

**CLIMATE VARIABILITY AND ITS PERCEIVED IMPACT ON HONEY  
PRODUCTION IN PAICHO AND PALARO SUB-COUNTIES, NORTHERN UGANDA.**

**BY**

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## DECLARATION

I, Anywar Boniface, declare that this Dissertation is my original work and has not been submitted elsewhere for any academic or professional purpose.

Date 03/09/2026

Signature 

## APPROVAL

The Research topic "Climate Variability and Its Perceived Impact on Honey Production in Paicho and Palaro Sub-Counties, Gulu District, Northern Uganda" have been done under our guidance and approval as Supervisors.

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## **DEDICATION**

I dedicate this research work to my family, Mr. Oruma Justine Mukasa (Father) and Auma Susan (Mother) who supported me throughout my academic journey, I dedicate this research work also to my brother Acaye Phillip, who has been instrumental in shaping my academic struggle through financial support, and not forgetting Ogenrwot Francis, Nockrach Cosmas, Lakica Mirriam Ayaa, Onenrwot Pius and Nyeko Christopher.

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## **List of Acronym**

|               |                                                    |
|---------------|----------------------------------------------------|
| <b>IPCC:</b>  | Intergovernmental Panel on Climate Change          |
| <b>FGD</b>    | Focus Group Discussion                             |
| <b>NGO</b>    | Non-Governmental Organization                      |
| <b>SDG</b>    | Sustainable Development Goal                       |
| <b>USAID:</b> | United States Agency for International Development |
| <b>GPS</b>    | Global Positioning System                          |
| <b>FGD:</b>   | Focus Group Discussion                             |
| <b>NOAA</b>   | National Oceanic and Atmospheric Administration    |
| <b>NFA:</b>   | National Forest Authority                          |
| <b>GUREC</b>  | Gulu University Research Ethical committee         |
| <b>UWA:</b>   | Uganda Wildlife Authority                          |
| <b>UBOS:</b>  | Uganda Bureau of Statistics                        |
| <b>KII:</b>   | Key Informant Interview                            |
| <b>UNMA:</b>  | Uganda National Meteorological Authority           |
| <b>SE</b>     | Standard Error                                     |

## **Abstract**

This study examined the Climate variability and its perceived impact on honey production. A case study in Paicho and Palaro Sub-counties, Gulu District, Northern Uganda. The study centered on the lack of comprehensive, localized understanding of how climate variability specifically affects honeybee production. A mixed-method design was employed. Primary data was collected from 133 purposively selected beekeepers using either structured questionnaires or key informant interviews. Rainfall and temperature data for the period 2000–2023 were obtained from the Uganda National Meteorological Authority. Quantitative data were analyzed using descriptive statistics and ANOVA, while qualitative data underwent thematic analysis focusing on indicators of climate variability and adoption of low-cost strategies. It was noted that annual rainfall ranged from 1,025.2 mm to 1,698.1 mm in Paicho and 935.2 mm to 1,575.8 mm in Palaro, followed by marked increases in mean annual temperatures (Paicho: 29.94–36.99 °C; Palaro: 29.94–38.22°C). ANOVA results revealed no significant differences in the yearly rainfall amounts for both locations ( $p > 0.05$ ), but high significant monthly differences ( $p < 0.05$ ). Maximum and minimum temperatures of Paicho showed no significant difference ( $p > 0.05$ ) across the 24-year periods. Palaro Sub-county showed yearly and monthly significant different in minimum and maximum temperatures ( $p > 0.05$ ) throughout the study period, indicating variability in the area. The average annual and monthly temperatures exhibited similar patterns with the statistical analysis for both minimum and maximum temperatures, this means that the average temperatures show the same trend with minimum and maximum temperatures in all the Sub-counties. Beekeepers unanimously perceived climate variability as negatively affecting honey production, mainly through reduced flowering of plants (94.7%), disruption of bee behavior and increase pests and disease prevalence. Spatial patterns showed apiaries concentrated near water bodies and woody areas, underscoring the importance of environmental resources for colony resilience. Although, common coping measures included shading the hives (64.7%) and planting forage crops (36.8%), adoption of more effective approaches such as supplementary feeding (15%) and use of modern hives (3.8%) are constrained by limited finance. The study concludes that unpredictable rainfall and rising temperatures threaten honeybee production. Strengthened climate-smart extension services, increased access to modern hive technologies and climate financing among others are recommended to enhance adaptive capacity.

**Keywords:** Climate variability, honeybee production, rainfall, temperature, adaptation strategies.

## **CHAPTER ONE: INTRODUCTION**

### **1.1 Introduction**

Climate variability refers to variations in climate elements such as temperature and rainfall within a given area over time. Worldwide, the average global temperature is rarely the same from year to year. One year might be cooler than the year before, even though the long-term trend shows increasing temperature over time due to climate change (IPCC, 2023). These occur because of natural fluctuations, like El Nino Southern Oscillation, which causes an increase in the probability of many extreme weather events. Global rainfall patterns are becoming increasingly variable, with an observed rise of about 1% in heavy precipitation events per decade since the mid-20<sup>th</sup> century (IPCC, 2023). Extreme rainfall events, previously occurring once every 20 years, now happen almost twice, and projections indicate that by the end of the 21<sup>st</sup> century, the frequency and intensity of such events could increase by 50-100% in many regions (IPCC, 2023). Global average temperature has increased by 0.2°C per decade since the late 20<sup>th</sup> century (NOAA., 2022). The years 2016 and 2020 are tied as the warmest years on record, with global temperatures of approximately 1.2°C (Schmidt, 2022). This matches with the maximum temperature in Palaro Sub-county in 2020 in this study.

Africa is one of the most vulnerable continents to climate variability, with temperature increase projected to be higher than the global average (Dawson & Spannagle, 2020). Uganda has undergone noticeable climatic shifts, including rising temperatures and increasingly erratic rainfall patterns (Egeru et al., 2019). According to (USAID, 2015; Zinyengere et al., 2016), mean annual temperatures in Uganda may increase by up to 1.5 °C by 2030, and by 0.9 to 3.3 °C by the 2060s. Rainfall projections in Uganda remain highly uncertain, with climate models indicating possible

changes ranging from a 16% decrease to a 43% increase, highlighting the variability and complexity of future precipitation patterns.

Climatic change is a threat to conservation of biodiversity (IPCC, 2023). For bees, increased temperatures due to climate variability can lead to colony stress and higher mortality rates (Gajardo-Rojas et al., 2022). Extreme heat, especially in tropical areas, increases the likelihood of flowering of some plants, collapse of honeycomb and reduced water availability necessary for cooling the hives (Landaverde et al., 2023). Furthermore, shifts in temperature and habitat conditions can restrict pollinator habitats, complicating the migration and survival of both native and managed bee populations (Novelli et al., 2021; Kumar et al., 2022;). As a result, beekeepers may face greater challenges in managing healthy colonies and sustaining honey production. Erratic rainfall can lower hive temperatures, causing bees to expend energy to maintain condition of the hive, it also breaks the wings of the bees disabling them to fly to collect nectars (Mohamed & Faraj, 2022). Excessive rainfall dilutes nectar and washes important nutrients, resulting in lower quality but sufficient rainfall induces a significant vegetation development and flowering (Schweitzer et al., 2013).

Coping with the impact of climate variability requires understanding the specific challenges faced by local beekeepers. Emerging research highlights various strategies farmers employ to adapt to changing climatic conditions, such as, altering planting schedules or diversifying crops, providing supplementary feeds to the bees, and changing location of the bee hive (Atube et al., 2021; Ojija & Leweri, 2022). Also, in attempt to cope with climate variability, farmers are planting draught resistant varieties of crops, which always blooms (Bewuketu, 2017). Given the increasing challenges posed by climate variability, especially in beekeeping, understanding localized adaptation strategies is essential. Despite the growing evidence of the effects of climate variability

on honeybees, and the adaptation strategies employed by beekeepers in different parts of the world, there remains insufficient knowledge of localized evidence from Paicho and Palaro Sub-counties. Existing studies have largely focused on other geographical settings, making it difficult to establish whether the reported impacts and coping strategies are applicable to the local climatic and ecological conditions of the two Sub-counties.

## **1.2 Statement of the problem**

Climate variability is increasingly threatening beekeeping productivity through extreme heat, which kills bee brood when above optimal bee brood temperature (34-35%) (Lead et al., 2023). It also influences flowering of the forages, causes honeycomb collapse, and reduces water availability (Landaverde et al., 2023). Erratic and excessive rainfall also lowers hive temperatures, damages bee wings, limits nectar foraging, and dilutes nectar quality (Mohamed & Faraj, 2022). To overcome these challenges, beekeepers have adopted several adaptation measures including: Altering planting schedules and diversifying crops to improve on forage inadequacy (Atube et al., 2021), providing supplementary bee feeds, relocating beehives to a cooler environments (Degu et al., 2021; Ojija & Leweri, 2022). However, the effectiveness of these strategies under specific local conditions, particularly the changing climatic conditions and their effects on honey production remains unclear, highlighting the need for context specific interventions to support beekeepers in addressing these challenges which would leads to increase in honey production. The insufficiencies of the evidence on bee productivity in Palaro and Paicho has caused the farmers to get low yield from honey harvested which in turn leads to low income hence affecting their economic livelihood. This has also made some beekeepers to operate on low scale production since there is no better economic return from their beehives, while other have completely dropped out of bee farming hence affecting diversity of farming practices. This study

analyzes climate variability, maps honey production patterns, and assesses the coping and adaptation strategies used by beekeepers in Paicho and Palaro Sub-counties, Northern Uganda.

### **1.3 Purpose of the study**

The purpose of this study was to investigate the climate variability and its perceived impact on honey production in Paicho and Palaro sub-counties, Northern Uganda and understand how farmers are coping to the challenges to improve on honeybee production for enhanced income and livelihood.

### **1.4 Objectives of the study**

#### **1.4.1 General objective**

To assess the impact of climate variability on honey production.

#### **1.4.2 Specific objectives**

- I. To analyze the variability in climate between the period 2000-2023 in the study area.
- II. To assess the beekeeper's perception of climate variability on honey production in Paicho and Palaro Sub-counties.
- III. To document the patterns of honey production in Paicho and Palaro Sub-counties.
- IV. To examine the coping strategies to climate variability by the beekeepers in the Sub-counties.

### **1.5 Research questions**

The following were the research questions for the study.

- I. What are the patterns of climate variability in the study area for the period 2000-2023?

- II. What are the beekeeper's perceptions of climate variability on honeybee production in Paicho and Palaro sub-counties?
- III. What are the spatial patterns of honey production in Paicho and Palaro sub-counties?
- IV. What coping strategies are being implemented by beekeepers to mitigate the impacts of climate variability?

### **1.6 Justification of the study**

Beekeeping is a key livelihood for many in Gulu District, making it vital to understand how climate variability is affecting this sector. Understanding the direct impacts of climate variations on honey production systems would provide critical insights necessary for developing effective adaptation strategies tailored to local conditions. Honey production does not only contribute to local economies but also supports biodiversity and agricultural ecosystems through pollination. Therefore, preserving and enhancing beekeeping in the face of climate variability aligns with broader environmental conservation goals. Given the existing reliance of many local households on income from honey production, there is an urgent need to integrate climate resilience into agricultural practices to ensure sustained livelihoods amidst changing climatic conditions. This study contributes to filling this gap in knowledge, enabling stakeholders, including policy makers and local communities, to develop more resilient agricultural strategies. The specific effects of climate variability on local beekeeping would remain unknown, limiting understanding of how environmental shifts affect honey yields if this study was not conducted.

### **1.7 Significance of the study**

This study contributes to poverty alleviation among beekeepers. Sustainable beekeeping can provide a reliable source of income, thereby improving livelihoods and reducing vulnerability to economic instability, and this align with the SGD 1 i.e., poverty eradication. By highlighting the

impacts of climate variability and coping strategies, the study contributes to the formulation of informed policies aimed at improving the resilience of the agricultural sector to climate variability. Understanding these coping strategies empowers local communities to foster resilience and sustainability in their beekeeping practices, thereby improving food security and economic stability. This study adds to the existing literature on climate variability, beekeeping, and adaptation strategies, serving as a case study for similar contexts within Uganda or even East Africa. The study identified practices that are effective in mitigating the effect of climate variability. This information can be shared across the beekeeping community, helping others to adopt the proven strategies that enhance the resilience of their life understanding which strategies works best, allows for better allocation of resources including time, money and home materials. This can improve the economic viability of beekeeping in the face of climate change which is in line with SDG 13 and Uganda vision 2040, talking about global effort to combat climate change and its effects on vulnerable communities and modernization of agriculture and the promotion of sustainable agricultural practices by focusing on adaptation strategies in beekeeping.

## **1.8 Scope of the study**

The study was conducted in Gulu district, Northern Uganda that is bordered by six districts; Lamwo to the North, Pader to the East, Omoro and Gulu city to the south, and Amuru to the west. The district headquarters is Awach Town Council and it approximately 372 kilometers by road north of Kampala, Capital City of Uganda. The coordinates of the district are  $02^{\circ} 45' \text{N}$  and  $32^{\circ} 00' \text{E}$ , while Palaro and Paicho Sub-counties are located in the following coordinates;  $3^{\circ} 4' 56 \text{N}$ .  $32^{\circ} 4' \text{E}$  and  $2^{\circ} 52' 6'' \text{N}$   $32^{\circ} 28' 54 \text{E}'$  respectively (Figure 2).

This study investigated the Climate variability and its perceived impact on honey production in Paicho and Palaro Sub-counties, focusing on analyzing the variability in climate of Paicho and Palaro Sub-counties, patterns of honey yield, assessing the impact of climate variability on honey production, challenges and adaptation strategies. The study was geographically limited to Gulu District targeting various beekeepers of Paicho and Palaro Sub-counties who have been in beekeeping sector for more than a year. The study involved two levels of data: historical climate data (rainfall and temperature) covering a period of 23 years (2000-2023) obtained from Uganda meteorological Centre located at Entebbe and field data was collected over a period of five months, from May to September 2025 (Appendix B). This enabled analysis of long-term climate variability, honey production patterns and adaptation strategies.

### **1.9 Conceptual framework of the study**

The conceptual framework represents the relationships between the key variables in the study, illustrating how climate variability influences honey production in Gulu District and coping strategies within the local context (Figure 1). Climate variability as an independent variable encompasses changes in temperature and precipitation. This study analyzed how these variables fluctuated over time in Paicho and Palaro Sub-counties.

Honey production as dependent variable focuses on how climate variability impacts the quantity and quality of honey produced, considering aspects that have direct link with the processes like nectar availability and bee behavior.

Coping strategies include the methods and practices adopted by beekeepers in the advert of climate challenges, which may involve changes in practices, diversification of crop species and adjusting hive location.

