical consideration

This study adhered to all legal and ethical requirements applicable to research in the Republic of Uganda. Prior to commencing this study, ethical clearance was obtained from the Gulu University Research Ethics Committee (GUREC). A letter of introduction was obtained from the Faculty of Agriculture and Environment to give confidence to the target respondents. Additionally, a letter of approval from the office of the Chief Administrative Officer in each district was obtained to conduct the research. During data collection, respondents were requested to sign the consent form upon accepting to take part in the study. Although responses were collected in English, the questionnaires were administered in the local dialect. The researcher ensured that human rights were fully respected. Standard Operating Procedures (SOPs) were followed in accordance with the guidelines provided by the Ministry of Health to mitigate the transmission of both Covid-19 and Ebola. Careful supervision of the research assistants was done throughout the data collection exercise to ensure strict compliance with research ethics. The privacy of respondents and confidentiality of their identities were strictly ensured. To avoid all forms of plagiarism, a thorough referencing procedure was followed. All resources intended for the study were solely used for its purpose, and the researchers plan to publish the study findings for the benefit of all stakeholders.

3.9 Limitations of the study

The study relied on self-reported data of farmers' use of farm inputs and their experience of climate variabilities in a six-year period. Therefore, this could be associated with recall bias and other related errors. This limitation was minimized by using a carefully designed and validated

questionnaire that enabled the collection of accurate and complete information. Also, since the questionnaire was researcher-administered, it facilitated recalling among respondents through rapport and probing questions. However, despite the observed limitation, this thesis adds significant insights to the literature on the relationship between perceived climate variabilities and effects, and the use of purchased inputs as a climate-resilient strategy employed by farmers.

CHAPTER FOUR: RESULTS

4.1 Socio-economic characteristics of coffee farmers in Luwero and Nakasongola district

The summary statistics for the socio-economic characteristics of coffee farmers are presented in Table 4.1. The average age of the household head is 53 years with farmers in Nakasongola being significantly ($p < 0.01$) older by at least 5 years. The findings indicate that the average household size is 7 individuals, with that of Luwero being significantly ($p < 0.01$) larger. Regarding education level, results reveal an average of 6 years of formal education with significant differences ($p < 0.01$) across the two districts. The results also show that the average farming experience is 24 years, with a significant difference ($p < 0.01$) observed across the districts. Finally, the average land under coffee production is 2.73 acres with no significant difference ($p > 0.05$) across the two districts.

The chi-square results show that male-headed households are significantly higher ($p > 0.05$) than their female counterparts across the two districts. Also, for access to credit services, a significant difference ($p<0.01$) is observed across the two districts. However, for both socioeconomic variables, a significantly higher proportion is observed in Luwero district. Lastly, the chi-square test results indicate that there is no significant difference ($p > 0.05$) in terms of marital status and access to extension services.

Table 4. 1: Socio-economic characteristics of coffee farmers in Luwero and Nakasongola

Variable	Mean (Standard dev.)			Mean Difference
	Overall N=272	**Luweero N=166**	**Nakasongola N=106**	
Age (years)	52.89 (13.88)	50.74 (12.51)	56.26 (15.25)	5.52 ***
Household size	7.32 (3.98)	7.84 (4.33)	6.5 (3.23)	-1.34***
Education (years)	5.56 (3.63)	5.10 (3.41)	6.28 (3.85)	1.18***
Farming experience (years)	23.89 (11.55)	22.19 (10.67)	26.56 (12.39)	4.36 ***
Land (acres)	2.73 (2.48)	2.85 (2.61)	2.55 (2.25)	-0.29
	Frequency (Percentage)			$\chi 2$
Sex				
Male	193 (70.96)	126 (75.90)	67 (63.21)	5.10**
Female	79 (29.04)	40 (24.10)	39 (36.79)	
Marital status				
Married	197 (72.43)	127 (76.51)	70 (66.04)	3.55
Un married	75 (27.57)	39 (23.49)	36 (33.96)	
Access to Extension services				
Accessed	144 (52.94)	85 (51.20)	59 (55.66)	0.52
Not accessed	128 (47.06)	81 (48.80)	47 (44.34)	
Access to Credit Services				
Accessed	83 (30.51)	61 (36.75)	22 (20.75)	7.80 ***
Not accessed	189 (69.49)	105 (63.25)	84 (79.25)	

Source: Field survey, (2023); $\chi 2$ denotes Pearson's chi-square coefficient; **notes** ***and ** indicates significance level at 1% and 5% respectively.

4.2 Farmer perceptions on temporal changes in climate variabilities and crop-climate effects

4.2.1 Perceived climate variabilities among coffee farmers

According to the results, farmers perceive a general increase in all climate events in the recent years except for high rainfall amounts and frequent occurrence of hailstorms (Table 4.2). Farmer perceptions show a significant increase ($p<0.01$) in short rainfall durations, low rainfall amounts and high temperatures from the period of 2017-2019 to 2020-2022. In addition, there is also a significant increase ($p<0.01$) in the frequency of hot days during rainy season, seasonal dry spells, short dry spells and strong winds. The other notable result is the significant decrease ($p<0.01$) in

incidences of high rainfall amounts. No significant relationship (p>0.1) is observed for other variables namely, heavy hailstorms and frequent hailstorm incidences.

Table 4. 2: Perceptions on temporal changes in climate variabilities among coffee farmers

Perceived climate Variability	N=272 Mean rating (SD)		Mean Difference
	Time Period 2 (2020-2022)	**Time Period 1 (2017-2019)**	
Short rainfall duration during the rainy season	3.02 (1.48)	1.28 (1.11)	1.74 ***
Low rainfall amounts during the rainy season	3.49 (1.58)	1.96 (1.44)	1.54 ***
High rainfall amounts during rainy season	0 .56 (0.71)	1.39 (1.12)	-0.83***
High temperatures during dry season	2.86 (1.76)	1.47 (1.39)	1.39 ***
Hot days during rainy season	1.18 (1.43)	0.71 (1.04)	0.47 ***
Seasonal dry spell	1.89 (0.96)	1.12 (0.98)	0.78 ***
Short dry spells	4.75 (2.56)	4.09 (2.92)	0.66 ***
Strong winds	1.19 (1.04)	0.65 (0.97)	0.54 ***
Occurrence of heavy hailstorms	0 .52 (0.75)	0.44 (0.73)	0.08
Frequent hailstorms	1.27 (1.36)	1.41 (1.46)	-0.14

Note: *** indicates significance level at 1%.

4.2.2 Perceptions on temporal changes in coffee crop-climate effects

Results presented in Table 4.3 reveal significant differences in farmer perceptions on crop-climate effects between two-time periods. Farmer perceptions show a significant increase (p<0.01) in drying of coffee leaves, level of flowering, dropping of flowers and worsening coffee yields from the period of 2017-2019 to 2020-2022. Furthermore, farmer perceptions also show positive and significant effects (p<0.01) with respect to incidences of low-weight coffee cherries, coffee cherries with unfilled beans, small size coffee beans, crop pests and drying of coffee trees. This suggests that climate variability is worsening the negative impacts on coffee production.

Table 4. 3: Perceptions on temporal changes in coffee crop-climate effects

Perceived crop-climate effects	N=272	Mean rating (SD)	Mean Difference
	Time Period 2 (2020-2022)	**Time Period 1 (2017-2019)**	
Drying of coffee crop leaves	1.40 (0.96)	0.77 (0.89)	0.63***
Dropping of coffee flowers	1.93 (1.65)	0.84 (1.05)	1.09 ***
Level of coffee flowering	2.43 (1.54)	0.92 (1.02)	1.51 ***
Low coffee yields	2.92 (1.49)	1.04 (1.03)	1.88 ***
Weight of coffee cherries	2.42 (1.58)	0.74 (0.95)	1.69 ***
Coffee cherries with unfilled beans	2.34 (1.62)	0.72 (0.96)	1.62 ***
Size of coffee beans	1.71 (1.66)	0.59 (0.96)	1.11 ***
Incidence of crop pests	3.47 (2.11)	1.64 (1.67)	1.84 ***
Drying of coffee trees	2.04 (1.39)	0.96 (1.11)	1.09 ***

Note: *** indicate significance level at 1%.

4.2.3 Change in application of purchased farm inputs in the two-study time periods

Table 4.4 shows results of the paired t-test which was used to compare the frequency of application of farm inputs in two-time periods. Farmers perceive a statistically significant ($p<0.01$) increase in the frequency of application of all farm inputs investigated. However, farmers perceive a relatively higher increase in the use of pesticides compared to other farm inputs. Regarding fertilizer application, farmers' perceptions indicate a higher increase in the use of soil fertilizers compared to foliar fertilizers.

Table 4. 4: Change in application of purchased farm inputs in the two-study time periods

Farm inputs	N=272	Mean rating (SD)	Mean Difference
	Time Period 2 (2020-2022)	**Time Period 1 (2017-2019)**	
Foliar fertilizers	2.827 (3.194)	1.739 (2.407)	1.088 ***
Soil fertilizers	3.287 (2.387)	1.816 (2.288)	1.471***
Manure	4.389 (3.733)	2.904 (3.128)	1.485 ***
Pesticides	6.938 (6.896)	4.169 (4.983)	2.768 ***
Herbicides	5.051 (3.530)	3.199 (3.095)	1.853 ***

Note: *** indicates $p < 0.01$.

4.3 Relationship between use of purchased farm inputs and crop-climate effects

4.3.1 Factors driving farmer decisions for use of purchased farm inputs

Probit model results on drivers of farmer decisions to use purchased farm inputs are presented in Table 4.5. These results show that the likelihood ratio statistic ($p<0.01$) is significant and thus, suggests robustness of the empirical model. Results also show a positive and significant association between the decision to use purchased farm inputs and access to labour ($p<0.01$), land size under coffee ($p<0.01$), extension services on climate variability ($p<0.05$), access to credit services ($p<0.1$). On the other hand, a negative and significant relationship is detected for age ($p<0.05$), household size ($p<0.05$), growing local coffee (0.05) and perceived change in frequency of hailstorms (0.05). Lastly, the results indicate no statistical significance ($p>0.1$) in terms of level of education, sex, and perceived changes in seasonal dry spell, rainfall and high rainfall amounts. In terms of marginal effects, the results imply that access to labour is associated with a probability of 23% more likelihood for the farmer to use purchased inputs. Similarly, access to extension services on climate variability and credit is associated with the probability of 13% and 11% more likelihood, respectively, to use purchased farm inputs. For land size, a one percent increase in acreage under coffee increases the probability for use of purchased inputs by 16%. For negatively signed coefficients, results mean that a one percent increase in age and house size is associated with a probability of 30% and 12% less likelihood, respectively, to use purchased farm inputs. Likewise, perceived change in frequency of hailstorms has a probability of 14% less chance to use purchased inputs. On growing coffee, reliance on local variety is associated with a probability of 18% less chance to use purchased inputs.

Table 4. 5: Determinants of farmer decisions to use purchased farm inputs

Variables	Coefficient (SE)	Marginal effects (SE)
Age	-0.89 (0.35) **	-0.30 (0.12)
Education level	0.02 (0.03)	0.01 (0.01)
Total land for coffee production	0.48 (0.13) ***	0.16 (0.04)
Household size	-0.36 (0.15) **	-0.12 (0.05)
Sex	0.03 (0.21)	0.01 (0.07)
Access to credit services	0.35 (0.20) *	0.11 (0.06)
Extension services on climate variability	0.39 (0.19) **	0.13 (0.10)
Access to hired Labour	0.64 (0.19) ***	0.23 (0.07)
Local coffee variety	-0.69 (0.44) **	-0.19 (0.09)
Perceived change in seasonal dry spell	-0.001 (0.14)	-0.0002 (0.05)
Perceived change low rainfall occurrences	0.01 (0.10)	0.004 (0.03)
Perceived change in high rainfall amounts	0.13 (0.18)	0.05 (0.06)
Perceived change in frequency of hailstorms	-0.42 (0.17) **	-0.14 (0.06)
Cons	4.26 (1.58)	
Loglikelihood	-136.21	
Number of observations	272	
Pseudo R^2	0.21	
Wald chi2 (13)	55.87	
Prob > chi2	0.0000	
Estat classification results		
Sensitivity	89.56%	
Specificity	54.44%	
Correctly classified	77.94%	

Note: Source: Survey, 2023, the asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%.

4.3.2 Differences in perceptions of crop-climate effects between users and non-users of purchased inputs

PSM results comparing incidences of perceived crop-climate effects between users and non-users of purchased farm inputs are presented in Table 4.6. These results reveal that the average treatment effect (ATET) on reduced coffee yields is negative and significant ($p<0.05$). This suggests that

non-users of purchased farm inputs experience lower coffee yields relative to the users. Related findings are detected with respect to incidence of crop pests ($p<0.05$), weight of coffee beans ($p<0.1$), seasonal coffee flowering ($P<0.05$) and drying of coffee leaves ($P<0.1$) implying that non-users of purchased farm inputs experience worse crop-climate effects than counterpart users. However, the average treatment effects for the variables of coffee cherries with unfilled beans, size of coffee beans, dropping coffee flowers and drying coffee trees are not statistically significant ($P>0.1$).

Table 4. 6: PSM results on differences in perceptions of crop-climate effects between users and non-users of purchased farm inputs

Perceived coffee crop-climate effects	ATET	Rob.SE
Coffee yields	-0.36 **	0.18
Incidence of coffee crop pests	-0.39 **	0.17
Weight of coffee beans	-0.33 *	0.18
Coffee cherries with unfilled beans	-0.27	0.23
Size of coffee beans	0.17	0.13
Dropping of coffee flowers	-0.27	0.18
Seasonal coffee flowering	-0.32 **	0.16
Drying of coffee trees	-0.29	0.57
Drying of coffee leaves	-0.26*	0.14

Note: Source: Survey, 2023, the asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%.

4.4 Influence of perceived climate variabilities on use of purchased farm inputs

Results of Zero-inflated Poisson regression concerning influence of perceived change in climate variabilities on the utilization of farm inputs are presented in Table 4.7. These results show that perceived change in seasonal dry spell is positively and significantly related to the use of foliar fertilizers ($p<0.05$), soil fertilizers ($p<0.01$), manure ($p<0.05$) and pesticides ($p<0.01$). It is only

the use of herbicides that was not significantly related to change in seasonal dry spell. For perceived low rainfall amounts within a rainy season, negative and significant relationships are detected for use of foliar fertilizers ($p<0.01$) and herbicide ($p<0.1$) while for other farm inputs, no significant effects were detected. Similarly, Perceptions on high seasonal rainfall are negatively and significantly related to foliar fertilizers ($p<0.1$), manure ($p<0.1$) and herbicides ($p<0.1$). However, the use of soil fertilizers and pesticides shows no significant relationship. Lastly, no significant relationships were found between perceived change in hot days during the rainy season and the use of all the farm inputs investigated.

For control variables, extension information on crop husbandry is positively and significantly related to the use of foliar fertilizers ($p<0.01$), manure ($p<0.01$) and herbicides ($p< 0.01$). It is only pesticides ($p<0.05$) that shows a negative and significant relationship. Extension information on climate variability only positively and significantly influenced pesticide use ($p<0.01$), while herbicide use ($p<0.01$) was found to be negative and significant. However, no significant relationship was detected for soil fertilizer, foliar fertilizer and manure. Annual coffee output positively and significantly influences the use of soil fertilizers ($p<0.1$) and foliar fertilizers ($p<0.05$). Similarly, a negative and significant relationship is detected for manure ($p< 0.01$) and herbicide use ($p<0.05$). No significant relationship was observed for pesticide use. For credit access, only pesticide use ($p< 0.01$) was found to be significant and positive. Though not statistically significant, soil fertilizers ($p>0.1$) and foliar fertilizers ($p>0.1$) present negative relationships, while a positive relationship was detected for manure ($p>0.1$) and herbicides ($p>0.1$). Regarding sex of household head, male coffee growers are significantly less likely to use manure and pesticides at $p<0.05$ and $p<0.01$, respectively. No significant relationship was observed for other farm inputs. Further, results indicate that farm labour is significantly and positively related to the use of manure and herbicides at $P<0.01$. Surprisingly, a negative relationship was detected

for foliar fertilizers, soil fertilizers and pesticides, though not statistically significant. Lastly, education level and age of the household head were negatively but significantly related to the use of foliar fertilizers, at $p<0.01$ and $p<0.1$, respectively.

Relatedly, farm management practices posted interesting findings. Findings reveal that mulching is positively and significantly associated with application of foliar fertilizers ($p<0.05$), soil fertilizers ($p<0.01$) and manure ($p<0.01$). However, mulching is negatively and significantly related to application of agro-chemicals i.e., pesticides ($p<0.01$) and herbicides ($p<0.05$). For the farm practice of intercropping using cover crops, results reveal negative and significant association with farmer application of foliar fertilizers ($p<0.05$), soil fertilizers ($p<0.1$), pesticides ($p<0.1$), while no significant relationship was observed for manure and herbicide use. Results for other farm practices were as follows: maintenance of shade trees in coffee crop is positively and significantly related to the use of foliar fertilizers ($p<0.05$), pesticides ($p<0.05$), and herbicides ($p<0.1$), although no significant relationship was detected for manure and soil fertilizers. Finally, for water harvesting trenches, it is only the use of pesticides ($p<0.1$) which is significant.

A follow-up with post-estimation analysis, incidence rate ratios (IRR) depict that perceived change in seasonal dry spell increases the odds for use of foliar fertilizers by 13.1% (Table 4.3). This same climate variability also increases the odds for use of soil fertilizers, manure and pesticides by 15.8%, 9.9%, and 18.8% respectively. In the case of perceptions on low seasonal rainfall, the odds for reduced use of foliar fertilizers are increasing by 86.5%. Also, the odds for reduced use of herbicides increase by 94.4% for this climate variability. For perceptions on high rainfall amounts, the odds for reduced use of foliar fertilizers, manure and herbicides increase by 87.9%, 89.4%, and 90.4%, respectively.

With respect to farm practices (dummies), the IRR values reveal that farmers maintaining shade trees are more likely to use foliar fertilizers, with odds increasing by 27.7% for each unit increase in shade trees. The odds are increasing by 18.9% and 15.7% for the use of pesticides and herbicides for each unit increase in shade trees. Interestingly, for intercropping coffee with cover crops, the odds are increasing by 81.1, 86.9% and 79.4% for reduced use of foliar fertilizers, soil fertilizers, and pesticides. This suggests that there is less chance for farmers applying cover crops to use these inputs. Further, mulching coffee gardens increases the odds for use of foliar fertilizers, soil fertilizers, manure and pesticides by 22.9%, 26.5%, 20.6% and 22.8%, respectively. Conversely, the odds for reduced use of herbicides are increasing by 88% for the same variable. Likewise, digging water harvesting trenches in the coffee garden increases the odds for reduced use of pesticides by 89.3%.

Regarding socio-economic factors and extension, the IRR findings indicate that a unit increase in coffee output increases the odds by 14.7% and 9.6%, respectively, for use of foliar and soil fertilizers. For manure and herbicide use, the odds are increasing by 83.6% and 92.6%, respectively, for reduced use of these inputs. The IRR results also reveal that male farmers are less likely to use manure and pesticides by 86% and 77.5%, respectively. In the case of labour, the odds for use of manure increase by 25.4% and 13.7% for herbicides. Surprisingly, access to credit services increases only the odds for the use of pesticides by 17%. Further, education level and age of household head reduce the odds for use of foliar fertilizers by 95.1% and 74.9%, respectively. Lastly, access to extension services on crop husbandry by farmers is more likely to increase the use of foliar fertilizers, manure and herbicides by 43.1%, 30.3% and 20%, respectively. However, the increase in odds by 80.5% is also noted for reduced pesticides use. For access to extension services on climate variability, the odds are increasing for pesticides use by 15.9% and 84.3% for decreased use of herbicides.