**Independent variables (IVs)**

**Dependent variables (DVs)**

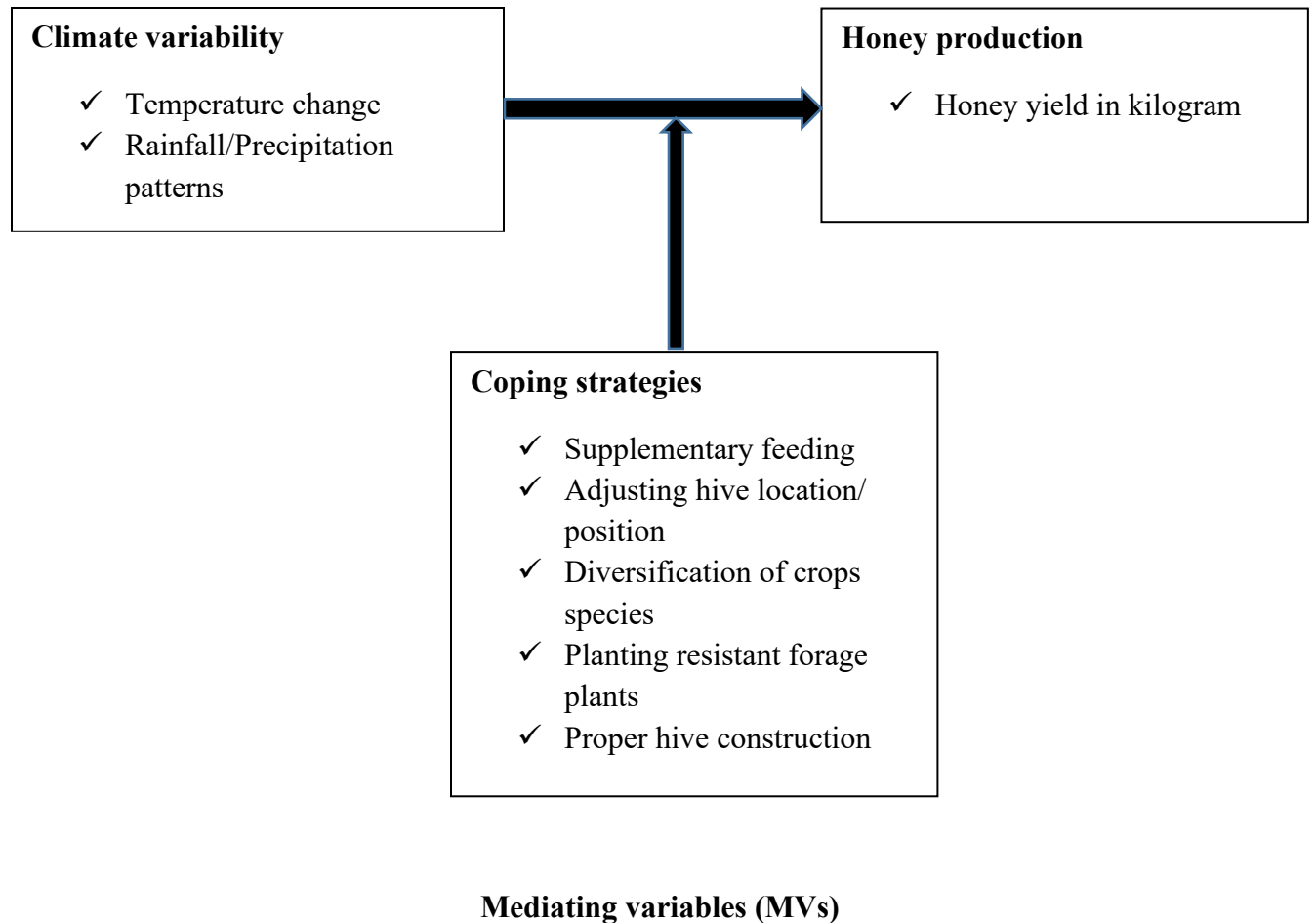


*Figure 1: Conceptual framework*

## **CHAPTER TWO: LITERATURE REVIEW**

### **2.1 Climate change and its causes**

According to IPCC (2022a), weather is defined as conditions, which shows how atmosphere changes over minutes, hours, days and week. Climate on the other hand, is the average weather condition of a place over several decades that is to say, 30-45 years (IPCC, 2022b). It can also be an average weather condition of a place recorded over a long period of time from 30-50 years. Climate change is described in terms of mean and variability of temperature, precipitation and wind over a period, ranging from months to millions of years (a classical period of 30 years) (Treut et al., 2007;IPCC, 2022).

Climate change across the globe is caused by a few interacting naturals and man-made factors, such as, volcanic eruptions injecting gases and ash into the atmosphere and slow orbital changes which often decrease global temperature and altering atmospheric circulation patterns (Rind, 1991), and deforestation, poor agricultural practices, burning fossil fuels which leads to desertification and high temperatures (Kumar et al., 2021). Similarly, Tabari, (2020) stated that climate change points out an increase in average global temperature, increase in severity of extreme weather events, declining air quality, and destabilizing natural system due to natural events and human activities. According to Spittlehouse et al., (2015), climate variability as variation in climate from a time scale to decade and it explains why winter is cold and summer is hot. The drivers of climate variability has been controlled by ocean and atmospheric processes such as El Nino Southern Oscillation, the Arctic Oscillation and the Northern Atlantic Oscillation (Rind, 1991).

## **2.2 Climate variability in Uganda**

Uganda is situated relatively within humid equatorial zone and its topography, prevailing winds and water bodies cause differences in the precipitation patterns across the country (USAID, 2013). Its average annual rainfall ranges from 800 to 1500mm, which decreases in the two seasons in the south during the months of March to May and September and November and one season in the north (April and October). Temperature also varies with altitude and seasons of the year. Uganda's temperature keeps varying from year to year on the order of 0.5 °C (IPCC, 2023).

Uganda has undergone noticeable climatic shifts, including rising temperatures and increasingly erratic rainfall patterns (Egeru et al., 2019). According to (USAID, 2015; Zinyengere et al., 2016), mean annual temperatures in Uganda may increase by up to 1.5 °C by 2030, and by 0.9 °C to 3.3°C by the 2060s. Rainfall projections in Uganda remain highly uncertain, with climate models indicating possible changes ranging from a 16% decrease to a 43% increase, highlighting the variability and complexity of future precipitation patterns. Climate change global projection for Uganda in the period of 2015 - 2045 indicates increase in the precipitation from December to February, which has been historically dry season across the country. It also projected temperature increase by more than 3 °C by 2030. This projection puts Uganda to be experiencing heavy hailstorm, flooding draught, landslides, which will lead to low yields of crops and livestock, hence affecting food security of the country (USAID, 2015).

Gulu District, located in Northern Uganda has been experiencing significant weather variations in last 2 decades. For example, a study by Oriangi et al. (2024) indicates a declined annual rainfall amount from 1980 - 2010 and a rise in both mean minimum and maximum temperature between a periods of 1990 - 2009. The deviation in the rainfall amount was because of prolonged draught, which led to reduced intensity of the rainfall and delayed on-set followed by early cessation and

this also showed decadal variations by the statistical data presented from 1980-2010. According to Oriangi et al. (2024), the longest rainy season recorded in Gulu stretches from March to October from a period of 1980 - 2012, which varied from 985 to 1624 mm. Causes in the variation of temperature in the district is not specific to each location but is interconnected to the global effect of human activities and natural factors, allowing for location specific analysis of climate variability on natural system. The Inter-decadal and intra-decadal temperatures shows high variances from 1990 -1999 and 2000 - 2009 and the highest temperature decadal monthly temperatures between these two decades were from 30 to 35 °C from the months of January, February and December, and the lowest temperature was from the month of March to September during rainy season. The same study conducted by Oriangi et al. (2024) in Gulu district on variability and changes in climate in Northern Uganda, projected a significant decrease in the amount of rainfall in Gulu district. The statistical data also revealed that there would be variation in maximum and minimum temperature by 2033.

### **2.3 Beekeepers perceptions of climate variability on honey production**

According to a study conducted by Wendimu, (2020) in two Agro-ecological zones, 70.12% of bee farmers perceived that climate change impacted negatively on honey production. That the impacts of climate shifts in terms of declining availability of forages, diminishing honey yield, and bee colony abscondment of hives. Beekeepers also ranked the effects of climate variability to be high, moderate and low. The perception on shortage of forages were ranked first, which is directly related to human deforestation, thus, increasing land under crop production/agriculture. Diminished honey yields was ranked second and associated to shortage of nectar caused by limited forages. Honeybee absconding, and high temperatures were ranked third and fourth respectively.

During high temperature in the beehive, foragers are usually busy collecting water to cool the hives rather than collecting nectar, which lead to low honey yield. (Bewuketue, 2017; Wendimu, 2020).

Usmail et al. (2023) found out that small holder farmers especially those that are in semi and arid areas perceived climate change and variability in terms of changes in the biophysical condition of water stress in their areas, perceived as a decrease and increase in temperature. A respondent said *“working in the farm during the day especially close to midday has become uncomfortable due to extreme temperature, we must start our farm work late afternoon, which has impact on working time”*.

Chisale et al. (2021) reported respondents’ perception of climate change as erratic rainfall, high temperature, strong winds, flooding and draughts, which affect the access to forest resources such as fruits, vegetation and others. This is similar to the climate change perception reported by Skambraks, (2014), where both female and male famers consider climate variability in terms of increased temperature, while others said an experience of a decrease in rainfall. One of the members in the study said, *“Everything has decreased, the rainfall, the river, the forest because of the temperature increase”* and these have affected their everyday task. From the above findings, increasing temperature led to physical stress on crops and animals with low productivity, attacked on crops such as maize by borers.

Further study on the perceptions of farmers by Nyunza et al. (2018) indicated that anthropogenic factors and climate change contributed to the drying of the forages and water sources which led to low honey production. While in Bangladesh, Famers experienced climate by observing increase in temperature, draughts, flooding, cyclones and soil salinity (Akala, 2019; Kumar, 2021; Uddin et al., 2017). Many of the farmers reported that they had short winters, long summer seasons, and

unpredictable rainfall and monsoon season changes. These resulted in water scarcity, which subsequently affected crop production negatively.

A study conducted by Atube et al. (2021) on the farmers' perceptions on climate change in Apac District, Northern Uganda found out that the farmers were aware of the climate change, manifested as extreme weather events (72%), and increased attack by pest and diseases (86%). Most of the farmers perceived climate change as decreased variation in onset of the rain and reduced rainy days, reduction in the rainy period and increased hot days or draught. A few farmers (14%) reported no change in climate. Although, the farmers are aware about climate variability, how the different perceptions relate to the occurrence of honey production is the gist of this study.

## **2.4 Honey production patterns**

Chakuya et al.(2024) found out that honey production patterns are influenced by a combination of ecological, climate and management related factors, which vary across space and time. Globally, honey yields are strongly determined by the availability of diversity of floral resources and water availability, which in turn are regulated by rainfall and temperature cycles According to Medina et al. (2018) nectar flow tend to peak during wet seasons when flowers are abundant, while prolonged draughts reduce colony strength and honey harvests. Similarly, (Schweitzer et al., 2013) reported that in tropical environments, honey production is highest during the rainy season and declines during dry months due to reduced forage availability.

In Africa, several studies have documented spatial and seasonal variations in honey production. Research in Ethiopia and Nigeria revealed that honey yields are significantly higher in regions with diverse vegetation cover and well distributed rainfall compared to semi-arid zones where rainfall is erratic and vegetation sparse (Ngala & Kongnso, 2020; Wendimu, 2020). According to

Espen et al, (2023) further demonstrated that differences in honey yield across agro-ecological zones are largely explained by rainfall intensity and flowering cycles, highlighting the importance of climate and forage conditions in shaping production patterns.

## **2.5 Impacts of climate variability on honey production**

Globally, climate affect 1,365 species of bees due to its changing nature and approximately 65% of bees have been recorded to have reduced in their distributions (Rahimi, 2024). Climate variability has been observed to be affecting bees across all the continents with Africa and Europe experiencing the most pronounced effects and North America being least affected and it has also been anticipated to continue altering bee distribution and potentially disrupting existing bee habitats (Rahimi, 2024).

Kimani, (2017) found out that, as temperature increases due to variation in climate, bees get stressed and become unable to pollinate flowers in time, consequently leading to low production in honey .Climate variability such as extreme weather events affects beekeeping sector through destroying their habitats and food resources with drops in honey average yields, high colony losses more especially during winter when there is very low temperature bees spend most of their time in the hive sucking the honey (Landaverde et al., 2023). High temperature during summer times has been noted to disrupt bee activities (Van Espen et al., 2023). Therefore, this impact is experienced across biophysical and social-ecological web, leading to reduced honey yields, colony losses and economic hardship.

Agriculture in every part of Africa runs the risk of being negatively affected by climate change, especially in smallholder systems with little adaptive capacity (Müller et al., 2011). Persistent weather events affect vegetation and hence foraging possibilities for honeybees. While heat stress

tends to negatively affect the longevity at which the honeybee forages and the colony fitness (Medina et al., 2018).

Ngala & Kongnso, (2020) revealed that climate variability is the dominant cause of falling honey yield, while socio-economic factors such as human pressure on the vegetation through land use pattern has also accounted for the low yields of honey. On the same note, the climate variability characterized by rising anomalies of both temperatures and erratic rainfall events coupled with floods which causes losses in apiaries and honey production, prevalence of pests and diseases of honeybees such as *Varroa destructor* and sugar cane aphids because of rising temperature and humidity leads to reduction in the beehive life expectancy hence economic losses to bee farmers (Kumar et al., 2022; Landaverde et al., 2023).

Switanek et al.(2017) revealed in his study that climate variability creates worse conditions for vegetation, bee reproduction and leads to prevalence of pests and diseases such as varroa mites which has pronounce effects on bee foraging activity and forage phenology, colony strength hence reduction in honey yield. A system approach is needed to address both climatic and associated stressors. Most studies lists impacts but did not quantify their relative severity or adaptive capacity of beekeepers in different contexts.

## **2.6 Management strategies in mitigating the impacts of climate variability**

Several adaptation strategies have been reported by many researchers from different part of the world (Landaverde et al., 2023; Novelli et al., 2021; Wendimu, 2020; LLOYD, 2021; Bewuketu, 2017; Ojija & Leweri, 2022; Atube et al., 2022; M.B Onabe et al.,2019; Ngala & Akoh, 2021; Degu et al., 2021, Gajardo-Rojas et al., 2021).

According to the study conducted by Landaverde et al.(2023) on the management adaptations to the impact of climate change on honey bees found out that beekeepers have started modifying their bee hives by constructing it in form of physical boxes and wooden frames, which are placed on the upper and lower lids of the hives to prevent extreme weather events such as fierce winds and rains that affect integrity of the hive. This modification also helps to protect the hive from attack by pests. He also found out that beekeepers have started providing supplementary feeds to their bees to respond to the low availability of feeds (Landaverde et al., 2023). But long-term sustainability and cost effectiveness of constant supplementary feeding are questioned. Beekeepers are also mitigating climate change impacts on bees by relocating their apiaries from extreme weather events such as floods, winds and tropical storms to an appropriate site where there are less extreme weather events with adequate food and water for the bees (Landaverde et al., 2023).

A study conducted by Novelli et al. (2021) found out that beekeepers realized that the most vital action related to lack of nectar is through provision of supplementary feeds such as syrups and candy for survival of the bees in a period when there is no flowering, low temperatures. And this is done not only at a period when there is no flowering, but a continuous practice adopted. This was done in a FGD where one of the beekeepers said *“last year, unlike in the past, we had to feed the honeybees in the harvesting period; otherwise they would have disappeared completely. Fortunately, beekeepers were vigilant and saved their honeybees (Antonio, FGD1).” you can feed them as long as you want but, in the end, it’s just Water and sugar”* (Silvan, FGD2).

According to Vercelli, (2021), beekeepers realized parasite infestation by the Varroa mites which come because of climate change especially during winter with high reproductive rate. There has been adoption by carrying out artificial interrupting brood production through seasonal and winter requeening caging and total brood removal, use of synthetic acaricides, oxalic, and formic acids to

treat the bees during a bad period of climate (Novelli et al., 2021). This has been noted by two farmers in two different focus group discussion saying, *“When winters are mild, the Varroa infestation level is very high, and the mite becomes more difficult to control”* (Sergio, FGD2). *“High temperatures in winter do not allow honeybees to stop their activity”* (Sergio, FGD2). *“We decided to use formic acid at the end of July, but we had to postpone treatment by one month due to high temperatures during the night, with the risk of compromising the Varroa control efficacy”* (Giovanni, FGD2).

(Wendimu, 2020) reported that to in response to the climate change impacts, beekeepers have supplemented their bee colony with additional feeds in the absence of forages, siting beehives in a shaded area to prevent from direct sunlight and heat into the hive, planting of bee foraging using micro irrigation.

According to a study conducted by Lloyd, (2021) on the apiculture adaptations in a shifting world found out that 94.6% of the respondents who were beekeepers in the US were providing supplementary nutrition for their bees such as sugar and pollen while in Malawi, beekeepers used maize flour as food and Cameroonian said they are planting trees and foraging materials such as moringa trees, corn and piment for the bees (Ojija & Leweri, 2022). These adaptation strategies are user friendly (Lloyd, 2021).