Table 4. 7: The influence of perceived climate variabilities on use of purchased farm inputs

Variables	Frequency of application of purchased farm inputs in the recent years (2020-2022)									
	Foliar Fertilizers		**Soil Fertilizers**		**Manure**		**Pesticides**		**Herbicides**	
	Coeff (SE)	**IRR (SE)**	**Coeff (SE)**	**IRR (SE)**	**Coeff (SE)**	**IRR (SE)**	**Coeff (SE)**	**IRR (SE)**	**Coeff (SE)**	**IRR (SE)**
Change in seasonal Low rainfall	-0.15 (0.04) ***	0.865 (0.04)	-0.001 (0.04)	0.999 (0.04)	0.002 (0.03)	1.002 (0.03)	-0.003 (0.03)	0.997 (0.03)	-0.05 (0.03) *	0.949 (0.03)
Change in seasonal dry spell	0.12 (0.06) **	1.131 (.07)	0.15 (0.05) ***	1.158 (0.06)	0.09 (0.05) **	1.099 (0.05)	0.17 (0.04) ***	1.188 (0.05)	0.05 (0.04)	1.054 (0.05)
Change in seasonal high rainfall	-0.13 (0.07) *	0.879 (0.06)	0.01 (0.07)	1.006 (0.07)	-0.11 (0.06) *	0.894 (0.01)	0.05 (0.05)	1.051 (0.05)	-0.10 (0.06) *	0.904 (0.05)
Change in Hot days during rainy season	0.05 (0.04)	1.052 (0.05)	-0.04 (0.05)	0.963 (0.05)	-0.04 (0.04)	0.961 (0.04)	-0.04 (0.04)	0.962 (0.03)	-0.04 (0.04)	0.961 (0.04)
Labour (log)	-0.07 (0.05)	0.936 (0.05)	-0.03 (0.05)	0.976 (0.05)	0.23 (0.04) ***	1.254 (0.05)	-0.04 (0.03)	0.958 (0.03)	0.13(0.04) ***	1.137 (0.04)
Access to credit	-0.05 (0.08)	0.951 (0.08)	-0.07 (0.08)	0.929 (0.07)	0.10 (0.07)	1.106 (0.07)	0.16 (0.05) ***	1.170 (0.06)	0.02 (0.06)	1.025 (0.06)
Sex (male=1)	-0.07 (0.09)	0.934 (0.09)	0.05 (0.09)	1.051 (0.09)	-0.15 (0.07) **	0.860 (0.06)	-0.25 (0.05) ***	0.775 (0.04)	0.10 (0.070)	1.109 (0.08)
Education level	-0.05 (0.01) ***	0.951(0.01)	0.01 (0.01)	1.005 (0.01)	-0.01 (0.01)	0.995 (0.01)	0.01 (0.01)	1.005 (0.01)	-0.001 (0.01)	0.999 (0.01)
Age (log)	-0.29 (0.16) *	0.749 (0.12)	-0.164 (0.138)	0.849 (0.12)	-0.05 (0.13)	0.949 (0.12)	0.04 (0.09)	1.041 (0.09)	-0.15 (0.11)	0.864 (0.09)
Coffee output (log)	0.14 (0.06) **	1.147 (0.06)	0.09 (0.05) *	1.096 (0.06)	-0.18 (0.04) ***	0.836 (0.02)	0.06 (0.03)	1.056 (0.04)	-0.08 (0.04) **	0.926 (0.04)
Extension on climate variability	0.07 (0.08)	1.075 (0.09)	0.02 (0.08)	1.024 (0.08)	0.05 (0.07)	1.055 (0.07)	0.15 (0.05) ***	1.159 (0.06)	-0.17(0.06) ***	0.843 (0.05)
Extension on crop husbandry	0.36 (0.12) ***	1.431(0.17)	0.13 (0.09)	1.134 (0.11)	0.26 (0.07) ***	1.303 (0.09)	-0.22 (0.09) **	0.805 (0.07)	0.18(0.070) ***	1.200 (0.08)
Shade trees (yes=1)	0.25 (0.12) **	1.277 (0.15)	0.15 (0.10)	1.163 (0.12)	-0.04 (0.09)	0.957 (0.08)	0.17 (0.07) **	1.189 (0.09)	0.15 (0.09) *	1.157 (0.09)
Intercropping with cover crops	-0.21 (0.09) **	0.811 (0.08)	-0.14 (0.08) *	0.869 (0.07)	0.08 (0.07)	1.081 (0.07)	-0.23 (0.06) ***	0.794 (0.05)	-0.01 (0.06)	0.986 (0.06)
Mulching	0.21 (0.08) **	1.229 (0.10)	0.24 (0.08) ***	1.265 (0.09)	0.19 (0.06) ***	1.206 (0.08)	0.21 (0.05) ***	1.228 (0.06)	-0.13 (0.06) **	0.880 (0.05)
Digging water harvesting trenches	0.05 (0.09)	1.047 (0.09)	-0.03 (0.09)	0.969 (0.09)	0.07 (0.08)	1.074 (0.09)	-0.11 (0.07) *	0.893 (0.06)	-0.01 (0.07)	0.989 (0.07)
Constant	2.29 (0.70) ***	9.907 (6.97)	1.14 (0.62) *	3.118 (1.92)	1.06 (0.56) *	2.888 (1.61)	1.75 (0.42) ***	5.756 (2.42)	1.69 (0.50) ***	5.392 (2.71)
Inflate (constant)	-0.33 (0.13) ***	-0.328 (0.13)	-3.01(0.40) ***	-3.007 (0.43)	-3.95 (0.54) ***	-3.953 (0.54)	-1.51 (0.16) ***	-1.507 (0.16)	-3.72 (0.48) ***	-3.721 (0.48)
Number of obs.	272	272	272	272	272	272	272	272	272	272
Non-zero obs	155	155	249	249	264	264	222	222	263	263
Zero obs	117	117	23	23	8	8	50	50	9	9
Inflation model	Logit	Logit	Logit	Logit	Logit	Logit	Logit	Logit	Logit	Logit
Log likelihood	-525.8424	-525.8424	-592.6487	-592.6487	-703.9712	-703.9712	-979.9918	-979.9918	-732.3848	-732.3848
LR chi2 (16)	61.15	61.15	34.08	34.08	107.11	107.11	152.16	152.16	57.81	57.81
Prob > chi2	0.0000	0.0000	0.0053	0.0053	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Source: Survey, 2022, the asterisks indicate levels of significance; *p < 0.1; **p < 0.05; ***p < 0.01.

CHAPTER FIVE: DISCUSSION OF RESULTS

5.1 Perceived climate variabilities and crop-climate effects

Based on the earlier research, it is evident that the socioeconomic attributes of farmers in a particular location are important in shaping their perceptions of climate events and their impact (Mulinde *et al*., 2019; Atube *et al*., 2021). As such, this study finds it necessary to examine these characteristics in detail. As per the results of this research (Table 4.1), the average household age (53 years) implies that coffee production is generally dominated by older farmers. The current results corroborate the findings of Salad *et al*. (2021) who indicated that the majority of the coffee farmers in their study in Uganda were in the age range of 43-54 years. Probably, this is likely due to the fact that older farmers acquire larger plots of land over time, enabling them to engage in coffee cultivation. Similar to the findings of Mubiru *et al*. (2018), coffee growing is dominated by male-headed households. According to Kangile *et al*. (2021), the structure of the coffee supply chain hinders the active involvement of women in production and marketing. This is primarily attributed to their limited ownership and control over resources, leading to their high involvement in lower-end tasks within the chain, i.e. harvesting, and post-harvest handling activities (Kangile *et al*., 2021). The average farming experience of coffee growers (24 years) corroborates the findings of Mairura *et al*. (2021). Experience and knowledge acquired over time enable farmers to analyze information on technology, including the utilization of inputs such as fertilizers (Mulinde *et al*., 2019). The findings further indicate that coffee farmers had completed an average of 6 years of formal education. This relates to the results of Salad *et al*. (2021) in eastern Uganda, which showed that most coffee farmers had attained at least primary level of formal education. The implication is that most coffee farmers are less educated and therefore may hardly access and comprehend information on climate variability. Similar to the findings of Mbowa *et al*. (2014), the average household size of coffee growers is seven

individuals. This signifies the availability of relatively cheap labour for coffee production in the study area. According to the study findings, it is unfortunate that few farmers (30.51%) have access to credit facilities. This is in consonance with the findings of Kangile *et al*. (2021) and Salad *et al*. (2021). In their study, Verter *et al*. (2015) stress that having access to credit plays a fundamental role in coffee production. For instance, it enables farmers to acquire climate-resilient farm inputs such as fertilizers.

Results on temporal changes in climate variabilities show that farmers perceive significant increase in seasonal low rainfall, short rainfall duration, strong winds, high temperatures, hot days during the rainy season, seasonal dry spells and short dry spells from 2017-2019 to 2020-2022 (Table 4.2). These findings imply that farmers realize a growing incidence of climate variabilities. Literally, coffee farmers are increasingly experiencing adverse climate and environmental conditions, which translates into worsening coffee yields. The findings of this study support earlier research on changing climate (Mubiru *et al*., 2018; Chisale *et al*., 2021). Regarding rainfall, Atube *et al*. (2022) reported similar findings in northern Uganda. Relatedly, research by Mubiru *et al*. (2012) in Uganda indicated that during certain seasons, rain may begin early but end when it is projected to continue, signaling a growing variability in rainfall. This is likely to cause flower abortions, affect fruit development, and reduce the yield potential of the coffee crop. Besides, Suh and Molua (2022) argue that erratic rains present a challenge for farmers in implementing timely farm management practices, such as pest and disease control. The current results on temperature corroborate the earlier research by Okonya *et al*. (2013), Chisale *et al*. (2021), Atube *et al*. (2022), Msuya and Mahonge (2022) and Jawo *et al*. (2023), that reported increasing temperatures. According to Suh and Molua (2022), rising temperatures favor pest and disease multiplication. Additionally, extreme temperatures accelerate crop development and shorten growth duration of the crop, which reduces crop yield and quality (Lobell & Gourdji, 2012). As indicated by Mertz *et al*. (2009), this study also reveals a significant

increase in hot days during the rainy season. Comparable to the results of Okonya *et al*. (2013) and Chisale *et al*. (2021), farmers perceive a significant increase in seasonal dry spells. Okonya *et al*. (2013), argue that dry spells result into total crop loss, decreased output, crop drying and elevated pest damage. Based on the findings, increasing short dry spells within the rainy season are detected, which corroborates the findings of Mubiru *et al*. (2015) and Nimusiima *et al*. (2013). Nimusiima *et al*. (2013) added that these short dry spells within the rainy season cause retarded growth of the already planted coffee crop and/or possible total crop failure. Moreover, this climatic event is associated with an increased risk of prolonged dry spells (Sanchi *et al*., 2021). With regard to strong winds, a significant increase is detected. These results concur with those of an earlier study by Chisale *et al*. (2021) who reported an increase in strong winds in their study in Malawi. This is probably due to delays in rainfall which cause the initial rains to come with strong winds and hailstorms. Okonya *et al*. (2013) asserted that strong winds destroy leaves, break shoots, and flowers, hence affecting coffee production. On the other hand, a significant decline is perceived in terms of high rainfall amounts. This supports the conclusions reached by Mubiru *et al*. (2018) in their study that a decreasing trend was observed in terms of average monthly rainfall and the number of rainy days.

In the current study, the analysis of perceived climate effects reveals a general increase in all the variables investigated (Table 4.3). A relatively higher increase is however detected for worsening coffee harvests. From the discussion with farmers, this was generally due to changes in rainfall patterns and prolonged droughts. Besides, Baca *et al*. (2014) and Bunn *et al*. (2015**)** predicted a reduction in coffee yields due to climate change events. The study findings are in agreement with those of Craparo *et al*. (2015), Mugagga (2017) and Mbwambo *et al*. (2021), but in contrast with Jayakumar *et al*. (2017)'s study observations in India who reported improved coffee yields. Likewise, the findings reveal that coffee crop pests (e.g., coffee berry borer and black coffee twig borer) are the second most important crop climate effect, following low yields. This could be due to rising

temperatures and erratic rainfall, which enable elevated reproductive rate of pests and thus increased infestation (Ghini *et al*., 2011; Magrach & Ghazoul, 2015; Haile, 2018). Similar results have been reported by several scholars (Jassogne *et al*., 2013; Magrach & Ghazoul, 2015; Mubiru *et al*., 2015; Mbwambo *et al*., 2021). Furthermore, findings reveal increasing incidences of low-weight cherries and unfilled coffee beans. These phenomena are said to occur under extreme temperature conditions, which negatively affect bean filling, which eventually affects coffee quality (Jassogne *et al*.,2013). Similarly, the observed rise in low flowering and flower dropping could be largely due to rising temperatures, short rains, and water stress. Camargo (2010) also contended that high temperatures, coupled with prolonged dry spells during blossoming, cause flower abortion. As indicated by Asegid (2020), erratic rainfall causes random flowering and flower dropping. Moreover, Jassogne *et al*. (2013) asserted that the irregular distribution of seasonal rain causes continuous flowering, forcing farmers to harvest small quantities of coffee throughout the year. Lastly, coffee growers also perceive a rise in the occurrence of excessive drying of coffee leaves and trees. This is consistent with previous research that found significant leaf loss under rising trends in temperature and prolonged droughts (Venancio *et al*., 2020).

5.2 Relationship between use of purchased farm inputs and crop-climate effects

This study analyzed input application between two time periods, the drivers of farmers' decisions to use purchased inputs, and the differences in perceptions of crop-climate effects between users and non-users of purchased inputs. Generally, farmers perceive an increase in the frequency of application of farm inputs across the study time periods (Table 4.4). These findings are in contrast with those of Eakin *et al*. (2014) who presented mixed results from two locations in Mesoamerica. The summary statistics show that pesticides are the most frequently applied inputs in both time periods. In their study, Eakin *et al*. (2014) also reported that pesticide use was common among respondents. This is probably a response to the increasing incidence of coffee pests as perceived by

the farmers. According to Bongase (2017), changing climate contributes to the proliferation of some coffee pests, which increases the need for pesticide use. Similar to the findings of Jawo *et al*. (2023) and Zuluaga *et al*. (2015), an increase in fertilizer usage is detected. However, the frequency of the application of granular fertilizers was higher than that of foliar fertilizers. A probable explanation for this result is that soil fertilizers provide a more comprehensive nutrient supply to plants for long-term needs than foliar fertilizers. Farmers also argued that they were more conversant with utilizing granular fertilizers than foliar fertilizers. According to Muller *et al*. (2009), providing adequate levels of nutrients to the coffee crop maximizes yields and enhances defenses against pests and diseases. Furthermore, the study findings indicate an increase in the frequency of manure application. This is in line with the findings of Jawo *et al*. (2023), who asserted that farmers use organic manure to respond to climate variability effects. Moreover, organic manure use is cost worthy because it does not require frequent application, improves soil water retention, and supplies nutrients to the coffee crop for a longer time. Similarly, Scherr *et al*. (2012) emphasized that the use of organic fertilizers lowers the costs of production for the farmer. Lastly, farmers perceive an increase in herbicide use. This is probably because humid and warmer conditions increase the proliferation of weeds (Zayan, 2019), which may increase the need for herbicides.

For drivers of decisions to use purchased farm inputs, the study findings indicate that having access to labour increases farmers' likelihood of using inputs (Table 4.5). This is because the effective and timely application of these inputs may require additional labour. Similarly, the positive relationship observed between total land under coffee and the use of inputs may be explained by the fact that farmers with large landholdings under coffee are more likely to invest in modern technologies, such as the use of purchased farm inputs, since they anticipate higher returns. These findings corroborate those of Khan *et al*. (2021) and Ali and Erenstein (2017) who reported a positive relationship between farm size and adoption of climate-resilient measures such as fertilizer use. Furthermore,

earlier research shows that farmers with larger landholdings are more likely to have the resources and capabilities to explore and invest in climate adaptation strategies (Ali & Erenstein, 2017). As expected, credit access positively influenced the use of purchased farm inputs. Deressa *et al*. (2009) and Mensah *et al*. (2012) also argue that obtaining credit services enhances the capacity of farmers to purchase farm inputs. A similar relationship is detected for access to extension services on climate variability. This implies that, through the provision of these services, farmers are educated on climate risks and mitigation measures (Mensah *et al*., 2012). The results align with those of Khan *et al*.(2021), who concluded that access to farm advisory services improves the possibility that farmers will apply techniques for coping with variations in climate, such as fertilizer use. On the other hand, the household head's age negatively influences the use of purchased inputs. These findings imply that older coffee growers are less likely to use purchased farm inputs. These findings are in concordance with those of Ali and Erenstein (2017), who observed that age was negatively related to the adoption of climate-resilient practices. They added that older farmers are often unaware of advancements in innovation and are hesitant to embrace the latest technologies. Also, Suh and Molua (2022) indicate that older farmers tend to be highly traditional and inclined towards primitive technologies, making it unlikely for them to readily adopt newly recommended technologies. In addition, the current study established that the use of purchased inputs declines with an increase in household size. This is likely due to the observation that when a household is large, it results in a reduction in available disposable household income, part of which would be used to purchase these inputs. Furthermore, farmers who grow the local coffee type are less likely to use purchased inputs. This is of no surprise because these farmers often tend to refrain from adopting improved technologies, including the use of purchased inputs, because they believe that this type can thrive even with minimal care compared to improved varieties such as clonal coffee. Finally, a reduction in frequent hailstorms is likely to decrease the use of purchased farm inputs. This is probably because the perceived reduction in hailstorm risk could

lead to the assumption that the coffee crop is less likely to be damaged, which might result in farmers feeling less pressure to enhance crop health and yield through the use of purchased farm inputs.

The PSM results reveal declining incidences of low coffee yields among farmers who use purchased inputs (Table 4.6). This implies that inputs use cushions the coffee crop against adverse climatic conditions, and therefore, enhance coffee production. In addition, as indicated by Musafiri *et al*. (2023), the use of farm inputs, such as inorganic fertilizers, enhances farmers' capacity to cope with climate-related risks. Further, a reduction in the incidence of coffee pests is observed among users of purchased farm inputs compared to their counterparts. This is because the effective use of farm inputs, such as pesticides, reduces pest populations, thereby minimizing their negative impact on the coffee crop. Moreover, Tudi *et al*. (2021) argued that pesticides also have the ability to reduce disease incidence. Also, the findings indicate that using purchased inputs reduces the occurrence of less flowering in coffee farming. Likewise, the incidence of low-weight coffee cherries and excessive drying of leaves reduced among users of purchased inputs. Excessive drying of leaves indicates plant stress, pests and disease, or suboptimal growing conditions, which can further impact coffee plant health and productivity. Using purchased inputs, such as manure, improves the soil moisture retention capacity, which ultimately reduces the incidence of excessive drying of leaves. Additionally, Jawo *et al*. (2023) argued that the application of manure improves soil fertility and resilience of the crop to drought, preventing excessive dehydration of coffee leaves.

5.3 Influence of perceived climate variabilities on use of purchased farm inputs

The zero-inflated Poisson results show a positive association between perceived seasonal dry spell and the use of farm inputs, namely, foliar fertilizers, granular fertilizers, manure and pesticides (Table 4.7). This could be because fertilizers improve water-holding capacity and fertility of the soil, thereby enhancing crop resilience to drought. Similarly, farmers may increase pesticide usage to combat the

increasing pest infestation levels arising from the elevated reproduction rates observed during dry spells. Further, the use of foliar fertilizers and herbicides is negatively related to perceived changes in low rainfall amounts. This implies that although farmers acknowledge the use of foliar fertilizers and herbicides as response measures to low rainfall events, they do not perceive that increased application of these inputs has a remarkable effect on the coffee crop performance in the wake of such climatic event. As indicated by Tucker *et al*. (2010), farmers may use less of purchased inputs when faced with low rainfall events, as they expect low harvests. This corroborates the findings of Mensah *et al*. (2012), who mentioned that expected lower yields do not justify farmers' increased use of purchased inputs. The present results also show that the perceived change in high rainfall amounts is significantly less likely to increase the frequency of use of foliar fertilizers, manure, and herbicides. This aligns with the findings of Deressa *et al*. (2008), who concluded that increased precipitation may reduce farmers' use of farm inputs as a response strategy to climate variability.

For the control variables, extension information on crop husbandry is positively related to the use of foliar fertilizers, manure, and herbicides. Probably this is because extension services improve farmers' accessibility and awareness of suitable product options, recommended formulations, application techniques and rates, facilitating the acquisition and utilization of these inputs by farmers. The negative influence on the application frequency of pesticides is probably because extension service providers in the study area focus their advice on integrated pest management techniques that prompt farmers to minimize pesticide usage. Based on the results, a positive relationship is observed between extension information on climate variability and pesticide use. However, for herbicides, a negative relationship is detected. This could be because farmers have acquired knowledge on environmentally friendly and sustainable measures of suppressing weed growth such as intercropping with cover crops and planting shade trees. Mkonda *et al*. (2018) also noted that farmers' knowledge on climate variability is vital in adopting effective climate-resilient inputs. However, despite having

received awareness on increased pest incidence due to climate variability, farmers may not have received specific guidance on alternative pest management practices**.** As a result, coffee farmers perceive pesticide use as the only feasible solution to cope with increased pest incidence. It is likely that they lack updated information on sustainable adaptation measures to climate variability events (Abid *et al*., 2015). Furthermore, the findings also show that farmers are more likely to use foliar and soil fertilizers when they perceive a projected increase in coffee output. The reason for this result could be that many farmers base their fertilizer usage decisions on historical yield patterns and social interactions. As such, they may increase fertilizer usage if they associate such a perceived higher coffee output potential with specific fertilizers based on past experience. However, the frequency of manure and herbicide use is perceived to decline with an increase in coffee output. Coffee farmers argued that due to the scarcity of manure, they are compelled to substitute manure usage with synthetic fertilizers that are readily available and provide quicker and more precise nutrient supply to the coffee crop. Regarding herbicides and output, Colbach and Cordeau (2018) reported contrasting results. The study reported that herbicide use intensity had no effect on yield loss.

Access to credit services is not statistically significant with the frequency of fertilizer, manure, and herbicide use, except for pesticides. This implies that much as obtaining credit enables farmers to purchase farm inputs (Mensah *et al*., 2012; Moahid & Maharjan, 2020; Atube *et al*., 2021), farmers will direct those resources to respond to climate change effects, such as pests which they perceive to cause immense damage to their crop. Regarding sex of household head, male coffee growers are less likely to use manure and pesticides. This is consistent with the research by Nhemachena and Hassan (2007), who concluded that "female-headed households are more likely to adopt different methods of climate change adaptation", including the use of manure and pesticides, than their counterparts. Besides, Ndambiri *et al*. (2012) asserted that the probability of perceiving climate change is higher for female-headed households than for male-headed households, and are therefore more likely to use

purchased inputs. However, these results contradict Atube *et al*. (2021)'s findings, who found that households headed by males were more likely to intensify the use of pesticides and fertilizers against the adverse effects of climate change. The current study also established that farm labour positively influences the use of manure and herbicides. This is because the handling and application of these inputs by smallholder farmers is largely manual and labour intensive, hence, with increasing labour availability, farmers are able to dedicate resources to their use. For education level, a negative influence on the frequency of foliar fertilizer use is observed. A probable explanation is that, as farmers' level of education increases, they acquire knowledge on various soil and land conservation techniques, which are more sustainable and environmentally friendly, reducing their reliance on chemicals. Pertaining age, the study reveals that older farmers are less likely to use more foliar fertilizers, probably because they have limited information and access to these fertilizers. This explains the partial perception to increase its frequency of use. In contrast with the present study, Luzinda *et al*. (2018) mentioned that there was no significant relationship between age and the use of coffee technologies, including the use of inputs, in their study conducted in central Uganda. Farm management practices such as mulching influence the frequency of use of all inputs. For instance, it is more likely to increase the frequency of use of foliar fertilizers, granular fertilizers and manure. Essentially, mulching improves soil temperature and moisture content, which are factors associated with effective utilization of chemical fertilizers and manure. Therefore, the resultant outcome in terms of high yields emanating from the combination of the latter with mulching is likely to cause increased usage of chemical fertilizers and manure. Conversely, the negative association between mulching and herbicides can be explained by the fact that mulches physically suppress weed growth, thus minimizing the need for herbicide use. Likewise, the frequency of pesticide use reduced with mulching. This could be because mulches provide ideal conditions for the growth of organisms, such as ground beetles and centipedes, which contribute to biological pest control. Furthermore,

intercropping with cover crops negatively influences the frequency of fertilizer and pesticide use. This is because it is a common practice for farmers in the study area to intercrop coffee with nitrogen-fixing cover crops, such as beans, which replenish soil nitrogen levels naturally, reducing the reliance on foliar and soil fertilizer applications. Moreover, Harelimana *et al*. (2018) argued that intercropping saves farmers the burden of purchasing expensive nitrogen fertilizers. In addition, non-host intercrops in coffee can help intercept pests such as soil nematodes which spread through injured or wounded roots (Avelino *et al*., 2011), reducing the burden of pesticide usage. Land conservation practices, such as digging water harvesting trenches, significantly influence only the frequency of pesticide use. This can be partially attributed to the fact that water harvesting trenches limit pest movement within the coffee garden and help contain pest populations reducing eventual damage to the crop, minimizing the need for pesticides. Lastly, for maintenance of shade trees, a perceived increase in the use of foliar fertilizers, pesticides, and herbicides is detected. According to Jonsson *et al*. (2015), some coffee pests, such as white stem borers, may thrive under shaded conditions, which could justify the increased use of pesticides. Shade trees also decrease evaporation of foliar fertilizers by creating favourable conditions for optimal absorption, thus encouraging the use of these fertilizers.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The present study investigated the influence of perceived crop-climate effects and climate variability on the utilization of purchased farm inputs. Overall, coffee growers in the study area perceived a general increase in the occurrence of low and short rainfall events, extreme hot days during the dry season, hot days during the rainy season, prolonged and short dry spells, and strong winds in recent years. Likewise, the study reveals an increase in all the observed effects of these climate events on the coffee crop, especially for pest incidence, low coffee harvests, low-weight coffee cherries, and coffee cherries with unfilled beans in recent years. The study further established that the use of purchased inputs, such as fertilizers, pesticides, herbicides, manure, and mulches, has generally increased in the study area in recent years. This suggests that farmers' perceptions on worsening climate variabilities increase the use of purchased farm inputs. Further, this study has established that socio-economic factors affecting farmers' decisions to use purchased inputs include age, land, household size, access to credit and extension services, access to hired labour, and type of coffee grown. In addition, the study reveals significant differences in perceived crop-climate effects between users and non-users of purchased farm inputs. As such, the study concludes that the incidences of crop-climate effects reduce with the use of purchased inputs. This research also reveals significant differences in the relationship between perceived change in climate variabilities and the use of purchased farm inputs. Accordingly, it can be concluded that farmer perceptions of changes in climate variability determine the level of use of farm inputs and that such use of farm inputs is moderated by socio-economic characteristics and the kind of husbandry practices on the farm in question.

6.2 Policy recommendations

This study points to the fact that the use of purchased farm inputs has increased in response to the perceived increase in climate variability events and crop-climate effects in recent years. However, it should be noted that an increase in the use of purchased inputs comes with additional costs to farmers, yet a few have access to credit services to finance purchases. It is therefore hereby recommended that farmers should be encouraged to embrace government programs such as the Parish Development Model (PDM) as well as agricultural financing institutions to enable them acquire inputs.

Further, since climate variability raises the risk of yield losses, insurance schemes for climate-related crop losses should be created to cushion farmers against such losses. Securing a financial buffer through insurance will likely encourage farmers to invest in climate-smart technologies, including the use of purchased inputs.

Finally, the study findings highlight the need for extension services that focus on educating farmers about sustainable climate variability adaptation strategies and the efficient use of purchased inputs to optimize coffee production. Moreover, access to weather information by coffee farmers should be accurate and timely to enable them make informed decisions regarding planting, harvesting, and other agricultural activities.

6.3 Areas for further research

The current study did not examine the effectiveness of purchased input use against the effects of climate variability. Therefore, further research should be conducted to compare the effectiveness of different combinations of purchased inputs against climate variability events and the cost burden on a farmer. In addition, we advise conducting research to identify optimal approaches for integrating the utilization of purchased inputs with other agricultural management practices for sustainable coffee production.

REFERENCES

Abdullahi Faisal Salad, Simon Zziwa, David Talengera, Lydia Nabatanzi, Olivia Makumbi, Vivian Najjuma, & Marveen Nafula. (2021). Adoption intensity of climate smart agricultural practices in arabica coffee production in Bududa District. *International Journal of Multidisciplinary Research Updates*, *1*(1), 016–025. https://doi.org/10.53430/ijmru.2021.1.1.0037

Abid, M., Scheffran, J., Schneider, U. A., & Ashfaq, M. (2015). Farmers' perceptions of and adaptation strategies to climate change and their determinants: The case of Punjab province, Pakistan. *Earth System Dynamics*, *6*(1), 225–243. https://doi.org/10.5194/esd-6-225-2015

Adhikari, M., Isaac, E. L., Paterson, R. R. M., & Maslin, M. A. (2020). A review of potential impacts of climate change on coffee cultivation and mycotoxigenic fungi. *Microorganisms*, *8*(10), 1–12. https://doi.org/10.3390/microorganisms8101625

Alex, N., Basalirwa, C. P. K., Majaliwa, J. G. M., Otim-Nape, W., Okello-Onen, J., Rubaire-Akiiki, C., Konde-Lule, J., & Ogwal-Byenek, S. (2013). Nature and dynamics of climate variability in the uganda cattle corridor. *Journal of Environmental Science and Technology*, *7*(8), 770–782. https://doi.org/10.5897/AJEST2013.1435

Ali, A., & Erenstein, O. (2017). Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Climate Risk Management*, *16*, 183–194. https://doi.org/10.1016/j.crm.2016.12.001

Ali, E. (2018). Impact of climate variability on staple food crops production in Northern Togo. *Journal of Agriculture and Environment for International Development*, *112*(2), 321–342. https://doi.org/10.12895/jaeid.20182.778

Amikuzuno, J., & Donkoh, S. A. (2012). Climate Variability and Yield of Major Staple Food Crops in Northern Ghana. *African Crop Science Journal*, *20*, 349–360. https://www.researchgate.net/publication/259799623%0A

Asegid, A. (2020). Impact of climate change on production and diversity of coffee (Coffea arabica L.) in Ethiopia. *Int J Res Stud Sci Eng Technol*, *7*(8), 31–38. http://www.ijrsset.org/pdfs/v7-i8/5.pdf

Atube, F., Malinga, G. M., Nyeko, M., Okello, D. M., Alarakol, S. P., & Okello-Uma, I. (2021).

Determinants of smallholder farmers' adaptation strategies to the effects of climate change: Evidence from northern Uganda. *Agriculture and Food Security*, *10*(1), 1–15. https://doi.org/10.1186/s40066-020-00279-1

Atube, F., Malinga, G. M., Nyeko, M., Okello, D. M., Mugonola, B., Omony, G. W., & Okello-Uma, I. (2022). Farmers' perceptions of climate change, long-term variability and trends in rainfall in Apac district, northern Uganda. *CABI Agriculture and Bioscience*, *3*(1), 1–16. https://doi.org/10.1186/s43170-022-00116-4

Avelino, J., Martijn, G., Hoopen, T., & Declerck, F. (2011). Ecological Mechanisms for Pest and Disease Control in Coffee and Cacao Agroecosystems of the Neotropics. In R. Bruno, L. C. Jean-Francois, & B. John (Eds.), *Ecosystem services from agriculture and agroforestry* (pp. 91–117). Earthscan Publications. https://doi.org/10.4324/9781849775656

Ayalew, B. (2018). Impact of shade on morpho-physiological characteristics of coffee plants, their pests and diseases: A review. *African Journal of Agricultural Research*, *13*(39), 2016–2024. https://doi.org/10.5897/ajar2018.13408

Baca, M., Läderach, P., Haggar, J., Schroth, G., & Ovalle, O. (2014). An integrated framework for assessing vulnerability to climate change and developing adaptation strategies for coffee growing families in mesoamerica. *PLoS ONE*, *9*(2). https://doi.org/10.1371/journal.pone.0088463

Baruch, Y. (1999). Response rate in academic studies -A comparative-analysis. *Human Relations*, *52*(4).

Bianco, G. B. (2020). Climate change adaptation , coffee , and corporate social responsibility : challenges and opportunities. *International Journal of Corporate Social Responsibility*. https://doi.org/10.1186/s40991-020-00048-0%0A

Bongase, E. D. (2017). Impacts of climate change on global coffee production industry: Review. *African Journal of Agricultural Research*, *12*(19), 1607–1611. https://doi.org/10.5897/ajar2017.12147

Bote, A. . (2016). Examining growth, yield and bean quality of Ethiopian coffee trees: towards optimizing resources and tree management. In *Doctoral dissertation, Wageningen University*

and Research.

Bunn, C., Läderach, P., Ovalle Rivera, O., & Kirschke, D. (2015). A bitter cup: climate change profile of global production of Arabica and Robusta coffee. *Climatic Change*, *129*(1–2), 89–101. https://doi.org/10.1007/s10584-014-1306-x

Bunn, C., Lundy, M., Läderach, P., Fernández-Kolb, P., & Castro-Llanos, F. (2019). Climate-smart coffee in Uganda. *International Center for Tropical Agriculture (CIAT), Cali, Colombia.* https://cgspace.cgiar.org/handle/10568/101331

Buyinza, F. (2017). Climate Variability and Crop Yields in Uganda. *Journal of Agricultural Science*, *8*(1–2), 15–31. https://doi.org/10.31901/24566535.2017/08.1-2.02

Camargo, M. B. P. De. (2010). The impact of climatic variability and climate change on Arabic coffee crop in Brazil. *Bragantia*, *69*(1), 239–247. https://doi.org/10.1590/s0006-87052010000100030

Chisale, H. L. W., Chirwa, P. W., Babalola, F. D., & Manda, S. O. M. (2021). Perceived effects of climate change and extreme weather events on forests and forest-based livelihoods in Malawi. *Sustainability (Switzerland)*, *13*(21), 1–15. https://doi.org/10.3390/su132111748

Cochran, W. G. (1977). *Sampling techniques.* John Wiley & Sons.

Cohn, A. S., Newton, P., Gil, J. D. B., Kuhl, L., Samberg, L., Ricciardi, V., Manly, J. R., & Northrop, S. (2017). Smallholder Agriculture and Climate Change. *Annual Review of Environment and Resources*, *42*, 347–375. https://doi.org/10.1146/annurev-environ-102016-060946

Colbach, N., & Cordeau, S. (2018). Reduced herbicide use does not increase crop yield loss if it is compensated by alternative preventive and curative measures. *European Journal of Agronomy*, *94*, 67–78. https://doi.org/10.1016/j.eja.2017.12.008

Craparo, A. C.W., Van Asten, P. J. A., Läderach, P., Jassogne, L. T. P., & Grab, S. W. (2015). Coffea arabica yields decline in Tanzania due to climate change: Global implications. *Agricultural and Forest Meteorology*, *207*, 1–10. https://doi.org/10.1016/j.agrformet.2015.03.005

Craparo, Alessandro C.W. (2017). Influence of climate change and variability on Coffea arabica in the East African highlands (Doctoral dissertation).

DaMatta, F. M., Rahn, E., Läderach, P., Ghini, R., & Ramalho, J. C. (2018). Why could the coffee crop endure climate change and global warming to a greater extent than previously estimated? *Climatic Change*, *152*(1), 167–178. https://doi.org/10.1007/s10584-018-2346-4

DaMatta, F. M., & Ramalho, J. C. (2006). Impacts of drought and temperature stress on coffee physiology and production: A review. *Brazilian Journal of Plant Physiology*, *18*(1), 55–81. https://doi.org/10.1590/S1677-04202006000100006

Davis, A. P., Kiwuka, C., Faruk, A., Mulumba, J., & Kalema, J. (2022). A review of the indigenous coffee resources of Uganda and their potential for coffee sector sustainability and development. *Frontiers in Plant Science*, *13*(February), 1–16. https://doi.org/10.3389/fpls.2022.1057317

Deressa, T., Hassan, R. M., Alemu, T., Yesuf, M., & Ringler, C. (2008). Analyzing the determinants of farmers' choice of adaptation methods and perceptions of climate change in the Nile Basin of Ethiopia. In *IFPRI Discussion Paper*. http://www.ifpri.org/publication/determinants-farmers-choice-adaptation-methods-and-perceptions-climate-change-nile-basi-0%5Cnhttp://www.ifpri.org/sites/default/files/publications/ifpridp00798.pdf

Deressa, T. T., Hassan, R. M., & Ringler, C. (2011). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *Journal of Agricultural Science*, *149*(1), 23–31. https://doi.org/10.1017/S0021859610000687

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*, *19*(2), 248–255. https://doi.org/10.1016/j.gloenvcha.2009.01.002

Eakin, H., Tucker, C. M., Castellanos, E., Diaz-Porras, R., Barrera, J. F., & Morales, H. (2014). Adaptation in a multi-stressor environment: Perceptions and responses to climatic and economic risks by coffee growers in Mesoamerica. *Environment, Development and Sustainability*, *16*(1), 123–139. https://doi.org/10.1007/s10668-013-9466-9

Eshetu, G., Johansson, T., Garedew, W., & Yisahak, T. (2021). Determinants of smallholder farmers ' adaptation options to climate change in a coffee-based farming system of Southwest Ethiopia. *Climate and Development*, *13*(4), 318-325. https://doi.org/10.1080/17565529.2020.1772706

Gay, C., Estrada, F., Conde, C., Eakin, H., & Villers, L. (2006). Potential impacts of climate change

on agriculture: A case of study of coffee production in Veracruz, Mexico. *Climatic Change*, *79*(3–4), 259–288. https://doi.org/10.1007/s10584-006-9066-x

Ghini, R., Bettiol, W., & Hamada, E. (2011). Diseases in tropical and plantation crops as affected by climate changes: Current knowledge and perspectives. *Plant Pathology*, *60*(1), 122–132. https://doi.org/10.1111/j.1365-3059.2010.02403.x

Haile, M. Y. (2018). A Review on Impacts of Climatic Variability on Arabica Coffee Improvement in Ethiopia. *International Journal of Forestry and Horticulture*, *4*(1), 9–18. https://doi.org/10.20431/2454-9487.0401002

Harelimana, A., Le Goff, G., Ntirushwa Rukazambuga, D. T., & Hance, T. (2018). Coffee Production Systems: Evaluation of Intercropping System in Coffee Plantations in Rwanda. *Journal of Agricultural Science*, *10*(9), 17–28. https://doi.org/10.5539/jas.v10n9p17

Harelimana, Anastase, Rukazambuga, D., & Hance, T. (2022). Pests and diseases regulation in coffee agroecosystems by management systems and resistance in changing climate conditions : a review. *Journal of Plant Diseases and Protection*, *129*(5), 1041–1052. https://doi.org/10.1007/s41348-022-00628-1

ICO. (2014). *World coffee trade (1963 – 2013): A review of the markets, challenges and opportunities facing the sector*. http://www.ico.org/news/icc-111-5-r1e-world-coffee-outlook.

Jassogne, L., Läderach, P., & van Asten, P. (2013). *Impact of Climate Change on Coffee in Uganda. Lessons from a Case Study in Rwenzori Mountains. Oxfarm Research Reports (April),Oxfam GB, 1-16.*

Jawo, T. O., Teutscherová, N., Negash, M., Sahle, K., & Lojka, B. (2023). Smallholder coffee-based farmers' perception and their adaptation strategies of climate change and variability in South-Eastern Ethiopia. *International Journal of Sustainable Development and World Ecology*, *30*(5), 533–547. https://doi.org/10.1080/13504509.2023.2167241

Jayakumar, M., Rajavel, M., Surendran, U., Gopinath, G., & Ramamoorthy, K. (2017). Impact of climate variability on coffee yield in India—with a micro-level case study using long-term coffee yield data of humid tropical Kerala. *Climatic Change*, *145*(3–4), 335–349. https://doi.org/10.1007/s10584-017-2101-2

Jonsson, M., Raphael, I. A., Ekbom, B., Kyamanywa, S., & Karungi, J. (2015). Contrasting effects of shade level and altitude on two important coffee pests. *Journal of Pest Science*, *88*(2), 281–287. https://doi.org/10.1007/s10340-014-0615-1

Kajembe, J., Lupala, I., Kajembe, G., Mugasha, W., & Faraji, N. (2016). The Role of Selected Agroforestry Trees in Temperature Adaptation on Coffea arabica: A Case Study of the Moshi District, Tanzania Jacqueline. In *Climate Change and Multi-Dimensional Sustainability in African Agriculture: Climate Change and Sustainability in Agriculture* (pp. 1–717). https://doi.org/10.1007/978-3-319-41238-2

Kangile, J. R., Kadigi, R. M. J., Mgeni, C. P., Munishi, B. P., Kashaigili, J., & Munishi, P. K. T. (2021). The role of coffee production and trade on gender equity and livelihood improvement in Tanzania. *Sustainability (Switzerland)*, *13*(18), 1–14. https://doi.org/10.3390/su131810191

Kath, J., Mittahalli Byrareddy, V., Mushtaq, S., Craparo, A., & Porcel, M. (2021). Temperature and rainfall impacts on robusta coffee bean characteristics. *Climate Risk Management*, *32*, 100281. https://doi.org/10.1016/j.crm.2021.100281

Khan, N. A., Qiao, J., Abid, M., & Gao, Q. (2021). Understanding farm-level cognition of and autonomous adaptation to climate variability and associated factors: Evidence from the rice-growing zone of Pakistan. *Land Use Policy*, *105*, 105427. https://doi.org/10.1016/j.landusepol.2021.105427

Khandker, S. R., Koolwal, G. B., & Samad, H. A. (2010). *4 . Propensity Score Matching: Handbook on Impact Evaluation PSM*. 53–66.