A study conducted by Bewuketu, (2017) on farmer’s perception and adaptation strategies to climate change in Northern Ethiopia reported that farmers are adapting to the climate change impacts through adjustment of planting dates of crops, practicing Agro-forestry, using draught resistant varieties of crops soil and water conservation, irrigation and changing livestock variety

(Atube et al., 2022). He added use of soil and water conservation is the most preferred methods that these farmers have adopted it use to for mitigation of climate change effect ( Bewuketu, 2017).

According to the study conducted by Onabe et al.(2019) on strategies for mitigating climate change effect on honeybee productivity in southern Nigeria indicates that beekeepers needs to have educational skills in order to be proficient in mitigating climate change effects in crop production and such as practice of Agro-forestry, cover cropping, intercropping and crop rotation.

According to a study conducted by Ngala & Akoh, (2021) on the adaptive responses to climate variability and change in western highland of Cameroon found out that bee farmers in this area has adapted to climate change effect of pests such as termites, toads, lizards and ants by switching from hanging their hives on the stones to installing it two meters above the ground, use of grease on the hive stands, and use of aluminum metal fixed on each foot of the stand of the bee hive. Ravaging forest fires has been observed in the mountain area of this region and being set by herd men and farmers has developed fire tracing tracks between apiary and grazing lands (Ngala & Akoh, 2021). To adapt to the drying of runnels, shrinking of brooks and frequent flooding and falling of the hive colonization, bee farmers in Mount Oku area in Nigeria has taken the precaution of starting to hang their beehives on trees but this has been difficult with the newly introduced KTB hives (Ngala & Akoh, 2021). Some bee farmers are adapting to effects of unexpected seasonal rain by checking and replacing the decayed grass with corrugated iron sheets (Ngala & Akoh, 2021).

A study conducted by Degu et al. (2021) on beekeepers' adaptation to climate change and variability in Ada Berga and Oromia, Ethiopia also found out that beekeepers in this area use what is called jump harvesting to feed bees with the existing hive resources such as pollen and honey

rather than purchasing supplementary feeds for the bees like sugar and bean flour and so this help to mitigate the climate change impact of lack of forage for the bees. Key informants in these areas were interviewed and noted that adaptation strategy during dearth period is done by piking honey and pollen from resourceful beehives and taking them to the less resourceful colonies to enhance their feeding (Degu et al., 2021). Most of the respondent (66%) in this area adopted supplementary feeding across Agro-ecologies to reduce impacts of shortage of feeds which comes because of indigenous plant species failing to flower due to high temperature which disrupts its growth leading to declined brood rearing, weaker colonies which eventually becomes vulnerable to pests and diseases (Degu et al., 2021, Monica Vercelli et al., 2021). This study concluded that beekeepers has adapted to climate change impact by planting improved bee forages such as *Callistemon citrinus* (bottle brush), *Vernonia amygdalina* (Ebicha), *Dovyalis caffra* (koshomi), *Phacelia tanacetifolia* (locally, Hamageta) and local plant weeds such alfalfa, of which some of these do dries up during dry season. Beekeepers looked at shading their hives against extreme temperature and heavy rain fall by putting shades like corrugated iron sheets, grasses over the hives and placing hives under the trees to provide shades (Degu et al., 2021).

According to Gajardo-Rojas et al. (2022), beekeepers from the Mediterranean region have started translocating their beehives to the temperate region in search of flowers and food for honeybees to adapt to changing climatic conditions. Many beekeepers have also started growing melliferous flora near the apiaries as an important adaptation measure to climate change (Gajardo-Rojas et al., 2022).

## 2.7 Literature gap

The extant literature firmly establishes that climate variability and change are globally perceived by agricultural communities and pose a multi-faceted threat to apiculture through direct stress on bees and disruption of floral resources. A repertoire of adaptation strategies, from immediate hive-level interventions to long-term landscape management, is being employed by beekeepers worldwide. However, critical gaps justify the present study in Paicho and Palaro Sub-counties, Gulu District, Uganda.

Different studies conducted like those of Usmail et al. (2023) in Ethiopia and Atube et al. (2021) in Northern Uganda provide valuable insights into general farmer perceptions, they do not specifically investigate beekeepers, whose perceptions are uniquely shaped by interactions between climate, flora, and insect behavior. Much of the impact and adaptation literature is derived from other continents or different African agro-ecologies such as, semi-arid Ethiopia and highland Cameroon. The specific manifestations of climate impacts and the suitability of adaptation strategies in the specific agro-ecological and socio-economic context of post-conflict Northern Uganda remain underexplored. There was a need for studies that integrate and analyze the climate of Palaro and Paicho Sub-counties and beekeepers' perceptions, the observed impacts on their honey production, and the suite of adaptation strategies they prioritize and implement. Therefore, this study was designed to address these gaps. It would provide a localized understanding of climate variability vulnerability within the beekeeping livelihood system in Gulu District, Uganda. By documenting and analyzing the variability in climate and perceptions, experienced impacts, and adaptation strategies of beekeepers in Paicho and Palaro Sub-counties, the research would provide context-specific evidence crucial for informing resilient beekeeping extension programs and policies, not only in Uganda but in similar smallholder contexts across East Africa.

## CHAPTER THREE: METHODOLOGY

### 3.1 Study area

The study was conducted in Palaro and Paicho Sub-counties, located in Gulu District, Northern Uganda. These Sub-counties were selected purposively because of the many households' active engagement in beekeeping. The climate in the area has been reportedly variable, thus, potentially vulnerable to the honey production. The study took place in the different parishes of the two Sub-counties of Paicho and Palaro, because of significant honey production activities and the potential vulnerability of the sector to climate variability impact.

Climate of the area is characterized by wet and dry seasons (Owori, 2013). The wet seasons extend from April to November with peaks in the month of May, August and October. The average total rainfall received is 1,500 mm per annum, with the monthly average ranging from 1.4 mm in January to 230 mm in August. While dry seasons extend from November to March, and with an average maximum temperature of 32.2 °C, and minimum of 21.9 °C (Gulu district, 2020). Climate of the area has been varying over time, which shows differences in the precipitation levels from 985 mm to 1624 mm averaging to 1305 mm from 1980 to 2012. This implies a high variance in seasonal rainfall and temperature varying from 17 °C to 20 °C averaging to 19 °C from 1990 to 2009 (Oriangi et al., 2024). According to this study, the average minimum and maximum temperatures were 29.4 °C and 31.9 °C averaging at 30.6 °C with an average rainfall of 109 mm, while Paicho minimum and maximum temperatures were 31.1 °C and 32 °C averaging at 32.6 °C with average rainfall of 119 mm. The area have several small streams with major river (Aswa) bordering from the east.

National Census puts the population of the district at approximately 135,133, with females 68,507 and males 66,626, with 11,523 and 26,873 people in Palaro and Paicho respectively (UBOS, 2024). The livelihoods of people in the study area are livestock rearing agriculture with main emphasis of food crop production such as Maize, Beans, SimSim, Cassava, Potatoes, Sunflower and Millet. Cash crops such as Cotton, Soya beans, and tobacco are also grown in the area. All these crops provide nectar and pollen for bees.

Beekeeping is one of the major agricultural practices in the two Sub-counties according to the production office of the district. However, the local beekeepers are experiencing reduction in their honey yield because of limited forages, water during dry season and the changing climatic conditions. But the specific climate variables remain undocumented in the two sub counties. Farmers in the district are aware of how climate variability is affecting their crop production, and their adaptive measures to mitigate the challenges (Olanya et al., 2019). It has not yet been documented how beekeepers in Palaro and Paicho Sub-counties cope with changes in climate to improve their honey yield. Source of land ownership is customary.

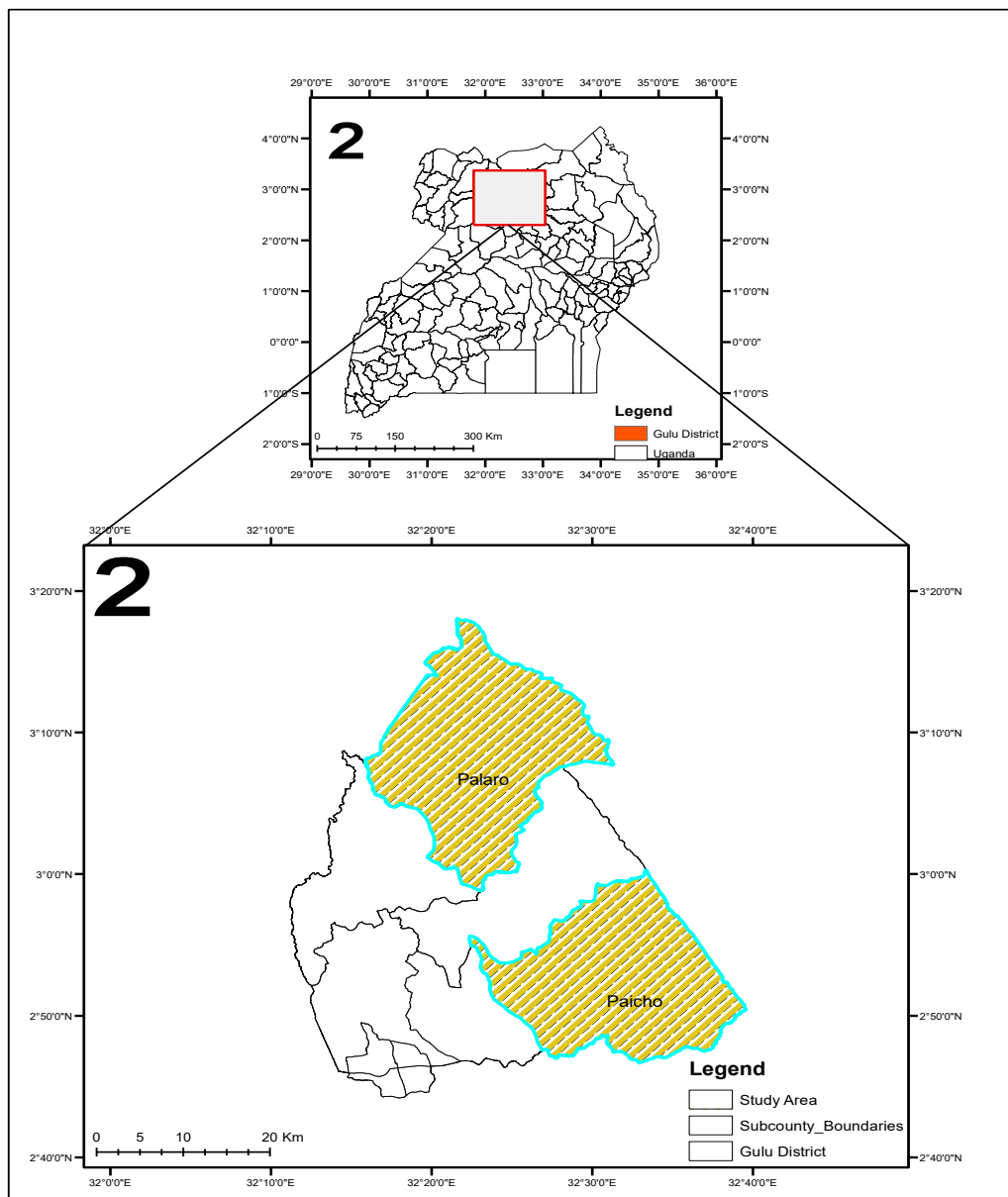


*Figure 2: Map of Gulu district showing study area of Paicho and Palaro Sub-County*

### 3.2 Research design

This study adopted a mixed-method research design, integrating both quantitative and qualitative approaches to provide a comprehensive understanding of the impacts of climate variability on honey production. The mixed-methods approach was selected because it enables the exploration

of both measurable trends and contextual experiences. Quantitative methods were used to analyze variability in climate assess the extent and patterns of changes in honey production, while qualitative methods provided deeper insights into the perceptions, live experiences, and adaptive strategies of local beekeepers in response to climate variability. The integration of these approaches enriched the study by offering multiple perspectives on the research problem and enhancing the validity of the findings. This design was preferred over purely quantitative or qualitative approaches due to the complex nature of climate variability, which require both statistical analysis and contextual interpretation.

### **3.3 Target population of the study**

The primary participants of the study were the local beekeepers with beehives in the area, and have been involved in beekeeping activities for at least a year or more years.

### **3.4 Sampling method**

This study employed a multi-stage sampling technique to select the participants. In the first stage, purposive sampling was used to select Palaro and Paicho Sub-counties as the study areas. These Sub-counties were deliberately chosen due to their relatively high number of active beekeepers and reported experiences of significant declines in honey production attributed to climate variability. The use of purposive sampling at this stage was appropriate because it enabled the researcher to focus on the study objectives, thereby, ensuring that the data collected would be rich and meaningful for analyzing the impact of climate variability on honey production. In the second stage, a census sampling method was applied where data was collected from every member of the define target population (beekeepers), rather than selecting a sample. The decision to use a census approach was made due to the manageable size of the target population and the desire to ensure

comprehensive coverage and minimize sampling error, thereby, enhancing the reliability of the findings. Additionally, key informants were purposively selected based on their experience in beekeeping and their association with local beekeepers. These informants included individuals with expert knowledge or leadership roles relevant to beekeeping in the study area.

### **3.5 Sample size**

The total accessible population for this study consisted of 133 registered and active beekeepers from the two Sub-counties: 65 in Palaro and 68 in Paicho. These figures were obtained from the most recent records maintained by the Entomology Officers and Agriculture Officers of the two Sub-counties. These lists provided the names and contact information of active beekeepers who have been consistently engaged in beekeeping activities over the years.

Given the relatively small population size, and in order to ensure comprehensive coverage, this study adopted a census approach, targeting all the 133 eligible beekeepers. Eligibility was based on having at least one year or more of beekeeping experience. Using census method enhanced reliability and validity of the findings by minimizing sampling error. It also ensured that the views of all experienced beekeepers were captured with the potential strength of the data richness, particularly regarding the impacts of climate variability on honey production. Out of 133 beekeepers surveyed, a sub-set of respondents participated in the qualitative part of the study. Specifically, 5 Key Informants Interviews were conducted with individuals selected purposively based on their expertise and involvement in beekeeping. These key informants are directly dealing with the beekeepers in the field such as entomology officers provide information concerning beekeeping to the beekeepers and a worker from Child Ministry who also deals with farmers in beekeeping by providing necessary support. This number (5 KII) was considered appropriate

(Muellmann et al., 2021) to emphasize an in-depth knowledge and insight richness of information by capturing perspectives from both technical experts and practicing beekeepers.

### **3.6 Demographic characteristics of the respondents**

The respondents were a male-dominated activity, with men accounting for 85% of respondents compared to 15% women. This reflects a gender imbalance in apiculture, where men are more actively engaged than women. The mean age was  $44.96 \pm 9.94$  years, highlighting a relatively mature population of practitioners and raising sustainability concerns, given the limited involvement of youth (only 2.3% in the 21–26 age group). Most respondents were married (94.7%), suggesting that family responsibilities and household livelihoods are strongly tied to beekeeping. Educational attainment was generally low, with 82.7% completing only primary education, 15% reaching secondary level, and very few with tertiary or technical training (0.8%). This indicates that beekeeping knowledge in the area largely stems from indigenous practices and experiential learning rather than formal training.

Beekeeping was often practiced alongside other economic activities, particularly crop farming (49.4%), showing its complementary role in household livelihoods. In terms of experience, 34% of respondents had over 10 years in beekeeping, while 28% had 7–10 years, 26% had 4–6 years, and only 12% had 1–3 years of practice. This demonstrates a strong presence of long-term practitioners and a wealth of practical knowledge within the community.

### **3.7 Data collection methods**

Data for this study were obtained from both secondary and primary sources. Secondary data comprised historical climatic records of the study area, which were obtained from Uganda National

Meteorological Authority (UNMA) located in Entebbe, Kampala. A formal application was made to request access to temperature and rainfall spanning the period 2000 to 2023. These data were used to analyze trends and variability in the local climate.