Kumari, V. V., Banerjee, P., Verma, V. C., Sukumaran, S., Chandran, M. A. S., Gopinath, K. A., Venkatesh, G., Yadav, S. K., Singh, V. K., & Awasthi, N. K. (2022). Plant Nutrition: An Effective Way to Alleviate Abiotic Stress in Agricultural Crops. *International Journal of Molecular Sciences*, *23*(15), 8519. https://doi.org/10.3390/ijms23158519

Lehmann, J., Gaunt, J., & Rondon, M. (2006). Bio-char sequestration in terrestrial ecosystems - A review. *Mitigation and Adaptation Strategies for Global Change*, *11*(2), 403–427. https://doi.org/10.1007/s11027-005-9006-5

Lemi, T., & Hailu, F. (2019). Effects of Climate Change Variability on Agricultural Productivity.

International Journal of Environmental Sciences & Natural Resources, *17*(1). https://doi.org/10.19080/IJESNR.2019.17.555953

Lemma, D. T., & Megersa, H. G. (2021). Impact of Climate Change on East African Coffee Production and Its Mitigation Strategies. *World Journal of Agricultural Sciences*, *17*(2), 81–89. https://doi.org/10.5829/idosi.wjas.2021.81.89

Lin, B. B. (2011). Resilience in agriculture through crop diversification: Adaptive management for environmental change. *BioScience*, *61*(3), 183–193. https://doi.org/10.1525/bio.2011.61.3.4

Lobell, D. B., & Gourdji, S. M. (2012). The influence of climate change on global crop productivity. *Plant Physiology*, *160*(4), 1686–1697. https://doi.org/10.1104/pp.112.208298

Luzinda, H., Nelima, M., Wabomba, A., Musoli, P. C., & Kakuru, A. (2018). Factors Influencing Adoption of Improved Robusta Coffee Technologies in Uganda. *Uganda Journal of Agricultural Sciences*, *18*(1), 33–41.

Lybbert, T. J., & Sumner, D. A. (2012). Agricultural technologies for climate change in developing countries: Policy options for innovation and technology diffusion. *Food Policy*, *37*(1), 114–123. https://doi.org/10.1016/j.foodpol.2011.11.001

Maddison, D. (2007). The Perception of and Adaptation to Climate Change in Africa. In *Centre for Environmental E conomics and Policy in Africa, University of Pretoria, South Africa.* (Vol. 4308). World Bank Publications.

Magrach, A., & Ghazoul, J. (2015). Climate and pest-driven geographic shifts in global coffee production: Implications for forest cover, biodiversity and carbon storage. *PLoS ONE*, *10*(7), 1–15. https://doi.org/10.1371/journal.pone.0133071

Mairura, F. S., Musafiri, C. M., Kiboi, M. N., Macharia, J. M., Ng'etich, O. K., Shisanya, C. A., Okeyo, J. M., Mugendi, D. N., Okwuosa, E. A., & Ngetich, F. K. (2021). Determinants of farmers' perceptions of climate variability, mitigation, and adaptation strategies in the central highlands of Kenya. *Weather and Climate Extremes*, *34*, 100374. https://doi.org/10.1016/j.wace.2021.100374

Makate, C., & Makate, M. (2022). Do Rainfall Shocks Prompt Commercial Input Purchases Amongst

Smallholder Farmers in Diverse Regions and Environments in Malawi? *Sustainability (Switzerland)*, *14*(22). https://doi.org/10.3390/su142214904

Mbowa, S., Odokonyero, T., & Munyambonera, E. (2014). The potential of coffee to uplift people out of poverty in Northern Uganda. *EPRC Research Reports*, *11*, 1–85.

Mbwambo, S. G., Mourice, S. K., & Tarimo, A. J. P. (2021). Climate Change Perceptions by Smallholder Coffee Farmers in Northern and sounthern Highlands of Tanzania. *Climate*, *9*(90). https://doi.org/https://doi.org/ 10.3390/cli9060090

Mbwambo, S. G., Mourice, S. K., & Tarimo, A. J. P. (2022). The Impacts of Current Climate Variability on Coffee Production in the Northern and Southern Highlands of Tanzania. *Journal of Agricultural Science*, *14*(3), *78–99*. https://doi.org/10.5539/jas.v14n3p78

Mendelsohn, R., & Wang, J. (2017). The impact of climate on farm inputs in developing countries agriculture. *Atmosfera*, *30*(2), 77–86. https://doi.org/10.20937/ATM.2017.30.02.01

Mensah, F. B. Y., Vlek, P. L. G., & MacCarthy, D. S. (2012). Farmers' perception and adaptation to climate change: A case study of Sekyedumase district in Ghana. *Environment, Development and Sustainability*, *14*(4), 495–505. https://doi.org/10.1007/s10668-012-9339-7

Mertz, O., Mbow, C., Reenberg, A., & Diouf, A. (2009). Farmers' perceptions of climate change and agricultural adaptation strategies in rural sahel. *Environmental Management*, *43*(5), 804–816. https://doi.org/10.1007/s00267-008-9197-0

Mkonda, Y. M., He, Xi., & Festin, S. E. (2018). Comparing Smallholder Farmers ' Perception of Climate Change with Meteorological Data : Experience from Seven Agroecological Zones of Tanzania. *Weather, Climate, and Society*, *10*(3), 435–452. https://doi.org/10.1175/WCAS-D-17-0036.1

Moahid, M., & Maharjan, K. L. (2020). Factors affecting farmers' access to formal and informal credit: Evidence from rural Afghanistan. *Sustainability*, *12*(3), 1268. https://doi.org/10.3390/su12031268

Msuya, A. M., & Mahonge, C. P. (2022). Impact of climate variability, farmers adaptation and coping strategies on coffee production in highlands of Kigoma District, Tanzania. *Asian Journal of*

Forestry, *6*(1), 34–42. https://doi.org/10.13057/asianjfor/r060105

Mubiru, D. N., Komutunga, E., Agona, A., Apok, A., & Ngara, T. (2012). Characterising agrometeorological climate risks and uncertainties: Crop production in Uganda. *South African Journal of Science*, *108*(3–4). https://doi.org/10.4102/sajs.v108i3/4.470

Mubiru, D. N., Kyazze, F. B., Radeny, M., Zziwa, A., Lwasa, J., & Kinyangi, J. (2015). *Climatic trends, risk perceptions and coping strategies of smallholder farmers in rural Uganda. CCAFS Working Paper no. 121. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark.* www.ccafs.cgiar.org%0A

Mubiru, D. N., Radeny, M., Kyazze, F. B., Zziwa, A., Lwasa, J., Kinyangi, J., & Mungai, C. (2018). Climate trends, risks and coping strategies in smallholder farming systems in Uganda. *Climate Risk Management*, *22*, 4–21. https://doi.org/10.1016/j.crm.2018.08.004

Mugagga, F. (2017). Perceptions and Response Actions of Smallholder Coffee Farmers to Climate Variability in Montane Ecosystems. *Environment and Ecology Research*, *5*(5), 357–366. https://doi.org/10.13189/eer.2017.050505

Mugenda, O., & Mugenda, A. (2013). *Research methods: Quantitative and Qualitative Approaches.* African Centre for Technology Studies.

Mulinde, C., Majaliwa, J. G. M., Twinomuhangi, R., Mfitumukiza, D., Komutunga, E., Ampaire, E., Asiimwe, J., Van Asten, P., & Jassogne, L. (2019). Perceived climate risks and adaptation drivers in diverse coffee landscapes of Uganda. *NJAS - Wageningen Journal of Life Sciences*, *88*, 31–44. https://doi.org/10.1016/j.njas.2018.12.002

Muller, R., Berry, D., Avelino, J., & Bieysse, D. (2009). *"Coffee diseases," in Coffee: Growing, Processing, Sustainable Production. A Guidebook for Growers, Processors, Traders, and Researchers* (J. N. Wintgens (WILEY- VCH) (ed.)).

Musafiri, C. M., Kiboi, M., Macharia, J., Ng'etich, O. K., Okoti, M., Mulianga, B., Kosgei, D. K., Zeila, A., & Ngetich, F. K. (2023). Use of inorganic fertilizer on climate-smart crops improves smallholder farmers' livelihoods: Evidence from Western Kenya. *Social Sciences and Humanities Open*, *8*(1), 100537. https://doi.org/10.1016/j.ssaho.2023.100537

Nanfuka, S., Mfitumukiza, D., & Egeru, A. (2020). Characterisation of ecosystem-based adaptations to drought in the central cattle corridor of Uganda. *African Journal of Range and Forage Science*, *37*(4), 257–267. https://doi.org/10.2989/10220119.2020.1748713

Ndambiri, H. K., Ritho, C., Mbogoh, S. G., Ng'anga'a, S. I., Muiruri, E. J., Nyangweso, P. M., Kipsat, M. J., Ogada, J. O., Omboto, P. I., Kefa, C., Kubowon, P. C., & Cherotwo, F. H. (2012). Assessment of Farmers ' Adaptation to the Effects of Climate Change in Kenya : the Case of Kyuso District. *Journal of Economics and Sustainable Development*, *3*(12), 52–61.

Nhemachena, C., & Hassan, R. (2007). *Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa.IFPRI Discussion Paper 00714*.

Nimusiima, A., Basalirwa, C. P. K., & Majaliwa, J. G. M. (2013). *Nature and dynamics of climate variability in the uganda cattle corridor*. *7*(8), 770–782. https://doi.org/10.5897/AJEST2013.1435

Nizeyimana, G., Mwiine, F. N., & Ayebazibwe, C. (2013). Comparative brucella abortus antibody prevalence in cattle under contrasting husbandry practices in uganda. *Journal of the South African Veterinary Association*, *84*(1). https://doi.org/10.4102/jsava.v84i1.943

Okonya, J. S., Syndikus, K., & Kroschel, J. (2013). Farmers' Perception of and Coping Strategies to Climate Change: Evidence From Six Agro-Ecological Zones of Uganda. *Journal of Agricultural Science*, *5*(8). https://doi.org/10.5539/jas.v5n8p252

Patt, A., Suarez, P., & Gwata, C. (2005). Effects of seasonal climate forecasts and participatory workshops among subsistence farmers in Zimbabwe. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(35), 12623–12628. https://doi.org/10.1073/pnas.0506125102

Pham, Y., Reardon-Smith, K., Mushtaq, S., & Cockfield, G. (2019). The impact of climate change and variability on coffee production: a systematic review. *Climatic Change*, *156*(4), 609–630. https://doi.org/10.1007/s10584-019-02538-y

Radeny, M., Desalegn, A., Mubiru, D., Kyazze, F., Mahoo, H., Recha, J., Kimeli, P., & Solomon, D. (2019). Indigenous knowledge for seasonal weather and climate forecasting across East Africa. *Climatic Change*, *156*(4), 509–526. https://doi.org/10.1007/s10584-019-02476-9

Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. 170–184. https://doi.org/10.1017/CBO9780511810725.016

Sanchi, I. D., Alhassan, Y. J., Sabo, Y. A., & Hamid, B. J. (2021). Critical Review of the Causes and Effects of Dry Spell in 2021 Rainy Season in Danko Wasagu Local Government. *Cross Current Int J Agri Vet Sci*, *3*(8), 66–75. https://doi.org/10.36344/ccijavs.2021.v03i08.001

Scherr, S. J., Shames, S., & Friedman, R. (2012). From climate-smart agriculture to climate-smart landscapes. *Agriculture & Food Security*, *1*(12). https://doi.org/10.1186/2048-7010-1-12

Singh, A. S., & Masuku, M. B. (2014). SAMPLING TECHNIQUES & DETERMINATION OF SAMPLE SIZE IN APPLIED STATISTICS RESEARCH: AN OVERVIEW. *International Journal of Economics, Commerce and Management*, *II*(11), 32–33.

Stark, J. (2011). Climate Change and Conflict in Uganda : The Cattle Corridor and Karamoja. *United States Agency for International Development*, *February*, 66. http://www.fess-global.org/Publications/Other/Climate_Change_and_Conflic_ in_Uganda.pdf

Suh, N. N., & Molua, E. L. (2022). Cocoa production under climate variability and farm management challenges: Some farmers' perspective. *Journal of Agriculture and Food Research*, *8*, 100282. https://doi.org/10.1016/j.jafr.2022.100282

Tucker, C. M., Eakin, H., & Castellanos, E. J. (2010). Perceptions of risk and adaptation: Coffee producers, market shocks, and extreme weather in Central America and Mexico. *Global Environmental Change*, *20*(1), 23–32. https://doi.org/10.1016/j.gloenvcha.2009.07.006

Tudi, M., Ruan, H. D., Wang, L., Lyu, J., Sadler, R., Connell, D., Chu, C., & Phung, D. T. (2021). Agriculture development, pesticide application and its impact on the environment. *International Journal of Environmental Research and Public Health*, *18*(3), 1–24. https://doi.org/10.3390/ijerph18031112

UCDA. (2015). Uganda Coffee Development Authority: Corporate Plan 2015/16 – 2017/18.

UCDA. (2017). Annual Report 2016/17. Kampala: Uganda Coffee Development Authority.

UCDA. (2021). Uganda Coffee Development Authority (UCDA) Strategic Plan: FY 2020/21 - 2024/25.

Venancio, L. P., Filgueiras, R., Mantovani, E. C., do Amaral, C. H., da Cunha, F. F., dos Santos Silva, F. C., Althoff, D., dos Santos, R. A., & Cavatte, P. C. (2020). Impact of drought associated with high temperatures on Coffea canephora plantations: a case study in Espírito Santo State, Brazil. In *Scientific Reports* (Vol. 10, Issue 1). Nature Publishing Group UK. https://doi.org/10.1038/s41598-020-76713-y

Verter, N., Bamwesigye, D., Darkwah, S. A., & Brno, M. U. (2015). Analysis of Coffee Production and Exports in Uganda. *In International Conference on Applied Business Research*, *1*, 1083–1090.

Wagner, S., Jassogne, L., Price, E., Jones, M., & Preziosi, R. (2021). Impact of climate change on the production of coffea arabica at Mt. Kilimanjaro, Tanzania. In *Agriculture (Switzerland)* (Vol. 11, Issue 1). https://doi.org/10.3390/agriculture11010053

Zayan, S. A. (2019). Impact of climate change on plant diseases and IPM strategies. In Plant Diseases-Current Threats and Management Trends. *IntechOpen.* https://doi.org/10.22268/ajpp-036.1.075079

Zhao, T., & Dai, A. (2017). Uncertainties in historical changes and future projections of drought. Part II: model-simulated historical and future drought changes. *Climatic Change*, *144*(3), 535–548. https://doi.org/10.1007/s10584-016-1742-x

Zuluaga, V., Labarta, R., & Läderach, P. (2015). Adaptation to Climate Change: The Case of Nicaraguan Coffee Sector. In Selected Paper prepared for presentation at the 2015 Agricultural & Applied Economics Association and Western Agricultural Economics Association Annual Meeting, San Francisco, CA, July.

APPENDICES

Appendix A1: Informed consent document (ENGLISH VERSION)

Version 2.0

Title of the study: "**The Relationship Between Perceived Climate Variabilities and the Use of Purchased Farm Inputs Among Coffee Growers in the Cattle Corridor of Central Uganda.**"

Investigator: Mbabazi Harriet

Institution: Gulu University

Introduction:

I am Mbabazi Harriet, currently enrolled as a student in the Master of Science program in Agri-enterprises Development at Gulu University. I'm conducting a survey on the **"The relationship between perceived climate variabilities and the use of purchased farm inputs among coffee growers in the cattle corridor of central Uganda"** You have been chosen to take part in this research due to your experience in coffee production. You will be requested to provide your consent by signing a document upon accepting to take part in the study, and you will be provided with a copy for your records.

Research funding:

This research is funded by MasterCard Foundation and Regional Universities' Forum for Capacity Building in Agriculture (RUFORUM).

Study purpose:

This research aims to examine the perceptions of farmers on climate variability in coffee production and the utilization of purchased inputs. This information will further guide policy makers and the government to design localized programs and estimate budgets for subsidizing coffee farm inputs aimed at mitigating climate risks. The study findings will also help build on the already knowledge as regards climate variability in coffee.

Procedures:

You will be required to attend to the questions presented in the questionnaire with the assistance of the research team.

Who will take part in this research?

You have been considered for this study because you're among the smallholder coffee growers in the dry cattle corridor of central Uganda. A maximum of 30 minutes will be required for the interview.

This research will consider a sample of about 385 participants.

Discomforts/Risks:

Risk of spread of Covid-19, the investigators are dedicated to ensure maximum safety of participants through observing the Standard Operating Procedures (SOPS) issued by the Ministry of Health to mitigate against the risk of infection of COVID-19. The following will be done; the research team will wear face masks prior to the interview and also provide participants with masks, physical distancing will be observed, and hand hygiene will also be maintained using sanitizers. Therefore, no risk or discomfort is expected to emanate from your involvement in this survey research, except for encroachment on your personal time.

Benefits:

After compilation of the study findings by the research team, and action from the relevant institutions, benefits can be obtained. For instance, all study participants will receive information on the progress and key findings of the study.

Confidentiality:

Your identity will remain confidential as we will employ codes for participant identification, and the data will not be disclosed to anyone other than the research team. The password will be used to safeguard soft copies of the data while the hard copy documents will be securely stored.

Alternatives:

Participation in this study is entirely optional, and you won't face any repercussions or loss of benefits if you choose not to participate.

Cost:

Your participation in this research will not result in any extra expenses.

Questions:

For any inquiries regarding this study, reach out to the principal investigator, Mbabazi Harriet, on telephone number 0773902992 or by email; harrietmbabazi28@gmail.com.

Statement of voluntariness:

The decision to take part in this study is entirely voluntary and you are free to decide whether or not to participate. You are free to withdraw from the study at any point without facing any consequences.

If you encounter any challenges pertaining to your rights and participation in the study, please reach out to the chairperson, Gulu University Research Ethics Committee, Dr. Gerald Obai Tel: No.,

0772305621; email: lekobai@yahoo.com/lekobai@gmail.com; or the Uganda National Council for Science and Technology, on plot 6 Kimera Road, Ntinda, Kampala on Tel 0414705500.

Statement of consent

The research team has described to me what is going to be done, the risks, the benefits involved and my rights as a participant in this study. I acknowledge that my decision to take part in this study will have no negative impact on me. I believe that my identity will be protected in the use of this information. I am aware that I may withdraw at any time. I understand that by signing this form, I do not waive any of my legal rights but merely indicate that I have been informed about the research study in which I am voluntarily agreeing to participate. A copy of this form will be provided to me.

Name of participant……Signature/Thumbprint……...Date…….

Name of witness……Signature……Date……

Name of interviewer……. Signature……Date……

Appendix A2: Informed consent document (Luganda version)

Version 2.0

<u>Ekiwandiiko Ekiteebwako Omukono Oluvanyuma Lw'okunyonyora Ebikwata Ku Musomo</u>

Omutwe gw'omusomo: "Okunonyereza kukirowoozebwa engeri enkyukakyuka yo'budde gy'ekosezzamu okulima emmwanyi naddala mubitundu ebisinga okosebwa ekyeya mu makati ga Uganda (oba kiyite cattle corridor)"

Omunonyereza: Mbabazi Harriet

Ettendekero: Gulu University

Okwanjula:

Elinya lyange nze Mbabazi Harriet, omuyizi kutendekero lya "Gulu University" era nga nkola diguri eyawaggulu mu byo kutumbula bizineensi ze'ebyobulimi oba kiyite "Agri-enterprises Development". Ndi mukkola okunonyereza kukirowoozebwa engeri enkyukakyuka yo'budde gy'ekosezzamu okulima emmwanyi naddala mubitundu ebisinga okosebwa ekyeya mu makati ga Uganda (oba kiyite cattle corridor). N'olwensonga eyo, olondeddwaokwetaba mumusomo guno olw'obumanyirivu bw'olina mukulima emmwanyi. Ojja kusabibwa okuteekako omukono oba ekinkumu oluvanyuma nga okkiriza okwetaba mumusomo guno. Olw'obulambulukufu, ojja kusigazaako kopi ku bbaluwa eno.