To spatially map honey production and identify potential hotspots, the GPS locations of the beekeepers were collected using Kobo Collect tool. These coordinates were used to display areas of concentrated honey production and to examine their correlation with climate variables such as rainfall and temperature.

To enhance efficiency, accuracy, and ease of data entry, the structured questionnaires (Appendix C) were used digitally through uploading to the Kobo Collect mobile data collection tool. Data were collected using mobile devices (smartphones), which facilitated data validation, and storage, even in remote areas without internet connectivity. The Kobo Collect tool also minimized manual errors and allowed for seamless integration with the central database for analysis. The questionnaire was designed to capture both quantitative and qualitative data relevant to the study objectives. Quantitative data focused on seasonal production patterns, beekeepers' perception on the impacts of climate variability on honey production and coping strategies employed to mitigate these effects, and the challenges encountered in implementing such strategies while qualitative data explored farmers' perceptions of climate variability, its impacts on honey production. The administration of each questionnaire took approximately 30-45 minutes per respondent.

Key informant interviews were conducted using interview guide (Appendix E) to gather in-depth insights from individuals with expert knowledge and long-term experience in beekeeping and climate related issues. Five key (5) informants were purposively selected based on their experience, professional roles, and interactions with the beekeepers. These key informants

included, Entomology Officers in charge of the two Sub-counties, Production Officer of the district, experienced beekeepers in leadership roles (one from each Sub-county) and one key stakeholder from relevant organizations dealing with farmers in the district, for example, child ministry in Paicho Sub-county dealing with beekeepers. Each key informant interview lasted between 30-60 minutes with semi structured guide tailored to elicit detailed information on honey production trends, microclimate variability impacts, and institutional responses to beekeeping challenges.

### **3.8 Method of data analysis**

Quantitative data analysis was conducted to address the first, second and fourth objectives of the study, which focused on examining rainfall and temperature variability, perception of beekeepers, and determining the relationship between climate variability and honey yields. Data from structured questionnaires were downloaded from Kobo Collect tool application in Microsoft Excel format, cleaned to remove incomplete entries, and imported into the Statistical Package for Social Sciences (SPSS) Version 27 for statistical analysis. Historical rainfall and temperature datasets (2000–2023) obtained from the Uganda National Meteorological Authority (UNMA) were also organized in Microsoft Excel for preliminary processing prior to statistical testing.

The analysis involved several steps. First, descriptive statistics, including means, standard errors, frequencies, and percentages, were computed to summarize rainfall, temperature, and honey yield data. The results were presented using tables, bar graphs, and line charts to visualize seasonal and inter-annual variations, while annual and monthly climate averages were compared to identify peak and low production periods.

Secondly, inferential statistics were applied, with one-way Analysis of Variance (ANOVA) to test for statistically significant differences in rainfall and temperature between years and months. The statistical significance was set at a 5% probability level ( $p \leq 0.05$ ). Following significant ANOVA results, post-hoc pairwise comparisons were performed using Bonferroni correction to control errors across the 276 potential year to year comparisons for each variable. But before ANOVA was conducted, preliminary assumption testing confirmed that the data were normally distributed with equal variances thereby validating use of inferential statistics.

Geospatial analysis was conducted using ArcGIS to process the geographic coordinates of apiary sites and generate honey production maps, while spatial overlays were performed to relate production patterns to climatic variations within the study area.

Qualitative data from Key Informant Interviews (KIIs) were analyzed using a thematic analysis approach facilitated by Nvivo software to enrich on the quantitative findings. The process began with verbatim transcription of audio recordings from the interviews. These transcripts were then carefully and repeatedly reviewed to identify recurring ideas and patterns, which were systematically coded into categories. Related codes were subsequently grouped into broader themes, including perceptions of climate variability, its impact on honeybee production, and the adaptation strategies employed by participants. Finally, these themes were elaborated through detailed narrative synthesis, enriched with direct participant quotes to authentically capture their perspectives.

### **3.9 Ethical consideration**

Ethical approval was obtained from Gulu University Research and Ethical Committee (GUREC) number GUREC-2025-1184 institutional review board to ensure that all research procedures

comply with ethical standards for research involving human participants. Ethical standards were carefully observed throughout the research process to ensure the protection, dignity, and rights of all participants. Prior to data collection, all participants were provided with comprehensive information regarding the study, including its purpose, procedures, and how the data would be used. Informed consent was obtained from the beekeepers to make the two parties (both researcher and the participant) agree before participation commenced. The consent forms were written in simple and clear language and were translated into the local language (Acholi) to facilitate understanding. For participants who were not comfortable with written consent due to literacy constraints, verbal consent was documented in the presence of a witness. The confidentiality and anonymity of all participants were strictly maintained. Personal identifiers were removed from all data, and unique codes were assigned to each participant to represent individual responses. The collected data were securely stored, with restricted access to the principal researcher. Participation in the study was entirely voluntary, and participants were informed that they could withdraw from the study at any point without penalty or consequence. The researcher was committed to treating all participants with fairness, sensitivity, and respect throughout the entire research process. To build trust and ensure ethical engagement, the researcher was actively present in the community during data collection, explaining the purpose and value of the study in an open and transparent manner. Participants were assured that there would be no form of coercion during the recruitment process. Efforts were made to establish a respectful and professional relationship with all participants, acknowledging their autonomy, dignity, and cultural values. Given that the majority of participants were rural beekeepers who might not be familiar with formal research processes, the study was conducted in a participatory and culturally sensitive manner. Prior to data collection,

the researcher collaborated with local leaders, such as Local Council 1 (LC1) chairpersons, to introduce the study and its objectives to the community in a respectful and transparent way.

### **3.10 Reliability**

To ensure the reliability of the data instruments, a pilot study was successfully conducted prior to the main collection phase. The pilot involved 12 beekeepers (approximately 10% of the planned sample size), selected from Koro Sub-county in Omoro District, a location chosen for its demographic and ecological similarity to the actual study areas (Palaro and Paicho Sub-counties), but outside the primary study zone to avoid data contamination.

The pilot participants were beekeepers with at least one year of experience and above in beekeeping, in alignment with the inclusion criteria of the main study. Feedback from the pilot study was used to assess the clarity, relevance and consistency of the questionnaire and interview guides. To evaluate internal consistency, Cronbach's alpha was computed for the questionnaire items. The resulting  $\alpha$  value was 0.8 indicating an acceptable level of internal consistency.

Based on the pilot findings, minor revisions were made to refine the structure and wording of several questions to improve clarity and response accuracy. The version of the instruments was submitted and approved by GUREC, which was used in the main study.

### **3.11 Validity**

To establish and enhance content and construct validity, the questionnaire and interview guides were reviewed by panel experts prior to data collection. The reviewers were one lecturer from the department of Science Education (Agriculture) at Gulu University, one scientist from Uganda National Meteorological Centre (UNMA), one senior Agricultural Extension Officer from Gulu

district. These experts assessed the tools for accuracy, comprehensiveness, and relevance to the study objectives, focusing on the domains of climate variability, honey production, coping strategies and socio-economic impacts. Their feedback was used to revise and finalize the data collection instruments to ensure contextual appropriateness and content completeness.

Member checking was conducted as a method of validation during data analysis. After transcription and thematic coding of qualitative data from the interviews, a summary of findings was shared with selected participants to confirm that the interpretations accurately reflected their views and experiences. This step enhances credibility and trustworthiness of the qualitative data.

### **3.12 Limitations and delimitations of the study**

A major limitation of this study was the lack of proper documentation on honey yields among most of the beekeepers. Many participants relied on memory to estimate their average annual production, which may have affected the accuracy and reliability of the data. The absence of consistent records made it difficult to validate yield trends over the years, thereby, limiting the precision of the production related analysis. The yield analysis were based on the estimated data provided by the beekeepers.

## **CHAPTER FOUR: PRESENTATION AND INTERPRETATION OF RESULTS**

### **4.1 Climate variability in Palaro and Paicho Sub-counties**

#### **4.1.1 Total and annual rainfall variability**

The trend observed in annual rainfall amounts over the period 2000-2023 in the two Sub-counties, indicated a fluctuating pattern over the years. In Paicho, total annual rainfall ranged from 1,025.2 mm to 1,698.1 mm, with a mean of  $1,431.1 \pm 170.78$  mm. The highest rainfall amounts were observed in 2012 (1,698.1 mm), followed by 2018 (1,682.9 mm) and 2019 (1669.7 mm), respectively.

Palaro Sub-county total annual rainfall varied from 2009 (935.2 mm) to 2018 (1575.8 mm), with an average of  $1310.7 \pm 158.53$  mm. The highest amount of rainfall (1575.8 mm, 1575.8 mm and 1480.1 mm) was received in 2012, 2018 and 2001, respectively. The lowest rainfall was received in the year 2009 (935.2 mm) followed by 2008 (1065.7 mm) and 2021 (1114.8 mm).

Average annual rainfall in both Palaro and Paicho Sub-counties showed inter-annual variability (Figure 3).

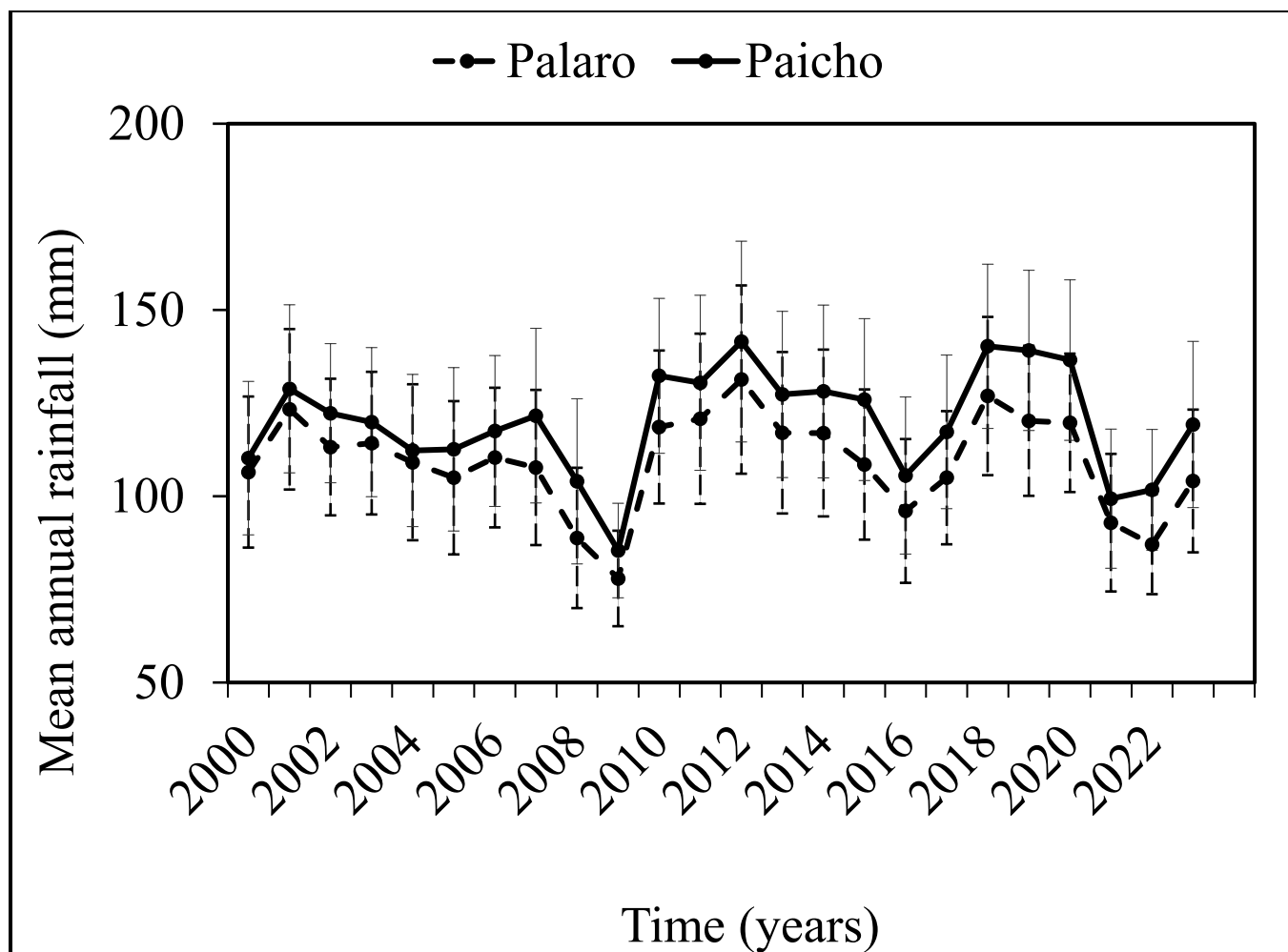


Figure 3: Mean annual rainfall in mm of Palaro and Paicho Sub-counties from 2000-2023. Error bars are (SE).

Paicho consistently received on average higher rainfall on annual basis with peak occurring in 2012 (141.51 mm), 2018(140.24 mm), and 2019 (139.14 mm). The lowest rainfall was recorded from 2008 to 2010, with relatively smaller amount at 2009. The standard error values ranged from  $\pm 12$  mm to  $\pm 27$  mm, indicating moderate variability of annual rainfall. The statistical analysis revealed that Paicho rainfall was not significantly different ( $p > 0.05$ ) across the 24 year period. The peak average rainfall amount for Palaro was 2012, 2018 and 2019 (Figure 3) However, highest variability was observed from 2010, 2012 and 2013 respectively. The standard error ranged from ( $\pm 12$  mm to 25 mm) suggesting moderate variability in rainfall. Palaro annual rainfall patterns

from 2000 to 2023 show no significant differences between years ( $p > 0.05$ ), demonstrating that annual rainfall totals across the entire 24-year is similar.

#### 4.1.2 Annual temperature variability

Generally, the data of temperature from 2000-2023 indicated increasing trend for both maximum and minimum temperature in Paicho and Palaro Sub-counties (Figure 4).

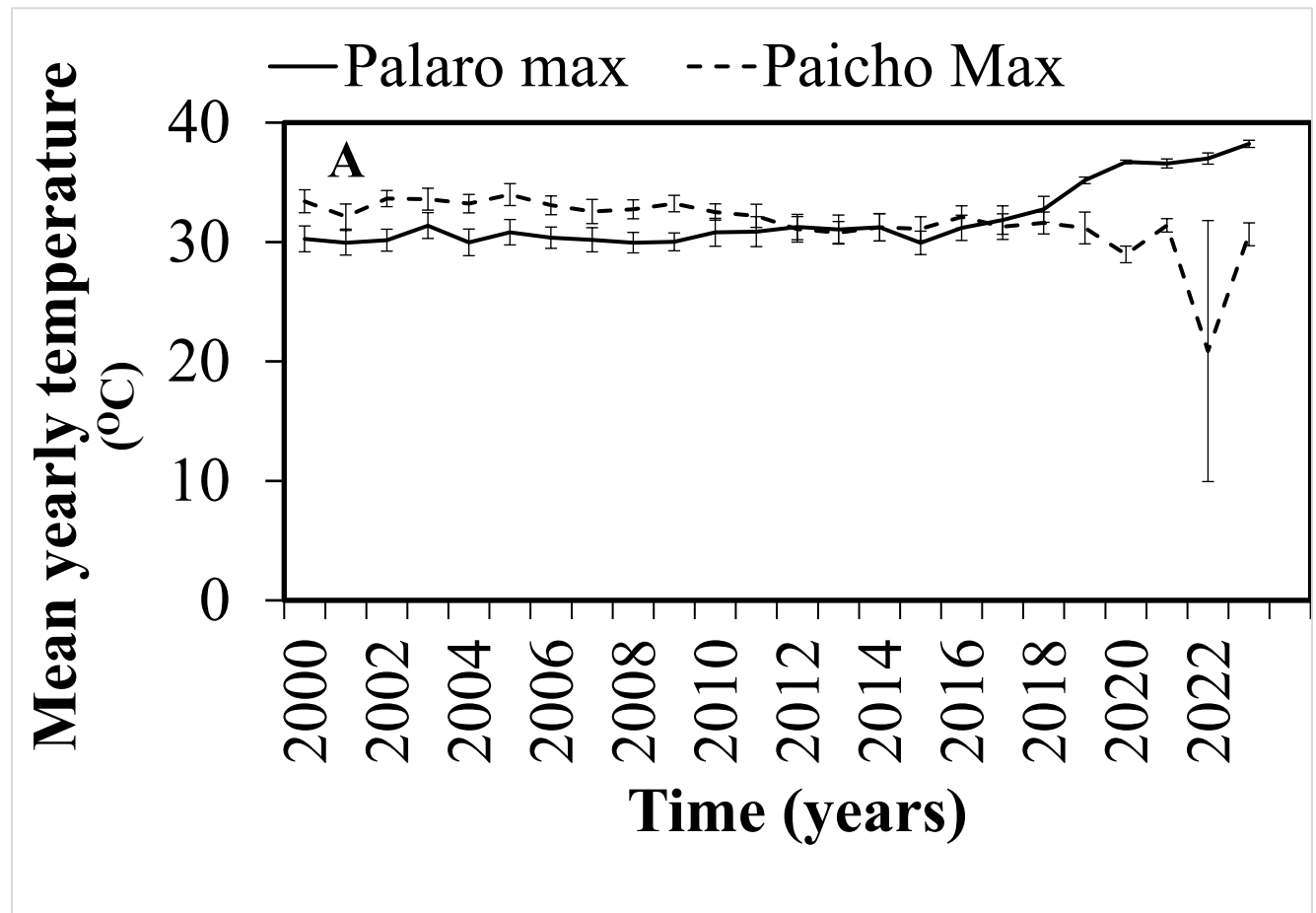


Figure 4: Average maximum temperature in degree Centigrade (°C) of Paicho and Palaro sub-counties. Error bars are SE

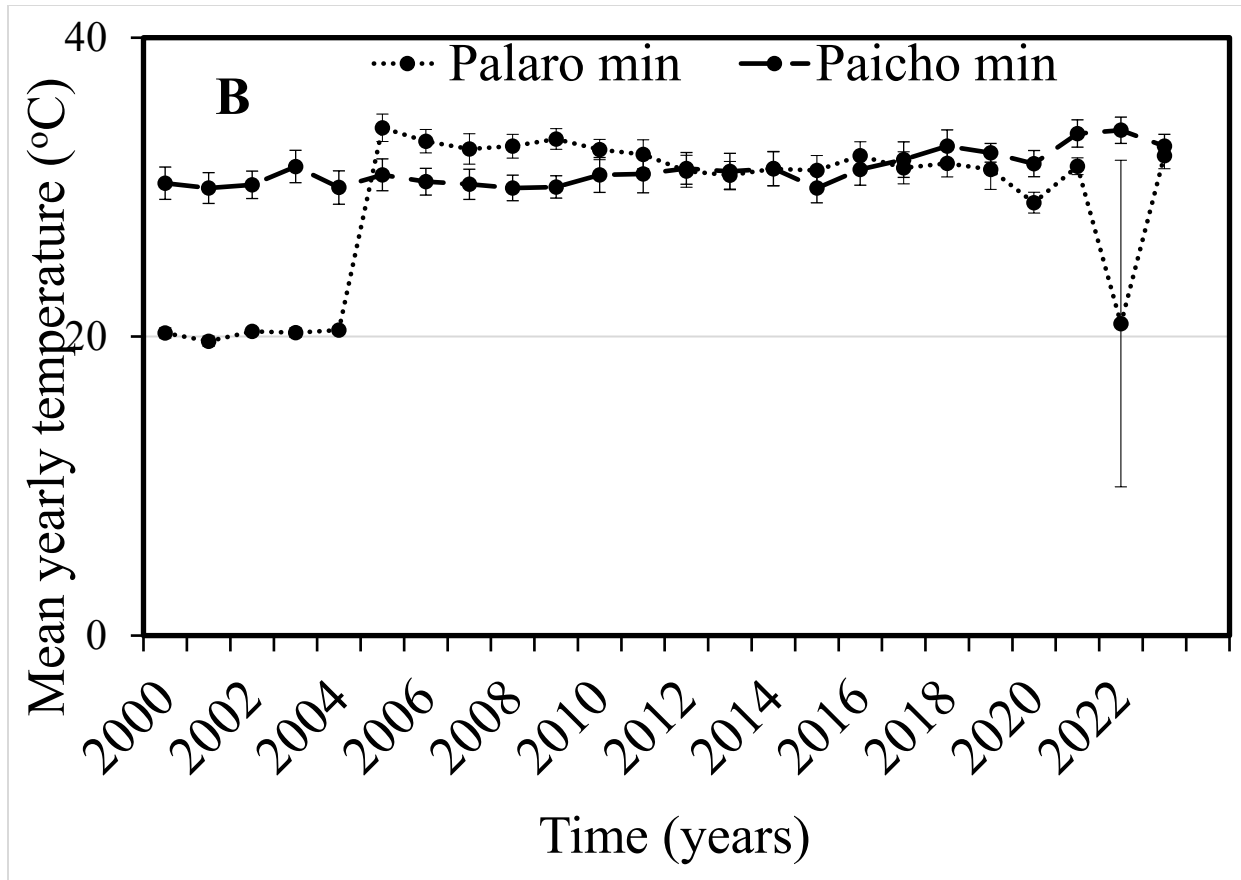


Figure 5: Average minimum temperature in degree Centigrade (°C) of Paicho and Palaro sub-counties. Error bars are SE

In Palaro Sub-county, the mean annual maximum temperature ranged from 29.94 °C in 2001 to 38.22 °C in 2023 (Figure 4), indicating an increased temperature over the years. Statistical analysis confirmed that Palaro maximum temperature exhibited similar trend from 2000 to 2018 ( $p > 0.05$ ) which is significantly different from 2019 to 2023 ( $p < 0.05$ ), which showed similar trend ( $p > 0.05$ ). The mean annual minimum temperature ranged from 19.69 °C in 2001 to 33.97 °C in 2023 (Figure 5), suggesting a rising temperature trend. The standard errors for both maximum and minimum temperatures suggests variations across years. The statistics revealed that Palaro minimum temperature from the year 2000-2004 showed similar trend ( $p > 0.05$ ), which were significant differently ( $p > 0.05$ ) from the year 2005-2023 which had the same trend ( $p < 0.05$ ).

In Paicho Sub-county, the maximum temperature (Figure 4) ranged from 29.94°C in 2001 to 36.99°C in 2022. The maximum temperature of Paicho showed no significant different ( $p > 0.05$ ) across the 24 year periods. However, the minimum temperature (Figure 5) ranged from 29.94°C in 2001 to 33.81°C in 2022, slightly higher than those recorded in Palaro. The associated standard errors, ( $\pm 0.7^{\circ}\text{C}$  in 2009 and  $\pm 1.2^{\circ}\text{C}$  in 2019), indicated consistent temperature patterns across years. These small SE values suggest that the recorded temperatures did not vary widely from the mean. Paicho's minimum temperatures stayed very steady year after year. No year was statistically different ( $p > 0.05$ ). This shows Paicho had a stable temperature trend throughout the study period. Overall, the average temperature of the two Sub-counties exhibited a similar pattern of the statistical analysis with Palaro showing significant different ( $p < 0.05$ ) and Paicho showing no significant different ( $p > 0.05$ ) from 2000 to 2024.

#### **4.1.3 Monthly variation in rainfall and temperature of Palaro and Paicho Sub-counties**

The mean monthly rainfall distribution from 2000 to 2023 is presented in Figure 6.

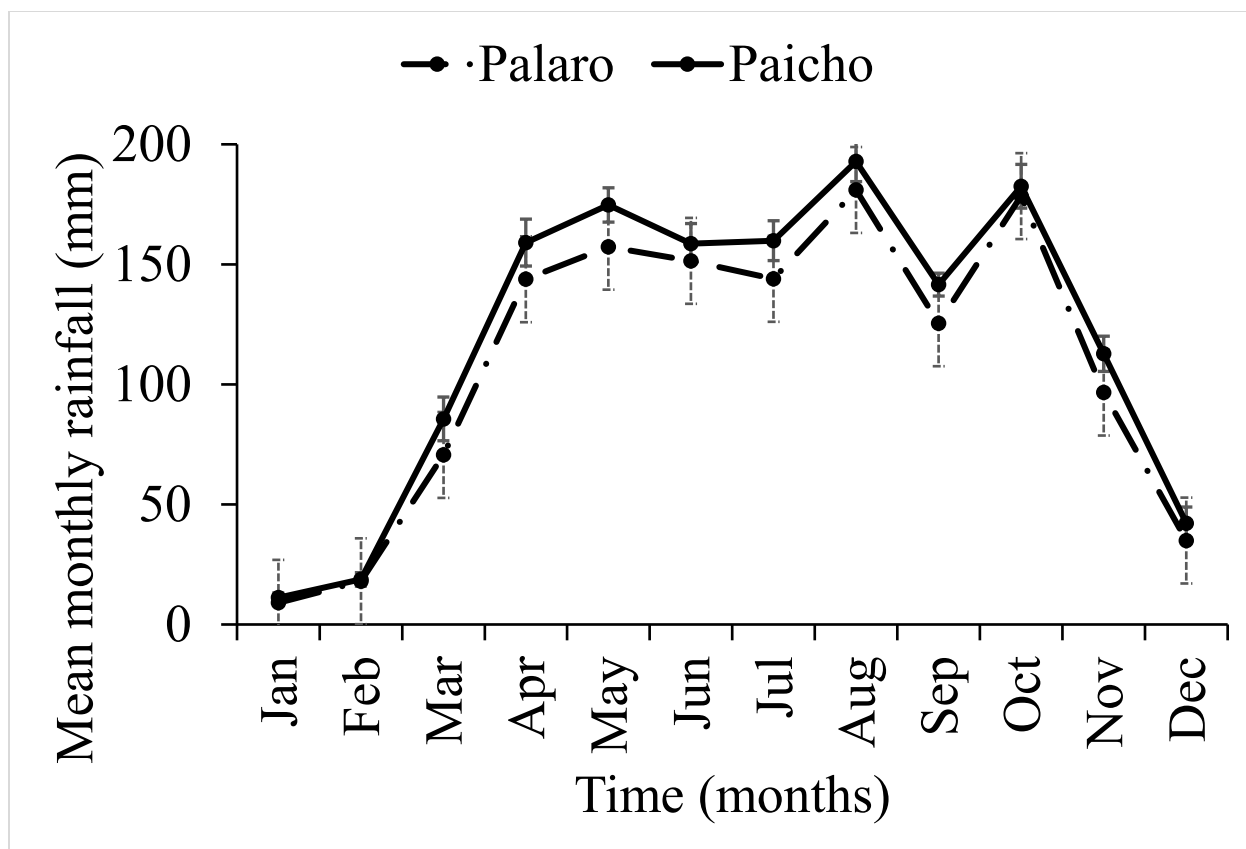


*Figure 6: Mean monthly rainfall in millimeters (mm) for Palaro and Paicho from 2000-2023.*

The rainfall amounts received in Palaro were 9.03mm in January to 18.01mm in February, but peaked at 180.98 mm in August and 178.43 mm in October .Rainfall then declines rapidly from November to December, reaching as low as 96.5 mm and 34.97 mm. Standard error values were low in January ( $\pm 1.5$  mm) and February ( $\pm 2.8$  mm), indicating stable dry conditions, but increased from ( $\pm 8$ mm to  $\pm 10$ mm) in peak rainfall months of August and October, reflecting higher variability rainfall. Statistically, Palaro rainfall exhibited a similar amount from January, February and December ( $p > 0.05$ ), these were significantly different with the amounts from March to December ( $p < 0.05$ ) which exhibited similar amount ( $p > 0.05$ ).

Paicho received low rainfall from 11.16 mm in January to 18.79 mm February. Rainfall increases sharply from March and peaked between April and October with highest in recorded at 192.83 mm

in August and 182.53 mm in October) respectively and declines from November to December. Paicho rainfall also exhibited a similar amount for January, February and December ( $p > 0.05$ ) but was significantly different from March to November ( $p < 0.05$ ) which exhibited similar amount ( $p > 0.05$ ). Like annual rainfall patterns reported earlier in this work (Figure 3).

The mean monthly maximum and minimum temperatures for Palaro and Paicho sub-counties from 2000-2023 (figure 7).

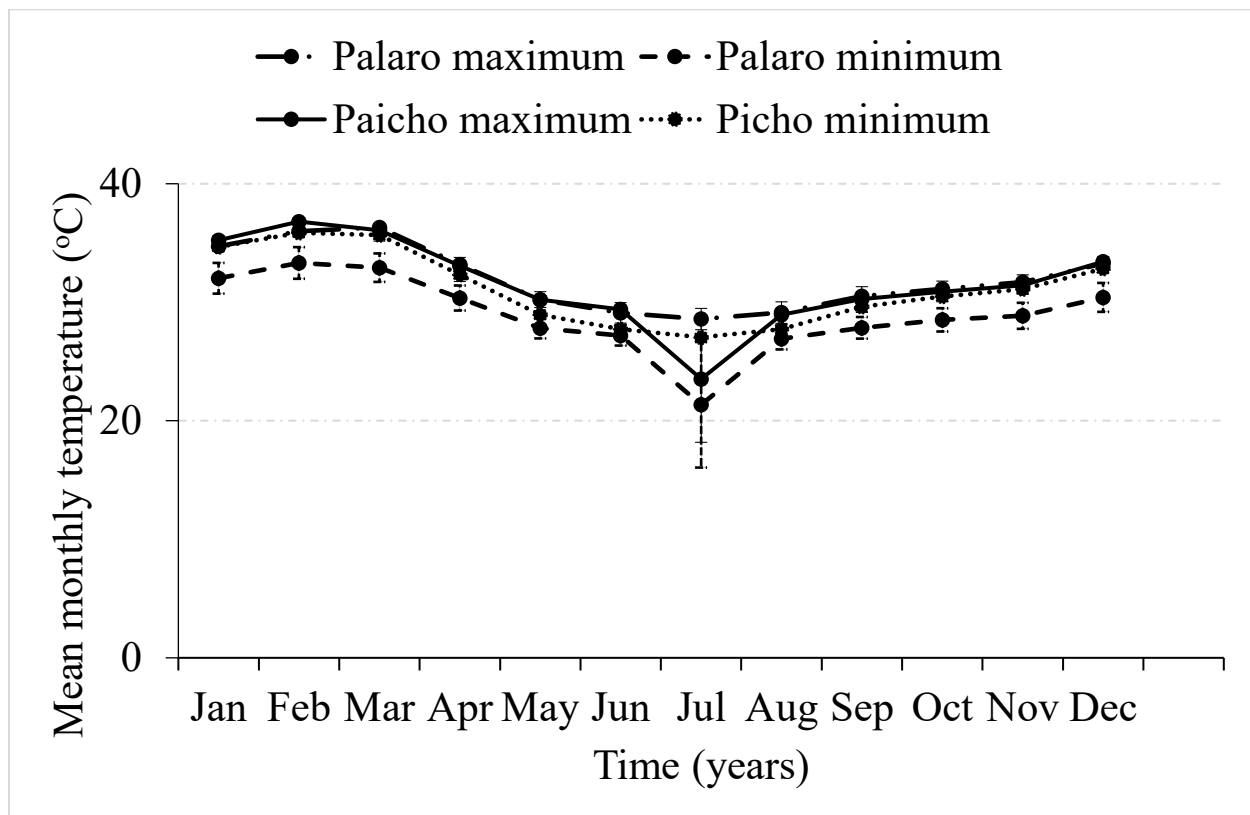


Figure 7: Mean monthly maximum and minimum temperatures in  $^{\circ}\text{C}$  of Paicho and Palaro sub-counties

The maximum temperature in Palaro ranged from  $28.5^{\circ}\text{C}$  in July (coolest month) to  $36.32^{\circ}\text{C}$  in March (hottest month). This pattern shows the warmest period occurs between February and April, followed by a decline during the rainy months of May to August. Temperatures rose again from September to November before dropping in December. The standard errors for maximum

temperature were small, ranging from  $\pm 0.27^{\circ}\text{C}$  (February) to  $\pm 0.90^{\circ}\text{C}$  (August), indicating minimal variability in the monthly mean values. Statistically, Palaro maximum temperature exhibited similar values for January, February, March, April, November and December ( $p > 0.05$ ) but was significantly different from May to October ( $p < 0.05$ ) which exhibited similar values ( $p > 0.05$ ). For minimum temperature, values ranged between  $21.35^{\circ}\text{C}$  in July (lowest) and  $33.32^{\circ}\text{C}$  in February (highest) with standard errors ranging from  $\pm 0.8^{\circ}\text{C}$  to  $\pm 1.34^{\circ}\text{C}$ , indicating low to moderate variability. A notable outlier was observed in July ( $\pm 5.30^{\circ}\text{C}$ ), implying higher inconsistency, probably due to greater cooling during the months. The higher standard error in June ( $\pm 0.86^{\circ}\text{C}$ ) and July ( $\pm 0.90^{\circ}\text{C}$ ), suggesting modest fluctuations. Palaro minimum temperature exhibited similar values for January through April and November through December ( $p > 0.05$ ), but was significantly different from May through October ( $p < 0.05$ ) which had similar values ( $p > 0.05$ ).