Okunonyereza kuno, kuwaggidwa ebitongole bino wamanga;

MasterCard Foundation ne Regional Universities' Forum for Capacity Building in Agriculture (RUFORUM).

Ekigendererwa ky'okunonyereza kuno:

Omusomo guno gugenderedwamu okumanya engeri abalimi b'emmwanyi mu makatti ga Uganda, gyebategeeramu ebyo ebiretebwa enkyukakyuka y'obudde ku mmwanyi. Olwonno, ebinaava mukunonyereza, bijja kuyambako abatekatekera eggwanggga okufuna enkola enayambako okusala kubisale by'ebikozesebwa mukulima gamba nga; ebigimusa, eddagala ly'ebirime n'ebirala. Enkola eno ejja kuyambako okukendeza kw'ebyo ebikosa emmwanyi olw'enkyukakyuka y'obudde. Okunonyereza kuno era kujjakwongera kwebyo ebigenze bizuulwa abanonyereza abalala kunkyukakyuka y'obudde ku mmwanyi.

Ebinagobererwa:

Aneetaba mukunonyereza kuno, ajja kuyambibwako omunonyereza okuddamu ebibuuzo ebinamubuzibwa.

Ani anetaba mu musomo gunno?

Omulimi w'emmwanyi yenna awangalirira mubitundu ebiriranye ebyo ebisinga okosebwa ekyeya mu makati ga Uganda (oba kiyite cattle corridor). Okubuzibwa ebibuuzo kujja kutwala eddakiika ezitassuka makumi asatu (30). Abantu nga bisatu kinaana mu ttaano (385) beebetagibwa okwetaba mumusomoguno.

Okutataganyizibwa/Ebizibu olw'okwetaba mumusomo guno:

Okutya okusigibwa covid-19, akabinja kabanonyereza kakakafu nti kajja kukuuma obulamu bwabaneetaba mukunonyereza kuno nga kassa munkola ebyo ebyaragirwa ekitongole kye'byobulamu mu kwetangira okusigiibwa covid-19. Bino wamanga bijja kukolebwa; akabijja kabanonyereza kajja kwambala obukokolo obubikka emimwa ne nyindo era bawe abanetaba mukunonyereza kuno obukokolo nga okunonyereza tekunatandika, ebbanga lijja kukumibwa wakati wenjuyi ebbiri n'okukakasa nti sanitayiza zikozesebwa okukuuma engalo nga nyojjo. Nowlekyo, tewajjakubaawo kizibu kyona kinakutukako nga kyekuusa ku kwetaba mumusomo guno. Mpoziko okutataganyizibwamu okutonotono olw'obudde bwonomala nga oddamu ebibuuzo ebinakubuzibwa omunonyereza.

Emigaso gy'okwetaba mumusomo guno:

Emigaso gy'okwetaba mumusomo guno gijja kutukibwaako oluvanyuma lw'abo bekikwatako okuteeka munkola ebyo omunonyereza byanaaba ayanjudde mu alipoota. Abaneetaba mukunonyereza kuno bajjakuba bategezebwa ebinaba bizuliddwa nga alipoota emaze okutekatekebwa.

Okukuuma n'obwegendereza ebikwata kw'oyo aneetaba mukunonyereza kuno:

Ebyo byonna ebikukwatako bijja kukuumibwa nga byakyama era bijja kukozesebwa abo bokka abavunanyizibwa kukunonyereza kuno.

Eddembe ly'okwesalirawo:

Oliwaddembe obuteetaba mu musomo guno bwoba nga toyagadde era tewali ayinza kukukaka.

Emisoso:

Toyina ssente zonna zojja kusaasanya olw'okwetaba mumusomo guno.

Ebibuuzo:

Bw'oba oyina ekibuuzo kyonna eky'ekuusa kukunonyereza kuno, oliwaddembe okutukirira omunonyereza omukulu ku nnamba y'essimu eno; 0773902992 oba kumukutu gwa Gmail; harrietmbabazi28@gmail.com.

Sitatimenti y'okwewayo okwetaba mumusomo guno:

Otegezebwa nti okwetaba mumusomo guno kyabweyagalire era oliwaddembe okuguvaamu kumutendera gwonna nga okunonyereza kugenda mumaaso. Tukutegeeza nti tewali kibonerezo kyonna kijja kukuweebwa nga osazeewo okuva mumusomo guno.

Bwoba nga olina okwemulugunya kwonna kubikwatagana ne ddembe lyo nga kwekuusa ku musomo guno, tuukirira Ssentebbe akulira akakiiko akakola ku by'empisa mukunonyereza ku tendekero lya Gulu; Dr.Gerald Obai ku ssimu eno; 0772305621 ne kumukutu gwa Gmail: lekobai@yahoo.com/lekobai@gmail.com. Oba tuukirira ab'akakiiko ka Uganda akavunanyizibwa ku bya sayansi ne tekinologiya, ku kibanja namba 6, Kimera Road, Ntinda, Kampala ku namba y'essimu eno, 0414705500.

Sitatiimenti y'okukkiriza okwetaba mumusomo guno:

Abanonyereza banyinyonyodde bulikimu ekikwatagana kumusomo guno, era nga ndi mumativu nti okwetaba mumusomo guno tekijja kunkosa mu buli ngeri. Nkakasiddwa nti ebinkwatako bijja kukumibwa nga byakyama eranga nsobola okuva mumusomo guno kumutendera gwonna nga okunonyereza kugenda mumaaso. Okussaako omukono kiwandiiko kino tekitegeeza nti eddembe lyange ely'okwerwanako mumateeka linzigiddwako, wabula okulaga nti ntegezeedwa ebikwatagana kumusomo guno era nenzikiriza okugwetabamu. Kopi y'ekiwandiiko kino ejja kuba nga empeebwa.

Elinya ly'oyo akkiriza okwetaba mumusomo……

omukono/Ekinkumu…….....Ennaku z'omwezi…….

Elinnya ly'omujurizi……. omukono/Ekinkumu……....Ennaku z'omwezi…….

Elinnya ly'omunonyereza…… omukono/Ekinkumu…….....Ennaku z'omwezi..

Appendix B: Research work plan

Activities / Months	2022						2023											
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Proposal writing and Defense																		
Site selection and designing the study sampling units																		
Acquisition of the research materials, equipment andstationeries.																		
Recruiting the research team																		
Data collection																		
Data cleaning and analysis																		
Thesis writing and progress report, intention to submit dissertation																		
Working on final comments from supervisors																		
Submission of dissertation for external examination																		
Viva Voce examination																		
Compilation of final book and submission to directorate of research and graduate training																		

Appendix C: Data collection tool (Questionnaire)

Version 2.0

Gulu University
Faculty of Agriculture and Environment
Department of Rural Development and Agribusiness
Household Survey Questionnaire on climate effects in coffee production

Questionnaire ID: …… Date of Interview:……. Name of interviewer:……

Introductory statement:

I am…… coming from the Department of Rural Development and Agribusiness, at Gulu University. We are conducting a study on climate effects in coffee production. You have been selected to participate in this study because of your involvement in coffee as a crop. We will be asking you some questions to help us complete this study. We request for your candid responses. For your assurance, all responses and your identity will be treated with confidentiality. Neither your identity nor your responses will be shared with any other person or organizations except for the purposes of this study. If you consent to participate in the study, kindly confirm by signing or thumb print in the space below. **Thank you for your kind co-operation**.

Respondent signature/ thumb print……

PART 1. HOUSEHOLD &VILLAGE IDENTIFICATION, SOCIO-ECONOMIC CHARACTERISTICS & INFRASTRUCTURE

1.1 Household Identification & socio-economic characteristics	**Code**		**7.** what is the education level of household head **(years of schooling**)	
1. District 1=Luwero 0=Nakasongola			**8.** What is the Farming experience of household head? (years)	
2. Sub-County 1=Kikyusa 0=Kakooge			**9.** In the previous 12 months have you received any extension advise on farm? **0=No, 1=Yes**	
3. Sex of household head 1=Male 0=Female			**10. If yes,** what was the focus of extension advise? **CODE 4** **(*Please select as many as may apply)***	
4. Age of household head (complete years**)**			**11. If yes,** what was the source of extension advise? **CODE 2**	
5. Number of people in the Household			**12.** Have you been able to borrow money in the previous 3years? **0=No, 1=Yes**	
6. Marital status of household head **CODE 1**			**13. If yes,** from which sources**?** **CODE 3**	

CODE 1	**CODE 2**	**CODE 3**	**CODE 4**
1.Married	1.Extension officers	1.Banks 3. village savings groups	1. Climate Smart practices 4. Land conservation practices

2.Never married 3.Divorced/separated 4.Widow/widower	2. Radio programs 3. Farmers' groups 4. Others specify……	2.Microfinace 4. farmer groups 5.othersspecify……	2. Pest and disease management 5. post-harvest handling 3. Marketing information on prices 6. market information on buyers 7. Crop husbandry practices 8. Livestock handling 9. Others specify……

PART 2: COFFEE PRODUCTION FOR 2021/2022 CROPPING SEASON

2.A: Coffee output.

In the table below, we are interested in information concerning your coffee production. Kindly respond to the questions below.

1. Do you grow coffee? **A1**	**2. If yes**,, what coffee types do you grow? **A2**	3. What are the reasons for growing the coffee types? **A3**	**4. If yes**, how many land parcels do you grow your coffee?	5. Please indicate the size of each land parcel **(acres**)		6. At what spacing did you plant your coffee? (ft)	7. How much dry coffee cherries did you collect in the last one year**? (kgs)**
				Parcels	**Size (acres)**		
				Parcel 1			
				Parcel 2			
				Parcel 3			
				Parcel 4			
A1: Grow Coffee Yes = 1 No = 0	**A2: Coffee Types** Clonal = 1 Elite = 2 Not sure = 3	**A3: Reasons for Coffee Type** 1.High yielding 3. Early maturing 5. Drought resistant 7. High Quality 2.Disease resistant 4. Less labour intensive 6. Attracts higher pay 8. Gives bigger cherries **9. Other specify** ……					

2.B: Use of Farm Inputs Use in Coffee Production

1. Have you bought farm inputs for your coffee before? **B1**	**2.** If yes, what kind of farm inputs did you buy? **(Please select as many as may apply) B2**	***3.* If not**, are there any inputs you acquire and apply on your farm? **B3**	**4. If you** have applied the inputs, which ones? **(Select as many as may apply) B4**	**5. If you are using inputs in your coffee,** indicate the number of times you have applied, against each of the inputs below in the last 3 years.	**6. If you are not** using the input, estimate the number of times, other coffee farmers you know have applied each of the input below in the **last 3 years?**	**7. If you are using the input**, **how** many times were you applying this input in a similar time period before **the last 3 years?**	**8. If not using,** estimate the number of times other coffee farmers you know have applied each of the input below in a similar period in the **last 3 years**?	**9. If you are using the inputs**, what quantity (**kg)** do you estimate to have used each time you apply the input in your coffee.
		B3: Apply inputs		Foliar Fertilizers ……	Foliar Fertilizers ……..	Foliar Fertilizers ……..	Foliar Fertilizers …….	Foliar Fertilizers …….

B1: Buy inputs Yes = 1 No = 0	B2: Inputs types bought **1**.Foliar Fertilizers **2**. Soil Fertilizers **3.** Manure **4.** Pesticides **5.** Herbicides **6.** Mulch	Yes = 1 No = 2	B4: Input types applied **1**.Foliar Fertilizers **2**. Soil Fertilizers **3.** Manure **4.** Pesticides **5.** Herbicides **6.** Mulch	Soil Fertilizers …… Manure …… Pesticides…… Herbicides …… Mulch……	Soil Fertilizers …… Manure …… Pesticides…… Herbicides …… Mulch……	Soil Fertilizers …… Manure …… Pesticides…… Herbicides …… Mulch……	Soil Fertilizers …… Manure …… Pesticides…… Herbicides …… Mulch……	Soil Fertilizers …… Manure …… Pesticides…… Herbicides …… Mulch……

In the table below, we are interested in information concerning the farm inputs you use in coffee production. Kindly respond to the questions below.

2.C: Labour Use in Coffee Production

In the table below, we are interested in knowing the Labour time allocated to coffee production. Kindly indicate your response in the table below.

1. Do you use hired labour in your farming activities? **C1**	**2.** What are the number of labour persons (including hired& family) and time spent in each of the indicated activities across in your coffee?		**Labour use in various coffee production activities for 2021/2022 cropping season**								
			3. Tilling in the coffee garden	**4.** Weeding coffee	**5.** Spraying herbicides	**6.** Spraying pesticides	**7.** Applying mineral fertilizer (e.g., NPK, or urea fertilizers)	**8.** Applying manure (e.g., livestock dung)	**9.** Pruning coffee trees	**10.**Harvesting coffee cherries	**11.** Drying coffee cherries
C1: Hire labour Yes = 1 No = 1	**Males**	# Persons									
		# Days									
		# Hours per day									
	Females	# Persons									
		# Days									
		# Hours per day									

2.C.3 What is the cost of hiring casual labor in your village (UGX/day) [……]

PART 3: FARMER PERCEPTIONS ON CLIMATE VARIABILTY AND MANAGEMENT PRACTICES

3.A: Farmer's perceptions on climate variability

In the table below, we are interested in knowing how you have experienced the following climate variabilities. Kindly indicate your responses below.

	Type of Climate Variabilities	**1. Please show** in the space provided whether you have experienced the climate variability in the last 3 years. **1=yes, 2=no & 3= Not sure**	**2. If yes, p**lease estimate the number of times this climate variability has occurred in the previous 3 years.	**3. If yes, p**lease, estimate the number of f times the climate variability was occurring in simila time period before the last 3 years	**4. On a scale** of 1-10 points, Please rate the extent of impact of the climate variability on your coffee ***(1=low impact & 10=very high impact)***
a)	**Perceived rainfall variability**				

1	Short rainfall duration during the rainy season				
2	Low rainfall amounts during the rainy season				
3	High rainfall amounts during rainy season				
b)	**Perceived temperature variability**				
4	Extreme hot days during dry season				
5	Hot days during rainy season				
c)	**Perceived dry spell variability**				
6	Prolonged (unusual) dry spell				
7	Short dry spells				
8	Occurrence of unusual dry spells with in a rainy season				
d)	**Perceived wind variability**				
9	Excessively Strong winds (probably, breaking trees)				
10	Frequent occurrences of strong winds with in a season				
e)	**Perceived hail storm variability**				
11	Unusually heavy hail storms				
12	Frequent occurrence of hailstorms				
13	Others specify……				

3.B Farmer Perceptions on coffee crop-climate effects

	Types of crop-climate effects	**1. Please** show whether you have experienced the crop climate effect(s) below in the previous 3 years. **1=yes; 2=no and 3=Not sure**	**2. Please**, estimate the number of times this crop climate effect has occurred in the previous 3 years	**3. Please**, estimate the number of times the crop climate effect was occurring in a similar time period before the previous 3 years.	**4. On scale** of 1-10 points, please the extent of impact of the climate crop effect on your earnings from coffee***. (1 = low impact and 10 = very high impact)***
a)	**Perceived climate effects on coffee Plants**				
1	Excessive drying of coffee crop leaves				
2	Excessive breakage of coffee tree branches				
b)	**Perceived climate effects on coffee flowering**				
3	Excessive dropping of coffee flowers				
4	Offseason coffee flowering				
5	Less coffee flowering				
c)	**Perceived climate effects on coffee yields**				
6	Low coffee harvests				
7	Large proportion of coffee cherry harvests with unfilled beans				
8	Low weight dry coffee cherries				
d)	**Perceived climate effects on coffee bean quality**				
9	Low weight coffee beans				

10	Small size coffee beans				
e)	**Perceived climate effects on pest and disease incidence**				
11	Increased incidence of usual pests				
12	Increased outbreak of unknown pests				
13	Increased outbreak of coffee crop diseases				
f)	**Perceived climate effects on arable coffee land**				
14	Unusual drying of the soil in the coffee garden				
15	Unusual soil water run off				
16	Unusual water logging in coffee garden				
17	**Others specify**……				

In the table below, we are interested in knowing how climate variabilities affect your coffee crop. Kindly indicate your responses in the spaces provided.

3.B.5 Did extension agents or others, discuss about climate variability effects on crop production and means of reducing it? [……] 0=No, 1=Yes

3. C: Land Conservation and Management Practices

In the table below, we are interested in knowing the soil and land management practices you carry out in regard on your farm. Kindly indicate your responses in the spaces provided.

1. Are you aware of any soil conservation practice(s)? **C1**	**2. If yes**, which ones do you know? ***Please select as many as may apply) C1***	**3. If yes**, which ones (s) do you practice on your farm? ***Please select as many as may apply) C1***	**4. If you have carried out the soil conservation practices below**, estimate the number of times you implemented this on your farm in the last 3 years?	**5. On a scale of 1-10 points**, please rate the extent to which the soil conservation practices reduce the climate impacts on your coffee***. (1 = low extent and 10 = very high extent)***	**6. On a scale of 1-10 points**, please rate the extent to which the soil conservation improves coffee harvests. ***(1 = low extent and 10 = very high extent)***
C1: Aware **Yes = 1** **No = 2**			Mulching ……...	Mulching ……	Mulching ……
			Organic manure……	Organic manure……	Organic manure……
			Planting cover crops……	Planting cover crops……	Planting cover crops……
			Breaking hard pan(s) ……	Breaking hard pan(s) ……	Breaking hard pan(s) ……
			Erosion control trenches ……	Erosion control trenches ……	Erosion control trenches ……
			Watering coffee crop ……...	Watering coffee crop ……...	Watering coffee crop ……...
			Slashing weeds……	Slashing weeds……	Slashing weeds……

C1: Conservation Practices

1. Mulching **3.** Intercropping with cover crops **5.** Intercropping (with bananas) **7.** Water harvesting trenches **9.** Manure application

2. maintaining shade trees **4.** watering coffee crop **6.** No tillage practices in coffee garden **8**. Breaking hard pans **10**. Others (specify)_____

Thank you for your time and participation

END

Appendix D: COVID 19 Risk Management Plan

MEASURES FOR THE PREVENTION AND CONTROL OF RISK OF SPREAD OF COVID-19 AND EBOLA

Study Title: The relationship between perceived climate variabilities and the use of purchased farm inputs among coffee growers in the cattle corridor of central Uganda.

Principal Investigator (s): Mbabazi Harriet -0773902992-harrietmbabazi28@gmail.com.

Introduction:

The novel Coronavirus is primarily transmitted from person to person through respiratory droplets and close contact with an infected individual. Symptoms of infection include; fever, cough, and, in severe cases, pneumonia, acute respiratory syndrome, kidney failure, and death. Uganda's government has implemented guidelines and restrictions since March 2020 to curb the spread of COVID-19, including ongoing travel restrictions. Additionally, the Uganda National Council for Science & Technology (UNCST) has issued research guidelines aligned with the Ministry of Health's COVID-19 and Ebola prevention guidelines, ensuring the safety and well-being of both research participants and teams.

Implementation of the prevention and control measures

The research team is dedicated to safeguarding the well-being of its members, research participants, and the communities involved in the study. They will comply with the Ministry of Health's Standard Operating Procedures and presidential directives to minimize the risk of COVID-19 and Ebola transmission. The measures will include screening, wearing masks, maintaining physical distance, and practicing good hand hygiene to rapidly identify and respond to any potential cases during the study.

Procedures to be followed during the implementation of the research. Prior to data collection.

1. **Health guidance:** Training sessions will be organized for COVID-19 & Ebola sensitization and awareness, to equip the research team with knowledge of signs and symptoms of the COVID-19 and Ebola, and preventive measures such as hand hygiene before placing and removing the

mask, as well as storage of the mask, social distancing. The research team will circulate notices, posters, charts on common signs and symptoms of COVID-19 and Ebola as provided by the Ministry of Health, and develop and/or use existing plan for the appropriate referral pathway for identified and/or suspected cases.