In Paicho, the maximum temperature ranged between  $23.53^{\circ}\text{C}$  in July and  $36.80^{\circ}\text{C}$  in February, following a trend similar to Palaro. The hottest months were February to April, while coolest months occurred between June and August, corresponding to the raining season. The standard errors ranged from  $\pm 0.31^{\circ}\text{C}$  and  $0.51^{\circ}\text{C}$  for most months, reflecting very stable maximum temperature patterns across years. The slightly higher standard error in July ( $\pm 5.34^{\circ}\text{C}$ ) reflects greater fluctuations during the wettest period, like the pattern observed in Palaro. Statistics revealed that Paicho maximum temperature exhibited similar values for January, February and March ( $p > 0.05$ ) but was significantly different from April to December ( $p < 0.05$ ) which showed progressive warming with some adjacent months being similar ( $p > 0.05$ ). The minimum temperature for Paicho ranged from  $27.02^{\circ}\text{C}$  in July to  $35.86^{\circ}\text{C}$  in February, showing that nighttime temperatures remain consistently over the year, with only a small difference between

the warmest and the coolest months. The associated standard errors were low ( $\pm 0.28^{\circ}\text{C}$  to  $\pm 0.58^{\circ}\text{C}$ ), indicating limited monthly variation. The lowest SEs in May ( $\pm 0.28^{\circ}\text{C}$ ) and in July ( $\pm 0.28^{\circ}\text{C}$ ) suggest very consistent temperature conditions during these months. Paicho minimum temperature showed similar values for January, February, March and December ( $p > 0.05$ ) but was significantly different from April to November ( $p < 0.05$ ). In general, the average monthly temperature of both Palaro and Paicho Sub-counties exhibited similar trend with the statistical analysis ( $p < 0.05$ ) for maximum and minimum temperatures.

#### **4.2 Beekeepers' perception of climate variability on honeybee production**

All the respondents (100%) in Paicho and Palaro Sub-counties acknowledged that they have observed changes in weather patterns over the past 10–20 years revealing a pattern change in Figure 3 and 4. The widespread perception indicates a strong collective awareness among the local beekeepers of shifts in climate conditions, such as changes in rainfall onset and cessation, temperature increases, and prolonged dry spells.

When asked to rate the impact of climate variability on honeybee production using a 5-point Likert scale, most beekeepers expressed concern (Table 1). Relatively a third (36.1%, and 34.6%) rated the impact as “significant” and minimal, respectively, while 22.6% reported a “moderate” impact. A small proportion (4.5%) rated it as “severe”. Only 2.3% believed that climate variability had no impact on honeybee production. This means a total (63%) of the beekeepers perceived at least a moderate to severe effect of climate variability on their apiculture activities. The findings offer important baseline evidence that beekeepers in the Sub-counties not only observe but also experience climate change in practical terms.

*Table 1: Perceptions of climate variability and its impact on honeybee production.*

| Question                                                             | Response           | Frequency | Percent (%) |
|----------------------------------------------------------------------|--------------------|-----------|-------------|
| Have you noticed changes in weather patterns in the past 1–20 years? | Yes                | 133       | 100.0       |
| Rate the impact of climate variability on honeybee production        | No impact          | 3         | 2.3         |
|                                                                      | Minimal impact     | 46        | 34.6        |
|                                                                      | Moderate impact    | 30        | 22.6        |
|                                                                      | Significant impact | 48        | 36.1        |
|                                                                      | Severe impact      | 6         | 4.5         |

Source; Primary data

#### **4.2.1 Observed indicators of climate variability among beekeepers**

Beekeepers in Paicho and Palaro Sub-counties provided multiple insights into how climate variability manifests in their environment. The respondents answered two multi-response questions regarding the changes they have observed and how they identify that climate variability has occurred. Since multiple responses were allowed, percentages reflect the proportion of total cases selecting each response, and the total response count exceeds the number of participants (Table 2). The most frequently observed climate changes were increased temperature (78.2%), unpredictable rainfall patterns (69.2%), and increased rainfall (57.1%). Other changes included decreased temperature (50.4%), decreased rainfall (38.3%), and more frequent droughts (6.0%). These findings reflect a wide range of climatic anomalies being experienced concurrently in the Sub-counties. The anomalies are the variability in the rainfall and temperature revealed in Figures 3, 4, 5 and 6.

When asked how they identify the occurrence of climate change, the most cited indicators were a reduction in flowering plants (94.7%) and delayed or early rainfall (75.2%). In addition, there were facts on extended dry or wet seasons (57.9%), loss of biodiversity (43.6%), and drying of rivers and streams (9.0%). These results suggests that farmers not only observe climatic shifts but also associate them with specific ecological disruptions relevant to honeybee health and forage availability that is critical elements of apiculture sustainability. Beekeepers are receptive to both meteorological changes and ecological symptoms of climate stress, reinforcing the need for localized adaptation strategies that integrate both climate data and farmers' experiential knowledge.

*Table 2: Indicators of climate variability*

| Category                     | Observation/Indicator           | Frequency | Cases (%) |
|------------------------------|---------------------------------|-----------|-----------|
| Observed climate changes     | Increased temperature           | 104       | 78.2      |
|                              | Unpredictable rainfall patterns | 92        | 69.2      |
|                              | Increased rainfall              | 76        | 57.1      |
|                              | Decreased temperature           | 67        | 50.4      |
|                              | Decreased rainfall              | 51        | 38.3      |
|                              | More frequent droughts          | 8         | 6.0       |
| Indicators of climate change | Reduction in flowering plants   | 126       | 94.7      |
|                              | Delayed or early rainfall       | 100       | 75.2      |
|                              | Extended dry or wet seasons     | 77        | 57.9      |
|                              | Loss of biodiversity            | 58        | 43.6      |
|                              | Drying of rivers or streams     | 12        | 9.0       |

Source: Primary data. The cases indicate multiple responses.

#### 4.2.1.1 Qualitative themes

The qualitative findings also provided rich, contextual insights into the lived experiences and perception of beekeepers. There was a unanimous consensus among all respondents during the key informant interviews that the local climate has become increasingly variable and unpredictable, a clear reflective of the results in Table 1. The key themes derived from the qualitative analysis were aligned with climate variability and local indicators of climate variability were;

- **Erratic rainfall and temperature extremes:** Beekeepers consistently reported a shift from historically predictable weather patterns. A beekeeper from Palaro stated, *"In the past, there was uniform rain and temperature but nowadays, rainfall and temperature has become unpredictable."* This was also echoed by the District Production Officer, who highlighted the breakdown of seasonal demarcations as *"There is variation in dry spell period where we could have clear demarcation of the seasons but now days things have changed. Farmers now do not understand the demarcation."*
- **Indicators of change:** Respondents identified specific ecological and apicultural indicators to discern these changes. The most frequently cited were **alteration of plant phenology** revealed as a widely spread reduction or complete absence of flowering in forage plants. The drying of traditional water sources causing water scarcity, especially during prolonged dry seasons. Evidence of **shifts in bee behavior was reported.** Beekeepers reported that *"bees spend more time inside hives during cold, rainy periods, while fanning the hive to get moderate temperature during heat period."* Beekeepers continued to report that *"bees have started absconding the hives activity due to unfavorable weather conditions to seek better conditions, often near water sources."*

The two (2) themes on the perception of bee farmers on climate variability indicators emphasize the elements of the quantitative analysis as well (Table 2), except the issues of the behaviors of the bees that change with climate variability.

#### **4.3 Spatial patterns of honey production in Palaro and Paicho sub-counties**

The spatial analysis of honey production patterns, indicating apiary locations and supported by qualitative data, reveals some associated factors to honey production in Gulu District. Figure 8 suggests that honey production is uneven across the landscape, and depended largely on proximity to critical resources that buffer against climate shocks such as drought, heat stress, and erratic rainfall. Apiary locations represented by red dots indicate areas of low production, typically associated with greater distance from essential resources such as forages and water. In contrast, blue dots represent apiaries located near water sources and floral resources, which were reportedly a relatively stable production though still lower compared to previous years.

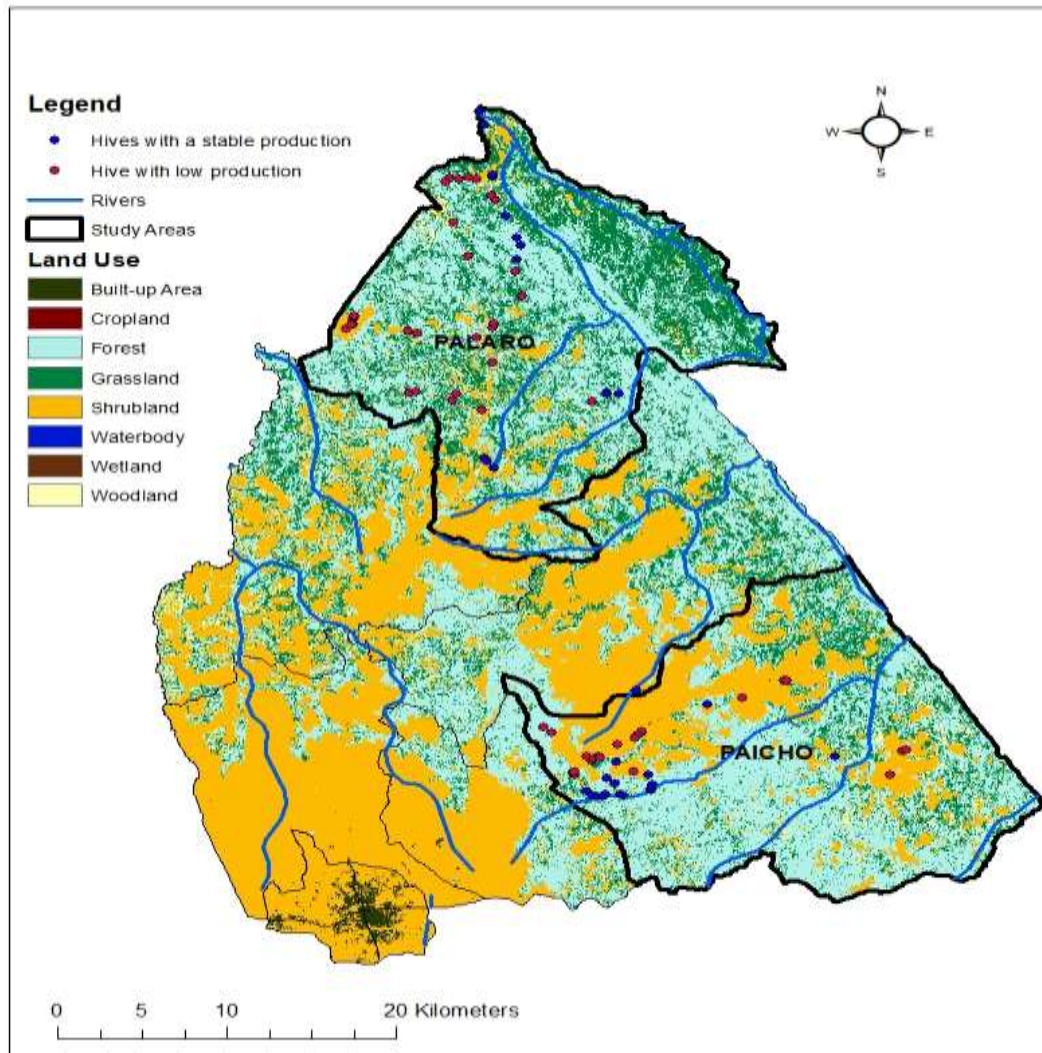


*Figure 8: Map of Palaro and Paicho Sub-counties showing honey production pattern*

Beekeepers in Paicho and Palaro Sub-counties reported using diverse locations to place their hives, depending on factors such as security, forage access, and climate conditions. The multiple-response question allowed participants to select more than one location, and a total of 132 valid responses were analyzed (99.2%). As shown in Table 7, the forest and bush areas were the most commonly hive locations, (70.5%). A suggestion that many beekeepers rely on natural vegetation and secluded environments to promote colony strength and reduce human disturbance. The adjacent position to the backyard garden was the second most common location (24.2%)

beekeepers, indicating some integration of apiculture with homestead-based agriculture. Near water bodies accounted for 6.8%, likely due to bees' need for water especially during dry seasons. Surprisingly, only 5.3% of beekeepers reported placing their hives in the homestead, possibly due to concerns about disturbance from household daily activities. These findings reflect varied strategies in hive placement that balance accessibility, productivity, and environmental suitability. The results provide evidence that the majority of hives are located in natural, less-disturbed areas. Future interventions promoting sustainable beekeeping should consider enhancing forage resources and water access in both forested and homestead-adjacent locations.

*Table 3: Locations where beekeepers place their hives.*

| <b>Hive Location</b>   | <b>Frequency (n)</b> | <b>Responses (%)</b> | <b>Cases (%)</b> |
|------------------------|----------------------|----------------------|------------------|
| Forest/Bush area       | 93                   | 66.0                 | 70.5             |
| Backyard garden        | 32                   | 22.7                 | 24.2             |
| Near water bodies      | 9                    | 6.4                  | 6.8              |
| Homestead              | 7                    | 5.0                  | 5.3              |
| <b>Total responses</b> | <b>141</b>           | <b>100</b>           | —                |

Source: Primary Data. The total number of responses (141) exceeded the number of valid cases (133) because respondents could select multiple options.

#### **4.3.1 Beekeeping practices and production patterns in Gulu District**

This section provides the insight into hive preferences, motivations for practicing beekeeping, and honey harvesting patterns. Majority of respondents (88.0%) reported using traditional hives, while only 5.3% used modern hives, such as, Langstroth or Kenya Top Bar, and 6.8% used both hive types. This reflects a strong reliance on indigenous apicultural methods, with minimal adoption of modern hive technologies in the study area.

When asked about their motivation for starting beekeeping, most participants (89.5%) cited personal interest as the driving factor. A smaller number indicated family tradition (6.0%), encouragement from friends (3.0%), or training by agricultural extension officers (1.5%) as the impetus for their entry into beekeeping. These indicate that apiculture is largely self-initiated or inherited rather than institutionally promoted.

In terms of honey harvesting frequency, 79.7% of the respondents harvest honey twice per year from a single hive. Only 16.5% harvest once per year, and 3.8% harvest three times per year. This trend highlights the seasonal nature of honey production in the region and may reflect constraints related to forage availability and climatic variability. These results are summarized in Table 4

*Table 4: Beekeeping practices and honey harvesting frequency*

| Category                       | Response                                      | Frequency | Percent (%) |
|--------------------------------|-----------------------------------------------|-----------|-------------|
| Type of beehives               | Traditional hives                             | 117       | 88.0        |
|                                | Modern hives (Langstroth/KTB)                 | 7         | 5.3         |
|                                | Both traditional and modern                   | 9         | 6.8         |
| Motivation for beekeeping      | Personal interest                             | 119       | 89.5        |
|                                | Family tradition                              | 8         | 6.0         |
|                                | Encouragement from friends                    | 4         | 3.0         |
|                                | Training from agricultural extension officers | 2         | 1.5         |
| Annual honey harvest frequency | Once                                          | 22        | 16.5        |
|                                | Twice                                         | 106       | 79.7        |
|                                | Thrice                                        | 5         | 3.8         |

Source: Primary data.

The findings underscore the dominance of traditional practices in beekeeping. This is attributed by the limited knowledge in how modern beehives works and affordability of the traditional beehives

in terms of cost effectiveness compared to modern ones such as Kenya Top Bar hive (KTB) and suggest opportunities for interventions such as training, promotion of modern hives, and enhanced extension services to boost productivity and climate resilience in northern Uganda.

#### 4.3.2 Number of beehives managed and yield levels

Beekeepers in Paicho and Palaro Sub-counties demonstrated a wide range in the number of hives managed and the corresponding honey yields per (Table 5). This suggests that while a few beekeepers manage large apiaries, the majority are smallholders operating at a modest scale. The relatively low average indicates possible production constraints. The large standard error in total honey yield reflects high variability between small-scale producers and a few large-volume beekeepers, further emphasizing the heterogeneous nature of honey production in the Sub-counties. These statistics reveal that while most beekeepers operate on a modest scale, there is potential for significant expansion in both hive numbers and productivity with the right support and training.

*Table 5: Individual beehive numbers and honey yields (n = 133)*

| <b>Variables</b>                                                              | <b>Minimum</b> | <b>Maximum</b> | <b>Mean <math>\pm</math> SE</b> |
|-------------------------------------------------------------------------------|----------------|----------------|---------------------------------|
| Individual number of beehives                                                 | 1              | 100            | 17.91 $\pm$ 1.48                |
| Average honey yield (hive <sup>-1</sup> year <sup>-1</sup> kg <sup>-1</sup> ) | 3              | 70             | 6.25 $\pm$ 0.50                 |
| Total honey yield (hive <sup>-1</sup> year <sup>-1</sup> kg <sup>-1</sup> )   | 4              | 3,640          | 133.09 $\pm$ 28.23              |

Source: Primary data

#### **4.4 Impacts of climate variability on honey production**

Nearly all surveyed beekeepers (98.5%,  $n = 131$ ) affirmed that climate variability has affected their honey production (Table 6). When asked how honey yield had been affected, the majority reported a significant decrease in production (58.6%,  $n = 78$ ), followed by 37.6% ( $n = 50$ ), who noted a slight decrease. A small number of respondents indicated no change (1.5%,  $n = 2$ ) or a slight increase in yield (1.5%,  $n = 2$ ). This clearly shows that yield reductions are widespread, with more than 96% of beekeepers reporting some form of a decline.

In terms of seasonal challenges, most respondents (57.1%,  $n = 76$ ) indicated that they experience difficulties in both the rainy and dry seasons, suggesting persistent stress across climatic extremes. Another 40.6% ( $n = 54$ ) cited the rainy season alone as problematic, while only 2.3% ( $n = 3$ ) said the dry season alone posed major challenges. These trends point to the compounding effects of erratic weather, affecting hive health, forage availability, and nectar flow throughout the year.

These results highlight not only the direct impact of climate variability on honeybee productivity, but also the dual seasonal burden faced by beekeepers in the Sub-counties. Strategic climate adaptation and apiculture-specific extension services are urgently needed to buffer these effects and support sustainable honey production year-round.

*Table 6: Perceived effects of climate variability on honey production.*

| <b>Category</b>                              | <b>Response</b>         | <b>Frequency</b> | <b>Percent (%)</b> |
|----------------------------------------------|-------------------------|------------------|--------------------|
| Climate variability affects honey production | Yes                     | 131              | 98.5               |
|                                              | No                      | 2                | 1.5                |
| Effect on honey yield                        | Decreased significantly | 78               | 58.6               |
|                                              | Decreased slightly      | 50               | 37.6               |
|                                              | No change               | 2                | 1.5                |
|                                              | Increased               | 2                | 1.5                |
| Season with most challenges                  | Both seasons            | 76               | 57.1               |
|                                              | Rainy season            | 54               | 40.6               |
|                                              | Dry season              | 3                | 2.3                |

Source: Primary data.

Other causes of declining honey production in the Sub-counties apart from the climate variability, reflecting a diverse understanding of environmental pressures are presented in Table 7. The most frequently cited causes of reduced honey production were reduced flowering plants (96.2%). Pests and diseases (84.2%) reported as a major challenge likely due to climate-driven shifts in pest dynamics and hive health vulnerabilities.

One-third of respondents (33.1%) reported lack of water sources as a contributing factor - An indication diverse placement of beehive. Given that bees require water for hive thermoregulation, especially during high temperatures; this represents an important but often overlooked production constraint. Droughts were mentioned by 14.3%, indicating their recognition as a secondary but relevant stressor. Only 0.8% indicated “others” which involves vandalization of beehives by the cattle keepers. The findings demonstrate that beekeepers perceive honey production to be sensitive

to a combination of climate variability, ecological degradation, and biological stressors, underscoring the need for a holistic adaptation approach.

*Table 7: Perceived causes of changes in honey production*

| Factor                   | Frequency (n) | Cases (%) |
|--------------------------|---------------|-----------|
| Reduced flowering plants | 128           | 96.2      |
| Pests and diseases       | 112           | 84.2      |
| Lack of water sources    | 44            | 33.1      |
| Others (specify)         | 1             | 0.8       |
| Total responses          | <b>434</b>    | —         |

Source: Primary data. There are multiple responses to the questions.

These perceptions emphasize the beekeepers' nuanced understanding of the interconnected environmental factors that influence honeybee productivity. They provide a valuable basis for targeting interventions such as pest control, forage improvement, and climate-adaptive hive management.

Thematic analysis also revealed that, the perceived impacts on honey production were severe and multifaceted, directly linking climatic shifts to **economic and livelihood consequences**. A beekeeper from Palaro lamented, *"I get little or small income. Yet the income would help me to buy basic needs."* The District Production Officer highlighted a broader market impact, noting that local institutions like St. Mary's College Lacor Hospital are now sourcing honey from other regions due to inconsistent local supply. This is contrary to Table 6, where few individuals reported no change in harvest. It was observed that all those who reported no change in yield were new entrance in bee keeping. Another, most frequently impact was a substantial reduction in honey harvests, which was **thematically a drastic decline in honey yield**. A Palaro beekeeper attributed this

directly to *"reduced nectars from the forages, exacerbated by bush fires and deforestation during dry spells."* The Sub-county Entomology Officer confirmed that farmers frequently harvest nothing in seasons that were previously productive, stating, he stated *"farmers are not harvesting anything."* **The disruption of bee behavior and colony health was another theme.** Climate stressors directly affect bee activity. During heavy rains, *"Bees fail to move outside and tend to cluster themselves to generate warmth while eating honey from the beehives, leading to low yields. "High temperatures force bees to divert energy from foraging to cooling the hive through fanning."* The District Production Officer elaborated, *"The fanning of the hives by the bees may take long, which takes energy from the bees and they end up not collecting food."* **In addition, there was reportedly an increased pest and disease prevalence.** The Entomology Officer linked heavy rainfall to breeding cycles of pests like safari ants, which then attack apiaries, which is confirmed by the quotation, *"bee disease and pests becomes common, such as viral, and bacterial diseases during very wet periods."* This is evident in Figure 9.

Honeybee diseases, pests, and reduced forage availability were frequently cited as compounding stressors, and noted a mismatch between honey flow periods and flowering cycles, disrupting harvests and reducing income (Figure 7).



*Figure 9: pest attack on the beehive*

#### **4.5 Coping strategies to climate variability**

In response to climate variability, beekeepers in the Sub-counties of Gulu District have adopted a variety of coping strategies, with 133 valid responses analyzed (Table 8). The most frequently adopted strategy was placing hives in shadier areas, reported by 64.7% of the beekeepers. Other widely practiced strategies included planting more flowering plants or trees (36.8%) and adjusting hive placement for better protection against sun and wind (36.1%). However, more resource-intensive or knowledge-demanding methods such as supplementary feeding (15%), water provision for bees (12%), using modern hives with better insulation (3.8%), and planting climate-resilient forage (3%) were less commonly practiced. This suggests a reliance on low-cost, traditional adjustments over technical or infrastructural solutions.

Despite their efforts, beekeepers reported several challenges in implementing these strategies. The most common barrier was limited knowledge or training (49.6%), followed by lack of resources such as money or equipment (37.6%), and severe climate conditions (33.1%). Some respondents (12.8%) also cited poor access to agricultural extension services, indicating institutional support gaps. A small portion (9.8%) mentioned other which include the categories of those who did not apply any coping strategy.

These strategies reflect both reactive and proactive adaptations aimed at minimizing the negative effects of temperature extremes, rainfall unpredictability, and forage loss. They underscore the need for increased extension support, technical training, and financial resources to enhance the adaptive capacity of local apiculture systems. In general, local beekeepers are actively trying to adapt but their efforts are constrained by systemic and environmental limitations. Strengthening

technical outreach and resource access could significantly enhance adaptive resilience in honeybee production systems.

*Table 8: Coping strategies and implementation challenges in response to climate variability (n = 133)*

| Category                  | Strategy/Challenge                               | Frequency (n) | Cases (%) |
|---------------------------|--------------------------------------------------|---------------|-----------|
| Coping strategies adopted | Placing hives in shadier areas                   | 86            | 64.7      |
|                           | Planting more flowering plants/trees             | 49            | 36.8      |
|                           | Adjusting hive placement (shade/wind protection) | 48            | 36.1      |
|                           | Providing supplementary feeding                  | 20            | 15.0      |
|                           | Water provision for bees                         | 16            | 12.0      |
|                           | Using modern hives with better insulation        | 5             | 3.8       |
|                           | Planting resistant forage plants                 | 4             | 3.0       |
|                           | Other (specify)                                  | 12            | 9.0       |
| Challenges faced          | Limited knowledge or training                    | 66            | 49.6      |
|                           | Lack of resources (money, equipment)             | 50            | 37.6      |
|                           | Climate conditions too severe                    | 44            | 33.1      |
|                           | Poor access to agricultural extension services   | 17            | 12.8      |
|                           | Other (specify)                                  | 13            | 9.8       |

Source: Primary data revealing multiple responses.

In response to the climate challenges, qualitative analysis revealed that, beekeepers and supporting organizations have developed and promoted a range of coping strategies, though their adoption is uneven. Two themes emerged from qualitative analysis where farmers registered institutional supported strategies. **Supported strategies such as Supplementary Forage Planting for** promotion of drought-resilient, year-round flowering plants like Calliandra was given by the Entomology Officer and the NGO. This supported strategy is still low as it is indicated in (Table 8) compared to low cost strategies. The NGO worker noted, *"We have given them seeds of*

*Calliandra and now advising these bee farmers to plant to provide supplementary feeds to the bees."* This knowledge was added to the quantitative data provided by the respondents in Table 8.

The most widely practiced adaptations were **low-cost, Indigenous strategies** and low-input and based on experiential knowledge. Beekeepers reported low-cost strategy as **strategic hive placement, where** hives are placed under shade trees to protect from sun and rain is a universal practice. As one beekeeper said, *"I always make sure I place my beehives under shade which cannot be affected by rainfall and direct sunlight. I also grow crops like sunflower and SimSim nearby so bees don't have to fly far."* Additionally, **water provision was also reported.** Beekeeper are providing water in containers with sticks or stones for landing platforms is a common response to water scarcity, valued for being *"very cost-effective."* One of the beekeepers reported that, *"I always provide water for my bees during dry season in order to avoid them coming to homestead in search for water."* Figure 10.



*Figure 10: provision of water to the bees*



*Figure 11: Adaptation by use of insulated hive and placement under shade.*

**Adoption of modern hives was taken up by some** beekeepers, particularly in Paicho, transitioning to modern technology, insulated hives like the Kenya Top Bar (KTB). One beekeeper attested to their effectiveness: *"The KTB hive has an insulator even if I put in the sun, it cannot be affected by the direct sun heat."* **Beekeepers are limited to institutional support:** As noted by the District Production Officer, *"There is no training on climate agriculture in Gulu district,"* highlighting a systemic gap as they implement the different strategies.

Beekeepers in Paicho and Palaro Sub-counties expressed strong demand for various forms of support to enhance resilience against climate-related challenges (Table 9). The most desired form of support was access to modern beekeeping equipment, reported by an overwhelming 97% of respondents. This was followed by demand for financial support or credit facilities (85%) and government or NGO programs targeting beekeepers (77.4%). Additionally, 63.2% of respondents requested training on climate-smart beekeeping practices, while 49.6% expressed a need for better access to climate information, such as weather forecasts and early warning systems. These highlights both material and informational needs among beekeepers seeking to adapt to increasing environmental variability.

In terms of information sources, 60.2% reported receiving guidance from agricultural extension officers, making it the most common channel for apiculture knowledge. However, over one-third

of the respondents (34.6%) reported receiving no information at all, suggesting significant communication and outreach gaps. Other channels, such as radio/TV programs (10.5%), local beekeeping associations (3.8%), and peer-to-peer learning (2.3%), were minimally utilized.

*Table 9: Support needed and current information sources for climate-smart beekeeping*

| <b>Category</b>      | <b>Support/Information Source</b>                 | <b>Frequency (n)</b> | <b>Cases (%)</b> |
|----------------------|---------------------------------------------------|----------------------|------------------|
| Support needed       | Access to modern beekeeping equipment             | 129                  | 97.0             |
|                      | Financial support or credit facilities            | 113                  | 85.0             |
|                      | Government/NGO programs for beekeepers            | 103                  | 77.4             |
|                      | Training on climate-smart beekeeping practices    | 84                   | 63.2             |
|                      | Access to climate information (weather forecasts) | 66                   | 49.6             |
| Current info Sources | Agricultural extension officers                   | 80                   | 60.2             |
|                      | Radio/TV programs                                 | 14                   | 10.5             |
|                      | Local beekeeping associations                     | 5                    | 3.8              |
|                      | Peer-to-peer learning (other beekeepers)          | 3                    | 2.3              |
|                      | None                                              | 46                   | 34.6             |

Source: Primary data.

These findings highlight an urgent need to strengthen institutional support systems and communication channels, particularly for training, extension services, and the provision of climate-resilient tools and financing. The data also suggest underutilization of community-based learning and media platforms, which could be expanded as cost-effective channels for outreach.

As one farmer emphasized:

*“I need financial support to buy modern hives and equipment. The government should include beekeepers in its programs, such as the Parish Development Model.”*

An NGO worker echoed the importance of training:

*“We provided site selection and climate adaptation training, and farmers started implementing what they learned. Some now process their honey and fetch better prices.”*

Respondents stressed the need for government policies targeting beekeeping in the context of climate change. Suggestions included the formulation of a dedicated beekeeping act, increasing extension outreach, and integrating beekeepers into broader agricultural resilience programs.

Respondents provided a diverse set of open-ended recommendations addressing the challenges of honeybee production under climate variability. Several key themes emerged from their responses, reflecting both practical needs and broader systemic concerns.

- The most frequently mentioned recommendation was the need for training and capacity building on modern and climate-smart beekeeping techniques. This included calls for both initial training and regular refresher programs for farmers. A significant proportion of respondents emphasized that *“we need financial support to enable us purchase modern beehives, protective gear, and honey-harvesting equipment.”* Others requested direct material support, such as distribution of beehives by government or NGOs, and support with establishing apiaries.
- Environmental concerns were also raised. Multiple beekeepers highlighted the need to plant more flowering trees and forage species, especially those that bloom year-round, to counteract declining bee forage. In their quotation, they said, *“more Calliandra seeds for planting should be provided to enable continuous collection of food by the bees.”* Many also stressed the importance of avoiding deforestation, especially the cutting down of trees that provide nectar sources for bees. A few respondents mentioned specific

recommendations such as using Calliandra trees, which are known for their long flowering periods.