2. **Personal Screening:** All the individuals engaged in research activities will screen temperature daily for fever. Screening for temperature will be carried out during planning meetings, trainings, community outreach. Any individual found with or suspected of COVID 19 and Ebola symptoms will be withdrawn and referred to the COVID – 19 and Ebola task force for further assessment and management. The withdrawn individual will be allowed to return only if they present a valid certification of their COVID-19 and Ebola status showing negative result
3. **Wearing face coverings:** All the individuals engaged in research activities that require interaction with fellow researchers or research participants or the community member will have to wear a face mask that fully covers the mouth and nose at all times. The study will provide face masks for individuals who do not have.
4. **Physical Distancing:** Social distancing of 2 meters minimum will be maintained during all the research activities. The research team will be advised not to congregate in common areas, especially during breaks.
5. **Good hygiene:** Use of hand sanitizers and washing of hands will be mandatory for the research team and other participants before and after entering the training room, and other common areas. Hand washing equipment shall be supplied and made available at all times. All surfaces and equipment shall be sanitized frequently.

During data collection

1. **Personal Protective Equipment (PPE):** All research assistants and participants will be required to wear personal protective equipment (PPE) including well-fitting face masks. They will also be expected to practice hand hygiene by either washing their hands with soap and water or using hand sanitizer before the interview. Physical contact, such as handshakes and hugging, is strictly prohibited. Furthermore, a minimum distance of 2 meters will be maintained during all research-related activities to ensure physical distancing.
2. **Consent Process:** The research team will maintain a distance of 2 meters when obtaining consent from participants upon arrival. All research participants will follow hand hygiene protocols by either washing hands with soap and water or using hand sanitizer before the

interview. Subsequently, participants will receive information and awareness regarding COVID-19 and Ebola, along with preventive measures.

During Dissemination/Community engagement

1. **Community Engagement:** The research team will carry educational materials on COVID-19 and Ebola prevention in a language comprehensible to the study participants. Also, these materials will have visual aids to facilitate better understanding. The research team and research participants will adhere to hygiene protocols, such as hand washing with soap and water or use of hand sanitizers before the interview. Additionally, screening for temperature will be conducted before community engagements.
2. **Equipment sanitization:** The research team shall frequently sanitize all the shared devices used during community engagements.

The preventive and control measures will continuously be reviewed based on new information and guidelines communicated by the Ministry of Health

Appendix E: community engagement plan.

Community Engagement Plan

The key community stake holders to be involved include; District Agricultural/ Extension Officers, Sub- County/parish chiefs and LC1 Chairpersons.

The research team will include the following;

- The research project leader; I will train the research team, oversee the activities and provide all necessary assistance to ensure success of the project.
- Supervisor(one); he/she will provide maximum guidance on the tool and all relevant support for enumerators to ensure that timely and quality data is collected.
- Data enumerators; a maximum of 7 enumerators will be recruited to gather data from a maximum of 385 coffee growers in two weeks' time.

Pre-study activities; community mapping to help in resource coordination; identification and consultation with key stakeholders, local leaders, identification of community norms and values, recruitment, training and introducing the research team to the community, mobilizing the target group, pre-testing of the Questionnaire and making necessary adjustments, community sensitization, and formative consultations all of which will set a good foundation for implementation.

Study Implementation activities; consulting key stakeholders, sensitizing the community about the research project; organizing the community for participation in the research project as key respondents. The farmers of the same parish will be will be organized in one place for interviews about the research project. Data collection and compilation will be conducted by the research team. Each farmer respondent will be given a bar of soap for appreciation.

Post-study activities: Providing feedback and disseminating research findings, and discussing the application of research findings with host communities and other relevant key stakeholders.

Appendix F: Binary Probit regression results for coefficients and Marginal effects (STATA output)

```
. probit B1_farminputs lnAge Educ_level lntotal_land lnHHSize Borrowing HH_Sex S3B5_extclimate  C1_usehiredlabour Types_grown_3local change_lowrainfall_ocurrances change_prolongedspell_oc
> urrances change_excessiverains_ocurrances change_freqhailstorms_ocurrances,robust

Iteration 0:   log pseudolikelihood = -172.66607
Iteration 1:   log pseudolikelihood = -136.91646
Iteration 2:   log pseudolikelihood = -136.20853
Iteration 3:   log pseudolikelihood = -136.20668
Iteration 4:   log pseudolikelihood = -136.20668

Probit regression                                 Number of obs     =        272
                                                  Wald chi2(13)     =      55.87
                                                  Prob > chi2       =     0.0000
Log pseudolikelihood = -136.20668                 Pseudo R2         =     0.2112
```

B1_farminputs	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnAge	-.8887941	.3508083	-2.53	0.011	-1.576366	-.2012225
Educ_level	.0184953	.0285493	0.65	0.517	-.0374603	.0744509
lntotal_land	.4831161	.1332255	3.63	0.000	.2219988	.7442333
lnHHSize	-.3551664	.1530142	-2.32	0.020	-.6550687	-.0552641
Borrowing	.3464235	.2013757	1.72	0.085	-.0482656	.7411126
HH_Sex	.0284706	.207317	0.14	0.891	-.3778632	.4348045
S3B5_extclimate	.3964211	.1878656	2.11	0.035	.0282113	.7646309
C1_usehiredlabour	.6428651	.1864016	3.45	0.001	.2775246	1.008206
Types_grown_3local	-.6894458	.440707	-1.56	0.118	-1.553216	.1743242
change_lowrainfall_ocurrances	.0110738	.0950501	0.12	0.907	-.1752211	.1973687
change_prolongedspell_ocurrances	-.0005382	.1371362	-0.00	0.997	-.2693203	.2682439
change_excessiverains_ocurrances	.1346484	.1769288	0.76	0.447	-.2121256	.4814224
change_freqhailstorms_ocurrances	-.4197977	.165368	-2.54	0.011	-.743913	-.0956824
_cons	4.260922	1.579699	2.70	0.007	1.164768	7.357076

Appendix G: Binary Probit regression results showing Marginal effects (Stata Output)

```
. mfx

Marginal effects after probit
      y  = Pr(B1_farminputs) (predict)
         =  .71556745
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
lnAge	-.3014592	.11798	-2.56	0.011	-.532701	-.070217	3.93261
Educ_l~l	.0062732	.00967	0.65	0.517	-.01268	.025226	5.5625
lntota~d	.1638622	.04443	3.69	0.000	.076788	.250937	.681883
lnHHSize	-.1204645	.05145	-2.34	0.019	-.221307	-.019622	1.82813
Borrow~g*	.1124745	.06226	1.81	0.071	-.009545	.234494	.305147
HH_Sex*	.0096891	.07083	0.14	0.891	-.12913	.148509	.709559
S3B5_e~e*	.1300284	.05941	2.19	0.029	.013597	.24646	.375
C1_use~r*	.2260659	.06699	3.37	0.001	.094776	.357355	.647059
Type~cal*	-.1876441	.08827	-2.13	0.034	-.360649	-.014639	.933824
change..	.003756	.03224	0.12	0.907	-.05944	.066952	.928529
c~rolo~s	-.0001826	.04651	-0.00	0.997	-.091349	.090984	.537316
change..	.0456697	.05998	0.76	0.446	-.07188	.16322	-.299265
change..	-.142386	.05594	-2.55	0.011	-.252028	-.032744	-.011066

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Appendix H: Post estimation multicollinearity test results for the binary probit regression model

```
. cor B1_farminputs lnAge Educ_level lntotal_land lnHHSize Borrowing HH_Sex S3B5_extclimate  C1_usehiredlabour Types_grown_3local change_lowrainfall_ocurrances change_prolongedspell_ocurr
> ances change_excessiverains_ocurrances change_freqhailstorms_ocurrances
(obs=272)
```

	B1_far~s	lnAge	Educ_l~l	lntota~d	lnHHSize	Borrow~g	HH_Sex	S3B5_e~e	C1_use~r	Type~cal	change..	c~rolo~s	change..	change..
B1_farminp~s	1.0000													
lnAge	-0.1960	1.0000												
Educ_level	0.2062	-0.2093	1.0000											
lntotal_land	0.2932	-0.0119	0.2002	1.0000										
lnHHSize	-0.0266	0.0065	0.0384	0.2328	1.0000									
Borrowing	0.1775	-0.1676	0.1130	0.1331	0.1966	1.0000								
HH_Sex	0.1009	-0.2084	0.2133	0.2956	0.1915	0.0195	1.0000							
S3B5_extcl~e	0.1735	-0.1174	0.1752	0.0764	0.0089	0.1134	0.0272	1.0000						
C1_usehire~r	0.2981	-0.0403	0.2144	0.2196	0.0281	0.1553	-0.0150	0.0318	1.0000					
Types_gr~cal	-0.1243	0.0716	-0.1750	-0.0561	0.0092	-0.0484	-0.0726	-0.0076	-0.0728	1.0000				
change_lo~es	0.0352	0.0279	-0.0838	0.0749	-0.0053	0.0672	-0.0256	-0.0923	0.0256	-0.0905	1.0000			
change_pro~s	-0.0335	0.0260	-0.1197	0.0231	0.0044	0.0231	-0.0443	-0.1610	-0.0791	-0.0123	0.4242	1.0000		
c~rains_oc~s	0.0109	-0.0146	0.0434	-0.0567	0.0246	0.0346	0.0258	-0.0265	0.0250	0.1345	-0.3002	-0.2307	1.0000	
change_f~ces	-0.1167	-0.0602	-0.0059	0.0037	-0.0961	-0.0087	0.0332	0.0107	-0.0177	0.0255	-0.0772	-0.0108	0.0301	1.0000

Appendix I: Estat classification results for the fitted binary probit regression model

```
. estat classification

Probit model for B1_farminputs

              -------- True --------
Classified |         D            ~D  |      Total
-----------+--------------------------+-----------
     +     |       163            41  |        204
     -     |        19            49  |         68
-----------+--------------------------+-----------
   Total   |       182            90  |        272

Classified + if predicted Pr(D) >= .5
True D defined as B1_farminputs != 0
--------------------------------------------------
Sensitivity                     Pr( +| D)   89.56%
Specificity                     Pr( -|~D)   54.44%
Positive predictive value       Pr( D| +)   79.90%
Negative predictive value       Pr(~D| -)   72.06%
--------------------------------------------------
False + rate for true ~D        Pr( +|~D)   45.56%
False - rate for true D         Pr( -| D)   10.44%
False + rate for classified +   Pr(~D| +)   20.10%
False - rate for classified -   Pr( D| -)   27.94%
--------------------------------------------------
Correctly classified                        77.94%
--------------------------------------------------
```

Appendix J: Propensity Score matching and covariate balance test results (summaries and Balance plots)-Stata outputs

J1: Treatment Effects test and balancing test of purchased inputs' use on coffee harvests

```
. teffects psmatch ( change_lowharvests ) (B1_farminputs lnAge Educ_level lntotal_land lnHHSize Borrowing HH_Sex S3B5_extclimate  C1_usehire
> dlabour Types_grown_3local change_lowrainfall_ocurrances change_prolongedspell_ocurrances change_excessiverains_ocurrances change_freqhail
> storms_ocurrances, probit), atet nneighbor(1)

Treatment-effects estimation                   Number of obs      =        272
Estimator      : propensity-score matching     Matches: requested =          1
Outcome model  : matching                                  min =          1
Treatment model: probit                                    max =          1
```

change_lowh~s	Coef.	AI Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
ATET						
B1_farminputs (Yes vs No)	-.3618132	.1776917	-2.04	0.042	-.7100826	-.0135438

```
. tebalance summarize
note: refitting the model using the generate() option
```

Covariate balance summary

	Raw	Matched
Number of obs =	272	364
Treated obs =	182	182
Control obs =	90	182

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
lnAge	-.4362051	.0595972	1.452186	1.030214
Educ_level	.4511648	-.1992218	1.143868	.6157331
lntotal_land	.6529803	-.0965064	1.066575	.5701487
lnHHSize	-.0569524	.17353	1.113724	1.510625
Borrowing	.3948116	-.0227235	1.500074	.9876161
HH_Sex	.2112719	.2149334	.8312587	.8343195
S3B5_extclimate	.3808476	.0667018	1.283939	1.022622
C1_usehiredla~r	.645885	.2736289	.7605877	.8023599
Types_grown_3~l	-.2900291	-.0398581	3.669424	1.129252
change_lowrai~s	.0744093	-.1345696	.9662149	2.122142
change_prolon~s	-.071428	-.4031569	1.088485	1.509537
change_excess~s	.0231006	-.0207376	1.053886	1.011094
change_freqha~s	-.242968	-.1462325	.7583755	1.299452



J2: Treatment Effects test and balancing test of purchased inputs' use on pest incidences

```
. teffects psmatch (Change_pestsincidence) (B1_farminputs lnAge Educ_level lntotal_land lnHHSize Borrowing HH_Sex S3B5_extclimate  C1_usehir
> edlabour Types_grown_3local change_lowrainfall_ocurrances change_prolongedspell_ocurrances change_excessiverains_ocurrances change_freqhai
> lstorms_ocurrances, probit), atet nneighbor(1)

Treatment-effects estimation                   Number of obs      =        272
Estimator      : propensity-score matching     Matches: requested =          1
Outcome model  : matching                                  min =          1
Treatment model: probit                                    max =          1
```

Change_pest~e	Coef.	AI Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
ATET						
B1_farminputs (Yes vs No)	-.3972528	.1737899	-2.29	0.022	-.7378748	-.0566308

```
. tebalance summarize
note: refitting the model using the generate() option
```

Covariate balance summary

	Raw	Matched
Number of obs =	272	364
Treated obs =	182	182
Control obs =	90	182

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
lnAge	-.4362051	.0595972	1.452186	1.030214
Educ_level	.4511648	-.1992218	1.143868	.6157331
lntotal_land	.6529803	-.0965064	1.066575	.5701487
lnHHSize	-.0569524	.17353	1.113724	1.510625
Borrowing	.3948116	-.0227235	1.500074	.9876161
HH_Sex	.2112719	.2149334	.8312587	.8343195
S3B5_extclimate	.3808476	.0667018	1.283939	1.022622
C1_usehiredla~r	.645885	.2736289	.7605877	.8023599
Types_grown_3~l	-.2900291	-.0398581	3.669424	1.129252
change_lowrai~s	.0744093	-.1345696	.9662149	2.122142
change_prolon~s	-.071428	-.4031569	1.088485	1.509537
change_excess~s	.0231006	-.0207376	1.053886	1.011094
change_freqha~s	-.242968	-.1462325	.7583755	1.299452



J3: Treatment Effects test and balancing test of purchased inputs' use on low weight of coffee beans

```
. teffects psmatch ( change_lowweight ) (B1_farminputs lnAge Educ_level lntotal_land lnHHSize Borrowing HH_Sex S3B5_extclimate  C1_usehiredl
> abour Types_grown_3local change_lowrainfall_ocurrances change_prolongedspell_ocurrances change_excessiverains_ocurrances change_freqhailst
> orms_ocurrances, probit), atet nneighbor(1)

Treatment-effects estimation                   Number of obs      =        272
Estimator      : propensity-score matching     Matches: requested =          1
Outcome model  : matching                                  min =          1
Treatment model: probit                                    max =          1
```

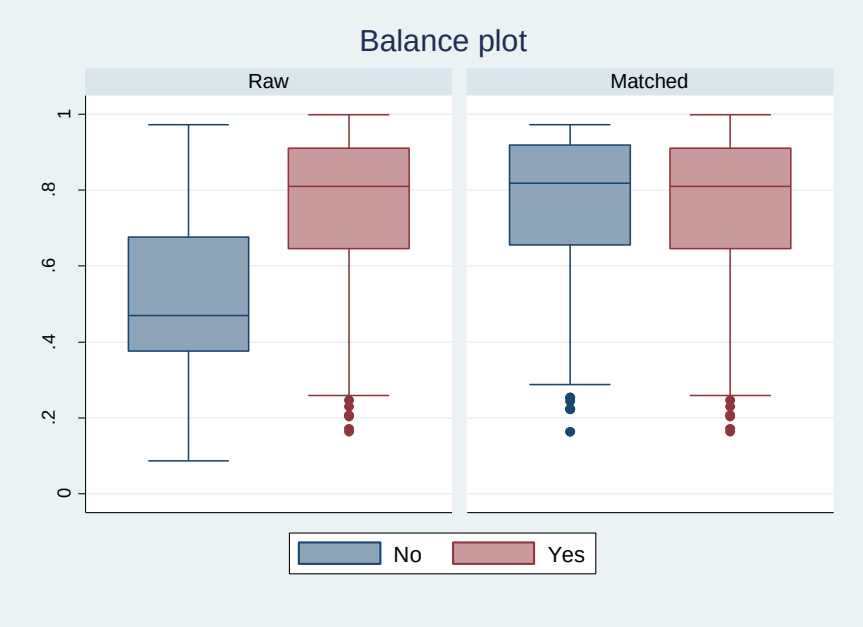
change_loww~t	Coef.	AI Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
ATET						
B1_farminputs (Yes vs No)	-.3247253	.1747842	-1.86	0.063	-.6672961	.0178455

```
. tebalance summarize
note: refitting the model using the generate() option
```

Covariate balance summary

	Raw	Matched
Number of obs =	272	364
Treated obs =	182	182
Control obs =	90	182

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
lnAge	-.4362051	.0595972	1.452186	1.030214
Educ_level	.4511648	-.1992218	1.143868	.6157331
lntotal_land	.6529803	-.0965064	1.066575	.5701487
lnHHSize	-.0569524	.17353	1.113724	1.510625
Borrowing	.3948116	-.0227235	1.500074	.9876161
HH_Sex	.2112719	.2149334	.8312587	.8343195
S3B5_extclimate	.3808476	.0667018	1.283939	1.022622
C1_usehiredla~r	.645885	.2736289	.7605877	.8023599
Types_grown_3~l	-.2900291	-.0398581	3.669424	1.129252
change_lowrai~s	.0744093	-.1345696	.9662149	2.122142
change_prolon~s	-.071428	-.4031569	1.088485	1.509537
change_excess~s	.0231006	-.0207376	1.053886	1.011094
change_freqha~s	-.242968	-.1462325	.7583755	1.299452



J4: Treatment Effects test and balancing test of purchased inputs' use on less coffee flowering incidences

```
. teffects psmatch ( change_lessflowering ) (B1_farminputs lnAge Educ_level lntotal_land lnHHSize Borrowing HH_Sex S3B5_extclimate  C1_usehi
> redlabour Types_grown_3local change_lowrainfall_ocurrances change_prolongedspell_ocurrances change_excessiverains_ocurrances change_freqha
> ilstorms_ocurrances, probit), atet nneighbor(1)

Treatment-effects estimation                   Number of obs      =        272
Estimator      : propensity-score matching     Matches: requested =          1
Outcome model  : matching                                  min =          1
Treatment model: probit                                    max =          1
```

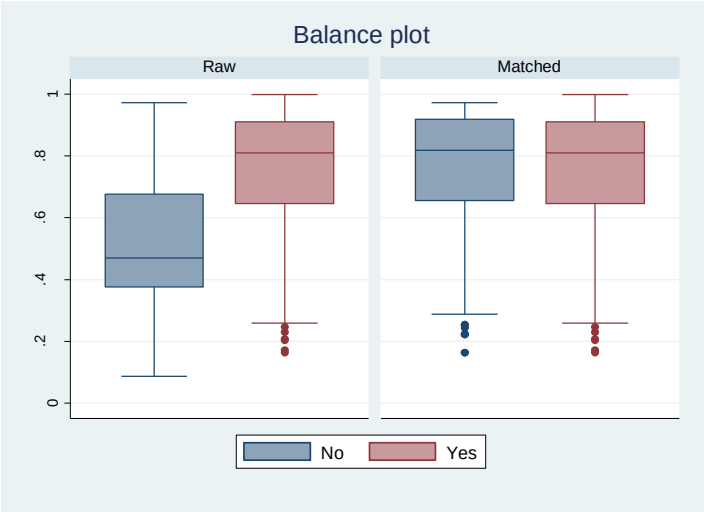
change_less~g	Coef.	AI Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
ATET						
B1_farminputs (Yes vs No)	-.3182967	.1600562	-1.99	0.047	-.6320012	-.0045922

```
. tebalance summarize
note: refitting the model using the generate() option
```

Covariate balance summary

	Raw	Matched
Number of obs =	272	364
Treated obs =	182	182
Control obs =	90	182

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
lnAge	-.4362051	.0595972	1.452186	1.030214
Educ_level	.4511648	-.1992218	1.143868	.6157331
lntotal_land	.6529803	-.0965064	1.066575	.5701487
lnHHSize	-.0569524	.17353	1.113724	1.510625
Borrowing	.3948116	-.0227235	1.500074	.9876161
HH_Sex	.2112719	.2149334	.8312587	.8343195
S3B5_extclimate	.3808476	.0667018	1.283939	1.022622
C1_usehiredla~r	.645885	.2736289	.7605877	.8023599
Types_grown_3~l	-.2900291	-.0398581	3.669424	1.129252
change_lowrai~s	.0744093	-.1345696	.9662149	2.122142
change_prolon~s	-.071428	-.4031569	1.088485	1.509537
change_excess~s	.0231006	-.0207376	1.053886	1.011094
change_freqha~s	-.242968	-.1462325	.7583755	1.299452



J5: Treatment Effects test and balancing test of purchased inputs' use on excessive drying of coffee leaves incidences

```
. teffects psmatch ( change_excessivedrying ) (B1_farminputs lnAge Educ_level lntotal_land lnHHSize Borrowing HH_Sex S3B5_extclimate  C1_use
> hiredlabour Types_grown_3local change_lowrainfall_ocurrances change_prolongedspell_ocurrances change_excessiverains_ocurrances change_freq
> hailstorms_ocurrances, probit), atet nneighbor(1)

Treatment-effects estimation                   Number of obs      =        272
Estimator      : propensity-score matching     Matches: requested =          1
Outcome model  : matching                                  min =          1
Treatment model: probit                                    max =          1
```

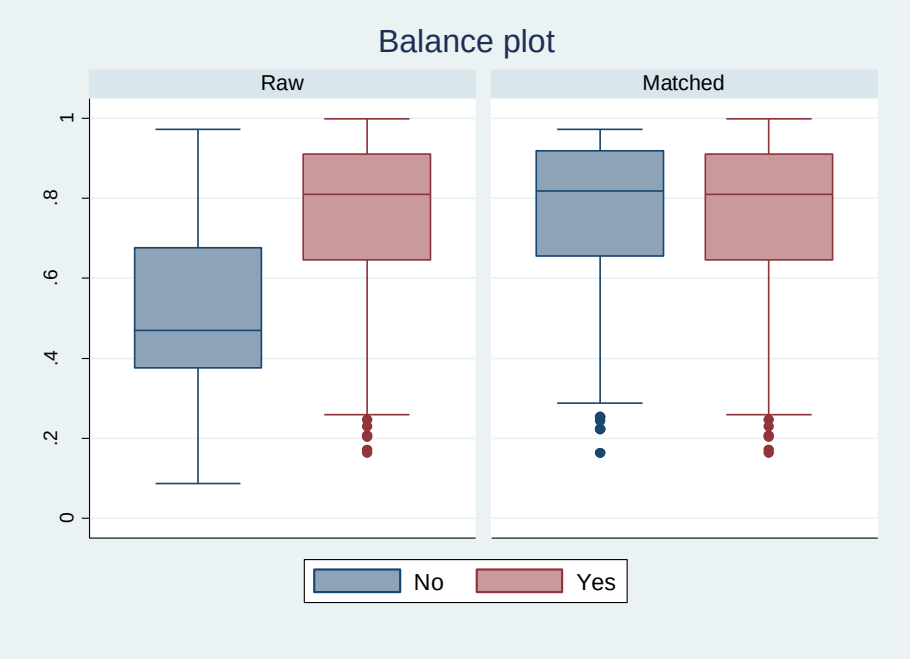
change_exce~g	Coef.	AI Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
ATET						
B1_farminputs (Yes vs No)	-.2615934	.136057	-1.92	0.055	-.5282602	.0050734

```
. tebalance summarize
note: refitting the model using the generate() option
```

Covariate balance summary

	Raw	Matched
Number of obs =	272	364
Treated obs =	182	182
Control obs =	90	182

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
lnAge	-.4362051	.0595972	1.452186	1.030214
Educ_level	.4511648	-.1992218	1.143868	.6157331
lntotal_land	.6529803	-.0965064	1.066575	.5701487
lnHHSize	-.0569524	.17353	1.113724	1.510625
Borrowing	.3948116	-.0227235	1.500074	.9876161
HH_Sex	.2112719	.2149334	.8312587	.8343195
S3B5_extclimate	.3808476	.0667018	1.283939	1.022622
C1_usehiredla~r	.645885	.2736289	.7605877	.8023599
Types_grown_3~l	-.2900291	-.0398581	3.669424	1.129252
change_lowrai~s	.0744093	-.1345696	.9662149	2.122142
change_prolon~s	-.071428	-.4031569	1.088485	1.509537
change_excess~s	.0231006	-.0207376	1.053886	1.011094
change_freqha~s	-.242968	-.1462325	.7583755	1.299452



J6: Treatment Effects test and balancing test of purchased inputs' use on unfilled coffee beans incidences

```
. teffects psmatch ( change_unfilledbeans ) (B1_farminputs lnAge Educ_level lntotal_land lnHHSize Borrowing HH_Sex S3B5_extclimate  C1_usehi
> redlabour Types_grown_3local change_lowrainfall_ocurrances change_prolongedspell_ocurrances change_excessiverains_ocurrances change_freqha
> ilstorms_ocurrances, probit), atet nneighbor(1)

Treatment-effects estimation                   Number of obs      =        272
Estimator      : propensity-score matching     Matches: requested =          1
Outcome model  : matching                                  min =          1
Treatment model: probit                                    max =          1
```

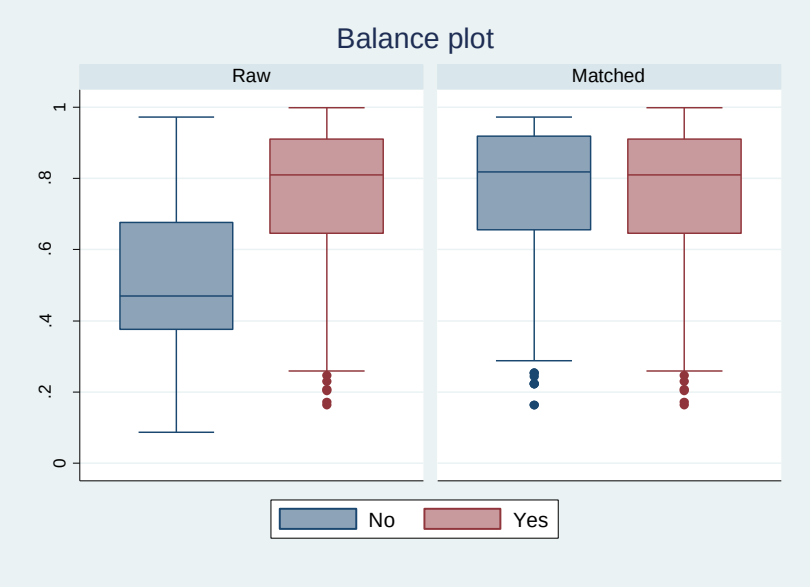
change_unfi~s	Coef.	AI Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
ATET						
B1_farminputs (Yes vs No)	-.2707692	.2337927	-1.16	0.247	-.7289945	.187456

```
. tebalance summarize
note: refitting the model using the generate() option
```

Covariate balance summary

	Raw	Matched
Number of obs =	272	364
Treated obs =	182	182
Control obs =	90	182

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
lnAge	-.4362051	.0595972	1.452186	1.030214
Educ_level	.4511648	-.1992218	1.143868	.6157331
lntotal_land	.6529803	-.0965064	1.066575	.5701487
lnHHSize	-.0569524	.17353	1.113724	1.510625
Borrowing	.3948116	-.0227235	1.500074	.9876161
HH_Sex	.2112719	.2149334	.8312587	.8343195
S3B5_extclimate	.3808476	.0667018	1.283939	1.022622
C1_usehiredla~r	.645885	.2736289	.7605877	.8023599
Types_grown_3~l	-.2900291	-.0398581	3.669424	1.129252
change_lowrai~s	.0744093	-.1345696	.9662149	2.122142
change_prolon~s	-.071428	-.4031569	1.088485	1.509537
change_excess~s	.0231006	-.0207376	1.053886	1.011094
change_freqha~s	-.242968	-.1462325	.7583755	1.299452



J7: Treatment Effects test and balancing test of purchased inputs' use on small coffee cherries incidences

```
. teffects psmatch ( change_smallbeans ) (B1_farminputs lnAge Educ_level lntotal_land lnHHSize Borrowing HH_Sex S3B5_extclimate  C1_usehired
> labour Types_grown_3local change_lowrainfall_ocurrances change_prolongedspell_ocurrances change_excessiverains_ocurrances change_freqhails
> torms_ocurrances, probit), atet nneighbor(1)

Treatment-effects estimation                   Number of obs      =        272
Estimator      : propensity-score matching     Matches: requested =          1
Outcome model  : matching                                  min =          1
Treatment model: probit                                    max =          1
```

change_smal~s	Coef.	AI Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
ATET						
B1_farminputs (Yes vs No)	.1720879	.1300328	1.32	0.186	-.0827717	.4269475

```
. tebalance summarize
note: refitting the model using the generate() option
```

Covariate balance summary

	Raw	Matched
Number of obs =	272	364
Treated obs =	182	182
Control obs =	90	182

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
lnAge	-.4362051	.0595972	1.452186	1.030214
Educ_level	.4511648	-.1992218	1.143868	.6157331
lntotal_land	.6529803	-.0965064	1.066575	.5701487
lnHHSize	-.0569524	.17353	1.113724	1.510625
Borrowing	.3948116	-.0227235	1.500074	.9876161
HH_Sex	.2112719	.2149334	.8312587	.8343195
S3B5_extclimate	.3808476	.0667018	1.283939	1.022622
C1_usehiredla~r	.645885	.2736289	.7605877	.8023599
Types_grown_3~l	-.2900291	-.0398581	3.669424	1.129252
change_lowrai~s	.0744093	-.1345696	.9662149	2.122142
change_prolon~s	-.071428	-.4031569	1.088485	1.509537
change_excess~s	.0231006	-.0207376	1.053886	1.011094
change_freqha~s	-.242968	-.1462325	.7583755	1.299452



J8: Treatment Effects test and balancing test of purchased inputs' use on flower abortion incidences

```
. teffects psmatch ( change_dropping ) (B1_farminputs lnAge Educ_level lntotal_land lnHHSize Borrowing HH_Sex S3B5_extclimate  C1_usehiredla
> bour Types_grown_3local change_lowrainfall_ocurrances change_prolongedspell_ocurrances change_excessiverains_ocurrances change_freqhailsto
> rms_ocurrances, probit), atet nneighbor(1)

Treatment-effects estimation                   Number of obs      =        272
Estimator      : propensity-score matching     Matches: requested =          1
Outcome model  : matching                                  min =          1
Treatment model: probit                                    max =          1
```

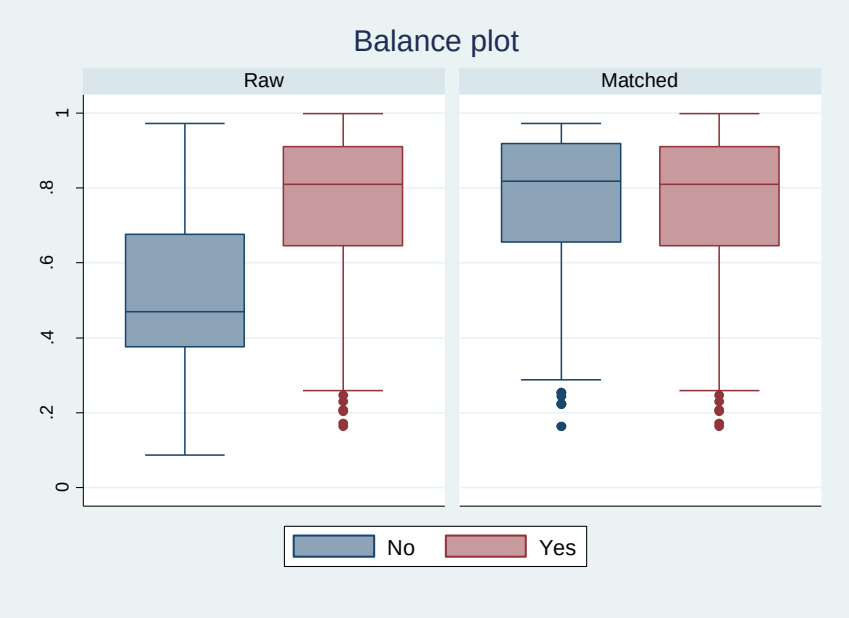
change_drop~g	Coef.	AI Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
ATET						
B1_farminputs (Yes vs No)	-.2720879	.1800161	-1.51	0.131	-.624913	.0807372

```
. tebalance summarize
note: refitting the model using the generate() option
```

Covariate balance summary

	Raw	Matched
Number of obs =	272	364
Treated obs =	182	182
Control obs =	90	182

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
lnAge	-.4362051	.0595972	1.452186	1.030214
Educ_level	.4511648	-.1992218	1.143868	.6157331
lntotal_land	.6529803	-.0965064	1.066575	.5701487
lnHHSize	-.0569524	.17353	1.113724	1.510625
Borrowing	.3948116	-.0227235	1.500074	.9876161
HH_Sex	.2112719	.2149334	.8312587	.8343195
S3B5_extclimate	.3808476	.0667018	1.283939	1.022622
C1_usehiredla~r	.645885	.2736289	.7605877	.8023599
Types_grown_3~l	-.2900291	-.0398581	3.669424	1.129252
change_lowrai~s	.0744093	-.1345696	.9662149	2.122142
change_prolon~s	-.071428	-.4031569	1.088485	1.509537
change_excess~s	.0231006	-.0207376	1.053886	1.011094
change_freqha~s	-.242968	-.1462325	.7583755	1.299452



J9: Treatment Effects test and balancing test of purchased inputs' use on incidences of unusual drying of coffee gardens

```
. teffects psmatch ( change_dryinggarden ) (B1_farminputs lnAge Educ_level lntotal_land lnHHSize Borrowing HH_Sex S3B5_extclimate  C1_usehir
> edlabour Types_grown_3local change_lowrainfall_ocurrances change_prolongedspell_ocurrances change_excessiverains_ocurrances change_freqhai
> lstorms_ocurrances, probit), atet nneighbor(1)
note: variance correction results in a negative variance estimate; ignoring the correction term

Treatment-effects estimation                   Number of obs      =        272
Estimator      : propensity-score matching     Matches: requested =          1
Outcome model  : matching                                  min =          1
Treatment model: probit                                    max =          1
```

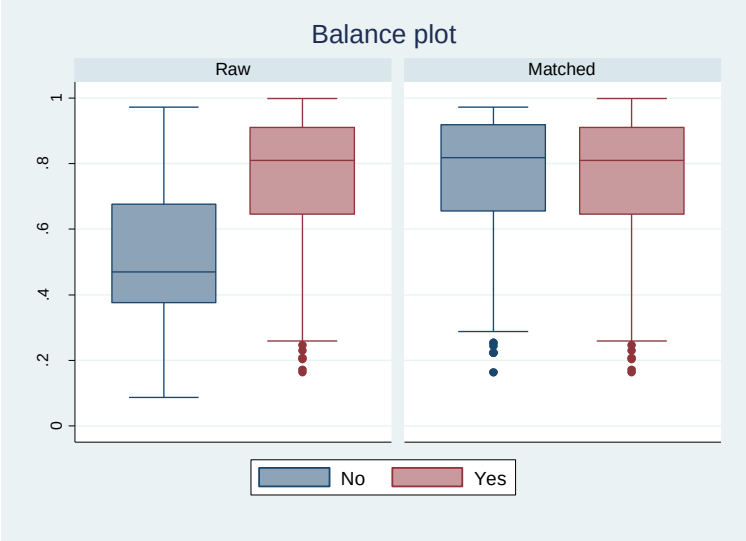
change_dryi~n	Coef.	AI Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
ATET						
B1_farminputs (Yes vs No)	-.2888462	.5694099	-0.51	0.612	-1.404869	.8271767

```
. tebalance summarize
note: refitting the model using the generate() option
```

Covariate balance summary

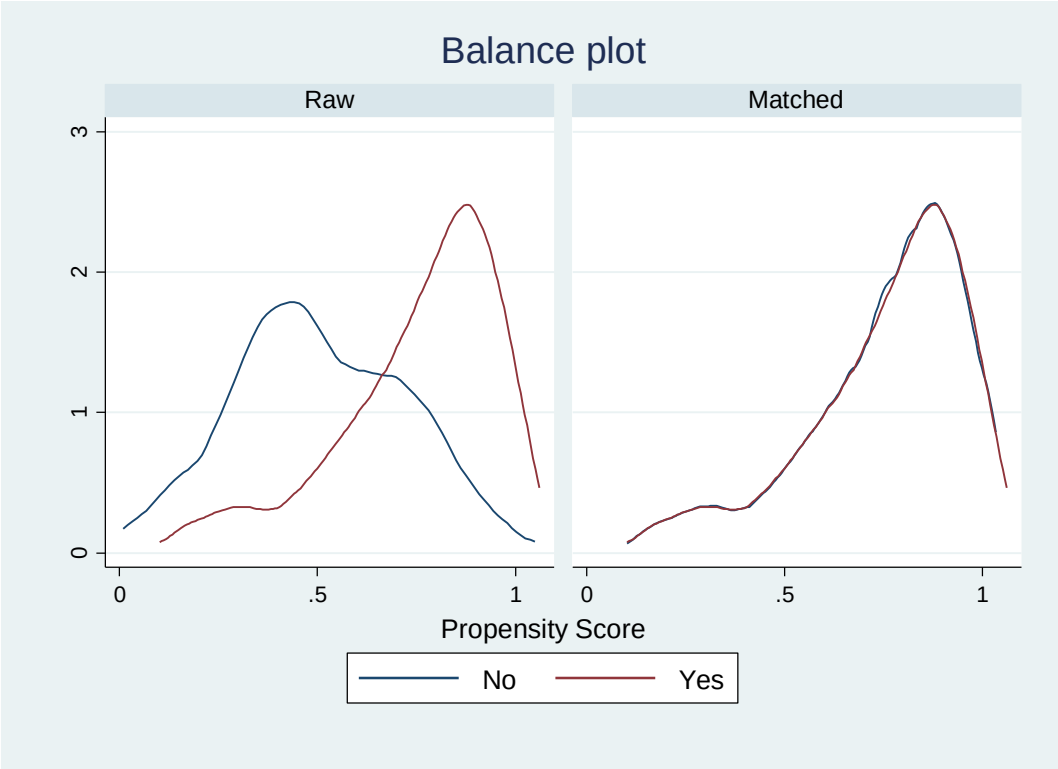
	Raw	Matched
Number of obs =	272	364
Treated obs =	182	182
Control obs =	90	182

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
lnAge	-.4362051	.0595972	1.452186	1.030214
Educ_level	.4511648	-.1992218	1.143868	.6157331
lntotal_land	.6529803	-.0965064	1.066575	.5701487
lnHHSize	-.0569524	.17353	1.113724	1.510625
Borrowing	.3948116	-.0227235	1.500074	.9876161
HH_Sex	.2112719	.2149334	.8312587	.8343195
S3B5_extclimate	.3808476	.0667018	1.283939	1.022622
C1_usehiredla~r	.645885	.2736289	.7605877	.8023599
Types_grown_3~l	-.2900291	-.0398581	3.669424	1.129252
change_lowrai~s	.0744093	-.1345696	.9662149	2.122142
change_prolon~s	-.071428	-.4031569	1.088485	1.509537
change_excess~s	.0231006	-.0207376	1.053886	1.011094
change_freqha~s	-.242968	-.1462325	.7583755	1.299452

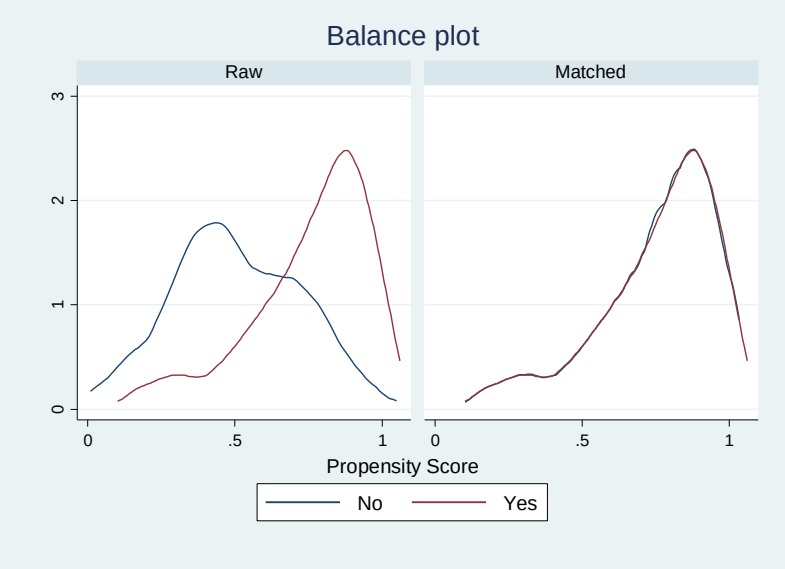


Appendix K: Balance density plots showing the regions of common support

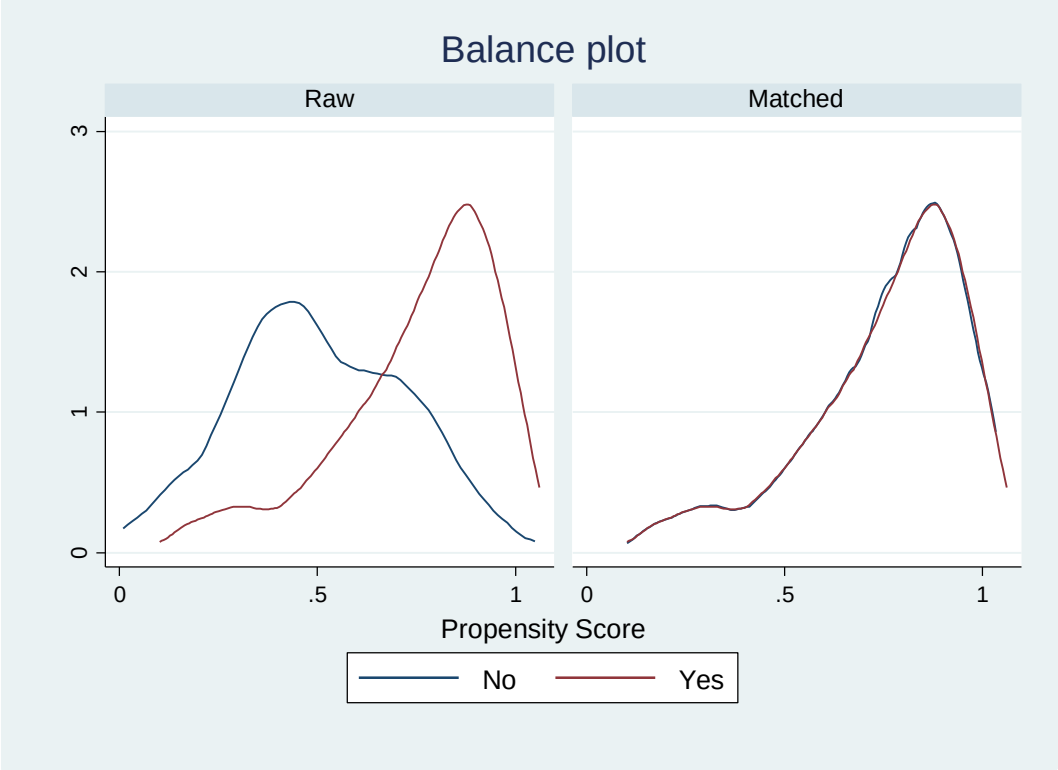
Balance plot for treatment effect on low harvests incidences



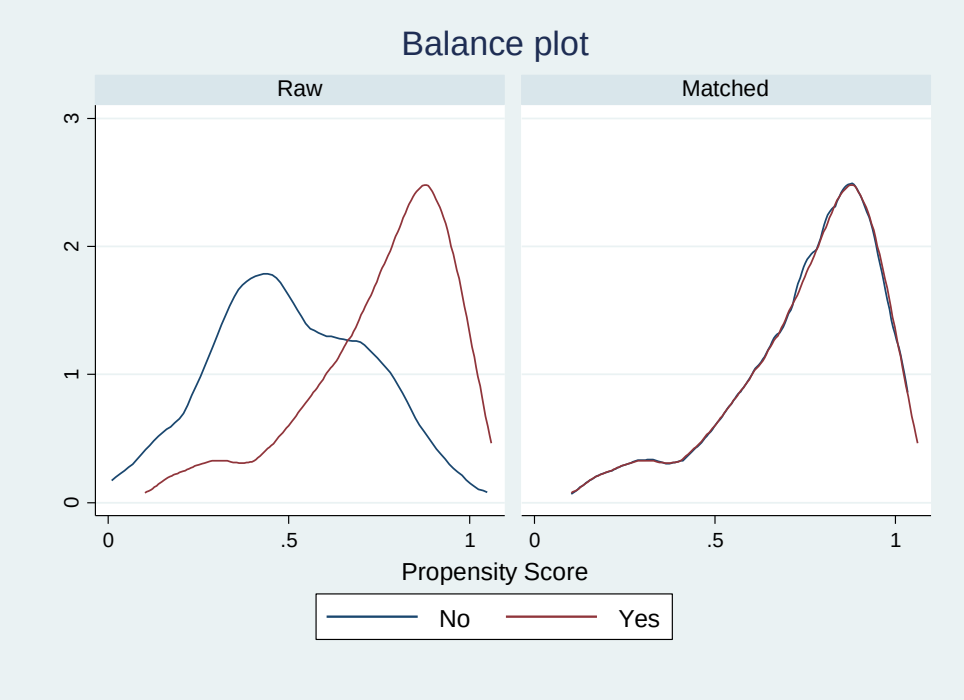
Balance plot for treatment effect on pest incidences



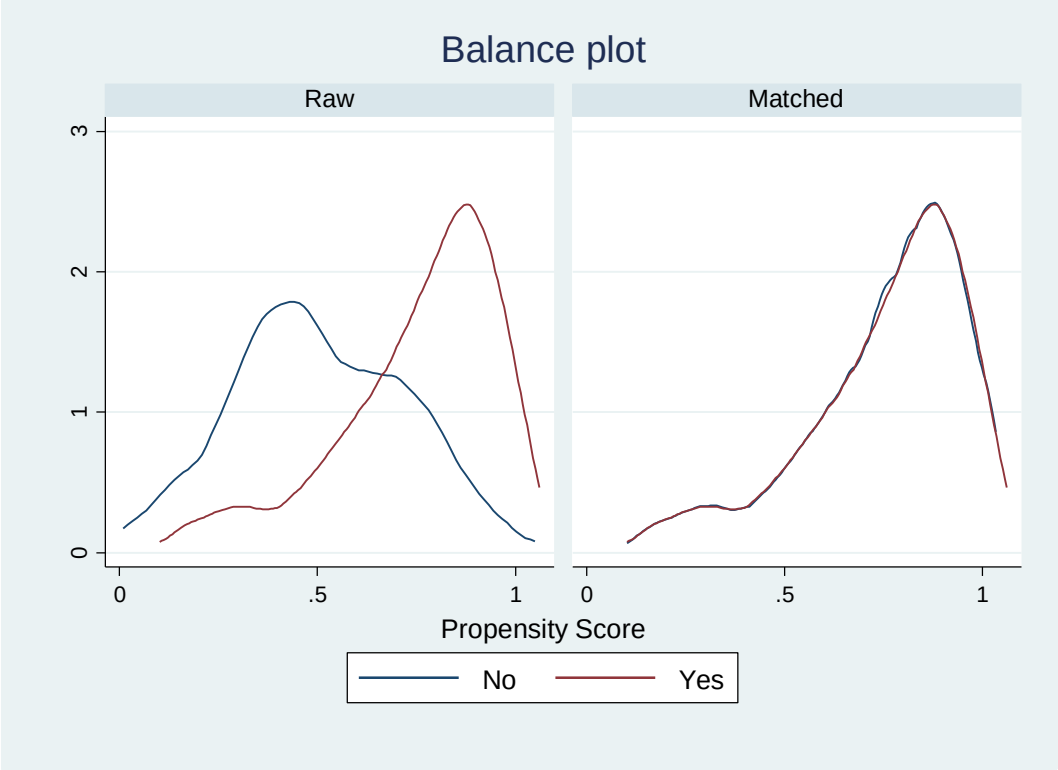
Balance plot for treatment effect on low weight incidences



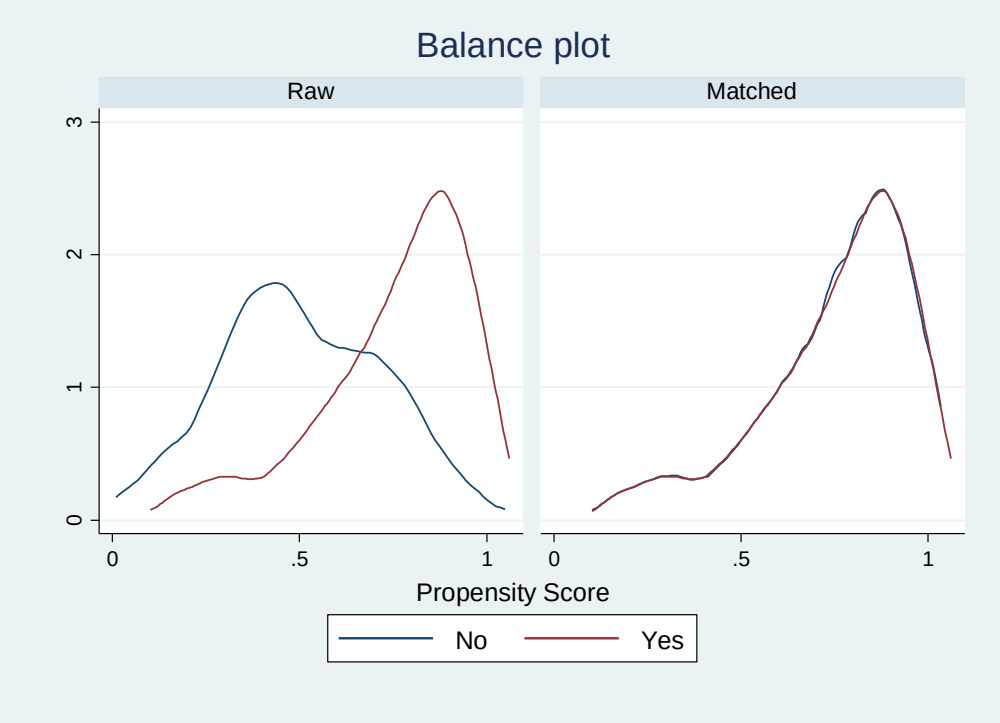
Balance plot for treatment effect on unfilled beans incidences



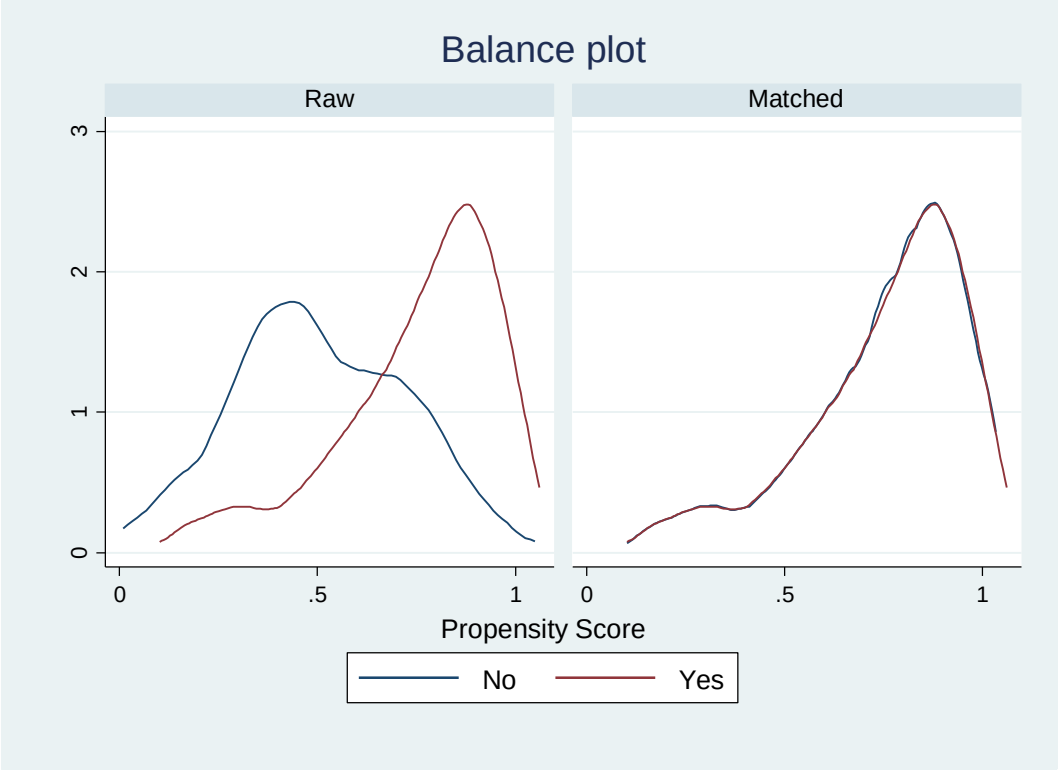
Balance plot for treatment effect on small beans incidences



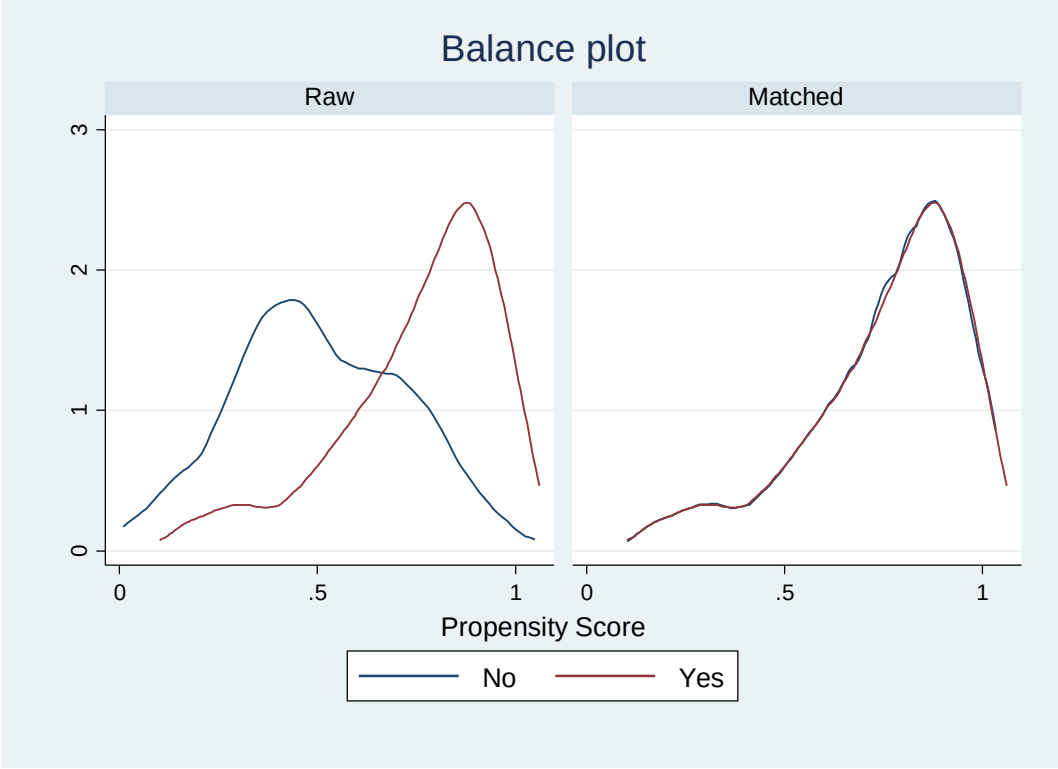
Balance plot for treatment effect on flower abortion incidences



Balance plot for treatment effect on less flowering incidences



Balance plot for treatment effect on unusual drying of coffee garden



Appendix L: Clearance from Gulu University Research Ethics Committee (GUREC)

GULU UNIVERSITY

P.O. Box 166, Gulu (U)
Website: www.gu.ac.ug
Email: gurec@gu.ac.ug

Tel: +256 471 432 096
Fax: +256 471 432 913
Mob: +256 772 305 621
+256 776 812 147

RESEARCH ETHICS COMMITTEE

09/03/2023

To: Harriet Mbabazi

+256 750 186 599

Type: Initial Review

Re: GUREC-2022-462: PERCEIVED CLIMATE VARIABILITY EFFECTS ON COFFEE PRODUCTION: A CASE OF AREAS PROXIMAL TO THE DRY CATTLE CORRIDOR IN CENTRAL UGANDA, 2, 2023-03-09

I am pleased to inform you that at the **95th** convened meeting on **19/01/2023**, the Gulu University REC, committee meeting, etc voted to approve the above referenced application.
Approval of the research is for the period of **09/03/2023** to **09/03/2024.**

As Principal Investigator of the research, you are responsible for fulfilling the following requirements of approval:

1. All co-investigators must be kept informed of the status of the research.
2. Changes, amendments, and addenda to the protocol or the consent form must be submitted to the REC for re-review and approval **prior** to the activation of the changes.
3. Reports of unanticipated problems involving risks to participants or any new information which could change the risk benefit: ratio must be submitted to the REC.
4. Only approved consent forms are to be used in the enrollment of participants. All consent forms signed by participants and/or witnesses should be retained on file. The REC may conduct audits of all study records, and consent documentation may be part of such audits.
5. Continuing review application must be submitted to the REC **eight weeks** prior to the expiration date of **09/03/2024** in order to continue the study beyond the approved period. Failure to submit a continuing review application in a timely fashion may result in suspension or termination of the study.
6. The REC application number assigned to the research should be cited in any correspondence with the REC of record.
7. You are required to register the research protocol with the Uganda National Council for Science and Technology (UNCST) for final clearance to undertake the study in Uganda.

The following is the list of all documents approved in this application by Gulu University REC:

GULU UNIVERSITY
RESEARCH ETHICS COMMITTEE
APPROVED UNTIL
★ 09 MAR 2024 ★
FACULTY OF MEDICINE
P. O. Box 166, Gulu

No.	Document Title	Language	Version Number	Version Date
1	Protocol	English	2	2023-03-09
2	Informed Consent forms	ENGLISH	2	2023-03-01
3	Informed Consent forms	LUGANDA	2	2023-03-01
4	Data collection tools	ENGLISH	2	2023-03-01
5	COVID-19 & EBOLA risk management plan for the study	ENGLISH	1	2022-11-10

Yours Sincerely,

GULU UNIVERSITY
RESEARCH ETHICS COMMITTEE
APPROVED UNTIL
09 MAR 2024
FACULTY OF MEDICINE
P. O. Box 166, Gulu

Dr. Gerald OBAI
For: Gulu University REC

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Personal File No.(staff) Reg. (**student**).___ 21/U/3332/MAE/PS_____
Faculty/Institute:___ AGRICULTURE & ENVIRONMENT_____
Department:____ RURAL DEVELOPMENT AND AGRIBUSINESS____
Title and bibliographic description of the work
THE RELATIONSHIP BETWEEN PERCEIVED CLIMATEVARIABILITIES AND THE USE OF PURCHASED FARM INPUTSAMONG COFFEE GROWERS IN THE CATTLE CORRIDOR OF CENTRAL UGANDA

Declaration.

1. I understand what plagiarism is and I am aware of the University policy on this regard,
2. I declare that this …**Thesis**… (thesis, dissertation, essay, assignment, paper, report etc.) is my original work and has not been submitted elsewhere for examination, award of a degree or publication. Where other people's work or my work has been used, this has been properly acknowledged and referenced in accordance with Gulu University requirements,
3. I have not sought or used the services of any professional agency to produce this work,
4. I have not allowed, and shall not allow anyone to copy my work with the intention of passing it off as his/her own,
5. I understand that any false claim of this work shall result in disciplinary action in accordance with University Policy on Plagiarism.

Signature _____ Date 08/01/2024

Originality Report

The article/thesis/document titled above have been subjected to plagiarism check and the level was found to be……**18%** (percent) this is classified as:

- ✓ **Minor**
- ☐ Moderate
- ☐ Serious

Yours sincerely,

Dr. Ongaya Kizito (PhD)
Senior Librarian