- Concerns about **pests and predators** were also prevalent. Some farmers suggested that, *“we need support from government official at the district to train us in controlling harmful insects particularly some flies we do not understand about it and wasps that are killing our bees.”* Others said, *“Insecurity around hives, especially in relation to (pastoralist intruders) who are destroying or spraying hives,”* was another notable issue.
- In addition, several beekeepers called for **better market access** and value chain development, suggesting that improving the availability of markets and processors could enhance economic returns from apiculture. Lastly, a few respondents emphasized the need for climate information services and advisory support to guide their timing and hive management decisions in the face of unpredictable weather.

## CHAPTER FIVE: DISCUSSION

### 5.1 Climate variability

The first objective of this study was to analyze the climate variability in Paicho and Palaro sub-counties, focusing on rainfall and temperature patterns from 2000 to 2023. The data showed a classic pattern of high inter-annual and monthly rainfall variability. ANOVA showed no significant differences in annual rainfall between years, monthly variations were highly significant ( $p < 0.001$ ), underscoring a strongly seasonal climate confirming the "increasingly erratic rainfall patterns" identified by Egeru et al. (2019) for Uganda. This variability is not random; underscoring the "uncertainty" in rainfall projections highlighted by USAID (2015), which noted possible changes ranging from a 16% decrease to a 43% increase.

The consistent observation that Paicho received higher and more variable rainfall than Palaro is a critical finding that underscores the concept of climate variability. It demonstrates that even within the same district, significant climatic differences exist. This finding aligns with the assertion by USAID (2013) that Uganda's topography and local conditions cause differences in precipitation patterns across the country. The higher standard errors during peak rainy months (August-October) further illustrate that the wet season is not only intense but also highly unpredictable from year to year, a key characteristic of climate variability as defined by Spittlehous et al. (2015).

The pronounced seasonal pattern with a sharp peak in August and October and very dry conditions in January and February directly reflects the "two seasons in the south and one season in the north (April to October)" described in the literature (USAID, 2013; IPCC, 2023). The study by Oriangi et al. (2024) specifically noted that the longest rainy season in Gulu District stretches from March

to October, which is precisely the pattern captured in the monthly data, with rainfall increasing sharply from March and peaking within this window.

The temperature data reveals a clear and concerning warming trend, particularly in Palaro Sub-county. The rise in Palaro's mean annual maximum temperature from 29.94°C in 2001 to 38.22°C in 2023 represents a significant increase. This observation supports the projections by USAID (2015) and Zinyengere et al. (2016) that mean annual temperatures in Uganda may increase by up to 1.5°C by 2030. However, the magnitude of increase observed in Palaro suggests that localized warming can be more severe than regional projections.

The finding that minimum temperatures have also risen substantially (from 19.69°C to 33.97°C in Palaro) is particularly significant. Rising nighttime temperatures can prevent bees and plants from recovering from daytime heat stress, exacerbating the impacts on honey production. This aligns with global concerns about increasing temperatures affecting bee colonies, as noted by Gajardo-Rojas et al. (2022).

The temperature pattern, with the hottest months being February to April and the coolest during the peak rainy season (June-August), is consistent with the tropical climate described in the study area. The inverse relationship between rainfall and temperature is a key climatic dynamic. The low standard errors for most monthly temperatures indicate that these seasonal patterns are consistent and reliable from year to year, unlike the more variable rainfall.

Qualitative insights further enriched these quantitative findings. Beekeepers' reports of extended dry seasons, erratic rainfall onset, and loss of seasonal demarcation reflect not just weather anomalies but systemic alterations in agro-climatic calendars. Such observations are consistent with findings from Apac District, Northern Uganda, where farmers noted reduced rainy days and

increased hot spells (Atube et al., 2021). Taken together, these findings demonstrate that climate variability exists even within the same district, with rainfall showing strong seasonal and inter-annual fluctuations and temperature exhibiting both seasonal and long-term increases, particularly in Palaro. Literature consistently emphasizes that such small-scale climatic variations significantly influence ecological processes and agricultural systems, including beekeeping (Van Espen et al., 2023). For Gulu district, this means that honeybee production will increasingly be exposed to risks associated with declining rainfall reliability and rising temperatures, unless adaptive and climate-smart practices are strengthened.

## **5.2 Beekeepers' perception of climate variability and its impact on honey production**

In assessing the beekeepers perception on climate variability and its impact, beekeepers unanimously acknowledged (100%) changes in weather patterns over the past 10–20 years, this underscores a collective consciousness of climatic shifts that aligns with regional scientific observations (Egeru et al., 2019; Atube et al., 2021). This high level of perception is not merely experiences but reflects tangible ecological and apicultural disruptions, positioning beekeepers as frontline witnesses to microclimate change.

The perception that climate variability significantly impacts honey production (with over 63% reporting moderate to severe effects) resonates strongly with studies in similar agro-ecological contexts by Wendimu (2020) in Ethiopia which found out that approximately 70% of beekeepers perceived climate change as negatively affecting honey production, primarily through forage scarcity and yield decline. The primary indicators cited by respondents; reduction in flowering plants (94.7%) and unpredictable rainfall (75.2%), demonstrate a sophisticated understanding of the cascade effects of climate variability: meteorological changes directly disrupt floral phenology, which in turn compromises nectar and pollen availability. This aligns with global literature on

climate-pollinator-plant mismatches (Switanek et al., 2017; Kimani, 2017), where shifting seasonal indicators are misaligned to bee foraging cycles with peak flowering periods.

Importantly, beekeepers' perceptions are not limited to climate parameters but extend to secondary ecological impacts, including biodiversity loss and drying water sources. This holistic awareness indicates that local knowledge systems encapsulate complex socio-ecological interactions, a theme noted in studies from Malawi and Tanzania (Chisale et al., 2021; Nyunza et al., 2018). The convergence of local perception with empirical climate data (Objective One) strengthens the credibility of both knowledge systems and highlights the value of integrating indigenous insight into climate adaptation planning.

The climatic trends documented in this study; erratic rainfall, rising temperatures, and increased variability directly threaten honeybee production through multiple physiological and ecological pathways. Unpredictable rainfall disrupts flowering cycles and nectar availability, a concern raised by beekeepers in Ethiopia and Nigeria (Wendimu, 2020; Ngala & Kongnso, 2020), while rising temperatures increase colony thermoregulatory costs and reduce foraging efficiency (Medina et al., 2018; Van Espen et al., 2023). The particularly sharp temperature rise in Palaro may explain the higher perceived climate impacts among beekeepers.

### **5.3 Honey production patterns**

The spatial analysis of honey production in Paicho and Palaro Sub-counties revealed that honey yield and apiary placement is strongly influenced by climate variability, particularly access to water, forage availability, and temperature moderation from woodland cover. This finding is consistent with Medina et al. (2018), who reported that honey yields are closely linked to the spatial distribution of ecological resources, especially water and floral diversity, which buffer colonies

against climate stress. Similarly, Schweitzer et al. (2013) emphasized that tropical ecosystems, honey production follows a spatial and seasonal cycle driven by rainfall and flowering patterns, which explains why apiaries near water and diverse forage mosaics in Gulu district exhibited more fluctuating yields.

Forage availability emerged as another key determinant of honey production patterns. Woodland and forest patches provided draught-resilient nectar sources, while crop land offered seasonal but climate-sensitive forage. These results align with Wendimu (2020), who reported that in Ethiopia, honey production was highest in areas with mixed vegetation cover, since tree species with deep root systems can flower even under water stress. According to this study, honey yields always peaked during rainy season when floral abundance is high, but declined sharply when erratic rainfall disrupted crop flowering cycles. This mismatch between planting seasons and honey flows described by beekeepers in Paicho directly mirrors this phenomenon.

Siting hives near to the water sources is linked high honey production and reflects a direct adaptation recurrent draughts in Northern Uganda and this align with a study conducted by Chakuya et al. (2024) in Zimbabwe that bees site their nests next to water sources to reduce their times spent on collecting water for the colony. Honey yields in Gulu District fluctuate with rainfall distribution, particularly during prolonged dry spells when water scarcity limits colony performance. The qualitative accounts from beekeepers in this study echo these findings, as respondents consistently described water shortages as a major production constraint during the dry season. This supports the argument that apiary proximity to rivers is not coincidental but a deliberate strategy to secure resilience under erratic rainfall conditions.

Apiaries located under woodland shade are known to moderate temperature extremes and reduced the energy bees spent on thermoregulation (Van Espen et al., 2023). Such landscapes create microclimate that buffer honeybee colonies against extreme weather events. Ngala and Kongnso (2020) noted that apiaries located near shaded, and diverse vegetation, experienced more stable production compared to those in open, grassland-dominated landscapes. The beekeepers' practice of deliberately placing hives under tree shade is therefore consistent with wider African evidence of climate smart apiary siting. The identification of vulnerable versus resilient apiaries based on location and landscape composition resonates with Ebuu et al.(2023), who documented that honey production in Northern Uganda tends to be clustered around riverine and forested ecosystems, while hives in open grasslands suffer frequent yields fluctuations. Therefore, resource-rich zones represent climate resilient production hotspots, whereas resource poor zones expose colonies to high vulnerability.

The widespread decline in honey production documented in this study reflects broader ecosystem disruptions caused by climate variability. The identification of reduced flowering plants (96.2%) as a primary impact indicator aligns with research by Switanek et al. (2017) demonstrating that climate variability affects vegetation phenology and subsequently impacts honeybee forage availability. The reported behavioral adaptations in bees such as increased hive clustering during cold rains or prolonged fanning during heat offer biological validation of perceived stress, echoing documented impacts of temperature extremes on colony energetics and foraging efficiency (Medina et al., 2018; Van Espen et al., 2023).

The low average yield of 6.25 kg per hive per year indicates significant productivity constraints compared to potential yields of 15-30 kg reported for similar climatic zones. This yield gap suggests substantial opportunities for improvement through climate-adaptive management

practices. The finding that 84.2% of beekeepers cited pests and diseases as contributing factors supports research by Kumar et al. (2022) and Novelli et al. (2021) showing that climate change creates favorable conditions for honeybee parasites and pathogens.

The year-round nature of climate challenges experienced by farmers (57.1%) suggests that adaptation strategies in tropical contexts must be designed for continuous implementation rather than seasonal responses.

#### **5.4 Adaptation strategies to climate variability and constraints**

The coping strategies identified reflect both local innovation and significant capacity constraints. The findings reveal a spectrum of low-cost, locally led adaptations alongside significant systemic constraints to building climate resilience.

The most widely adopted strategies by beekeepers included placement of hives under the shade (64.7%), planting forage such as Calliandra and strategic hive placement are indicative of pragmatic, resource-limited responses that leverage local materials and knowledge. These measures align with documented adaptations in Ethiopia and Cameroon, where beekeepers use shade trees and forage diversification to buffer against heat and forage scarcity (Degu et al., 2021; Ngala & Akoh, 2021). However, the low adoption of supplementary feeding and modern insulated hives proven resilience-building practices in temperate apiculture (Lloyd, 2021; Landaverde et al., 2023) which highlights a critical gap between potential and practiced adaptation.

However, the low adoption of proven technologies such as supplementary feeding (15.0%) and modern hives (3.8%) contrast sharply with practices in developed countries where such strategies are standard (Lloyd, 2021). This disparity reflects the resource constraints facing smallholder

beekeepers in northern Uganda and highlights the need for targeted support to enhance adaptive capacity.

The primary barriers to implementing more effective strategies were limited knowledge or training and lack of resources. This underscores a failure in extension systems to deliver context-specific, climate-smart apiculture training a gap noted across smallholder farming systems in Uganda (Atube et al., 2021). The heavy reliance on agricultural extension officers (60.2% of information sources) is encouraging yet problematic, given that 34.6% of beekeepers receive no advisory support at all. This uneven access exacerbates vulnerability and limits the scaling of adaptive practices.

Beekeepers' expressed needs such as modern equipment (97%), financial support (85%), and climate-smart training (63.2%) point to clear pathways for intervention. The demand for climate information services further reflects a desire for anticipatory adaptation, enabling beekeepers to align management decisions with forecasted conditions. These needs resonate with calls in the literature for integrated support systems that combine technology transfer, capacity building, and climate finance to enhance adaptive capacity (Landaverde et al., 2023; Onabe et al., 2019).

Qualitative insights reveal that where institutional support has been provided such as NGO-led training in forage planting and hive management, beekeepers have successfully adopted and benefited from new practices. This suggests that targeted, participatory extension can effectively bridge knowledge and resource gaps. However, the absence of a dedicated beekeeping policy or climate adaptation plan at the district level remains a critical institutional void, limiting coordinated action and resource allocation.

## **CHAPTER SIX: CONCLUSION AND RECOMMENDATION**

### **6.1 Conclusion**

This study was motivated by the significant challenges that increasing climate variability poses to agricultural livelihoods in Gulu district, specifically focusing on the vital and vulnerable sector of apiculture. The problem centered on the lack of comprehensive, localized understanding of how climate variability specifically affects honey production in Paicho and Palaro sub-counties, and how beekeepers are coping with these changes. This research sought to bridge the gap by analyzing climatic trends, mapping honey production patterns, and documenting local perceptions and adaptation strategies.

Rainfall were unpredictable in both Paicho and Palaro Sub-counties with no significant difference across the 24 year periods but showed similar patterns. However, the monthly rainfall variation exhibited similar pattern but was significantly different in both Sub-counties. Palaro experienced a notable and rapid rise in temperature from 2000 to 2023. Paicho Sub-county maximum and minimum temperature showed no significant throughout the study period.

The combination of unreliable rainfall and extreme temperatures disrupts flowering cycles, reduces forage availability, and stresses bee colonies, leading to decreased honey yields. This evidence directly links climate variability to the vulnerabilities in the local apiculture sector, underscoring the urgent need for climate-resilient beekeeping practices.

The study on beekeepers perception of climate variability on honey production concludes that beekeepers have a strong negative perception of climate variability and its effects on honey production. They observed changes in temperature, rainfall patterns and the availability of flowering plants, which they associated with reduced forage and nectar availability. These changes

were perceived to disrupt bee behavior, colony development and honey production. Beekeepers also linked changing climatic conditions to increased pest and disease problems, further affecting colony productivity. Overall, their experiential knowledge indicates that climate variability is a major threat to sustainable honeybee production in the study area.

The spatial and temporal analysis of honey production patterns demonstrates that apiary productivity is highly dependent on access to key resources that buffer against climate variability. Apiaries located near perennial water sources, within diverse woodland vegetation, or under shade exhibit greater resilience and more stable yields compared to those in resource-poor, open areas. This finding emphasizes the importance of landscape management and strategic apiary siting as fundamental components of climate adaptation. However, the overall low average yield of 6.25 kg per hive per year signals a significant productivity gap driven largely by climate-induced constraints compounded by limited adoption of improved practices.

Beekeepers have adopted a range of low-cost coping strategies such as shading hives, planting supplemental forage, and providing water, these measures are insufficient to fully offset the escalating impacts of climate variability. The limited adoption of more effective, resource-intensive adaptations like supplementary feeding, modern insulated hives, and diversified climate-resilient forage points to systemic barriers including inadequate technical knowledge, financial constraints, and weak institutional support. The heavy reliance on traditional practices, coupled with gaps in extension services and climate information dissemination, restricts the adaptive capacity of beekeepers and leaves the sector vulnerable to further climatic shocks.

## 6.2 Recommendations

Based on the findings and discussion, the following recommendations are proposed for different stakeholders:

1. Development organizations and NGOs should address critical gaps by implementing comprehensive training on climate-smart practices and supporting large-scale forage development with resilient tree species. Furthermore, they must facilitate access to modern beekeeping equipment through subsidized programs or lending libraries and actively promote the formation of cooperatives. These cooperatives will enable collective action, improve market access, and foster crucial peer-to-peer learning among beekeepers.
2. Research institutions have a vital role in building a stronger evidence base. They should conduct long-term studies to definitively link climate variables with honey production and develop new, resilient technologies suited to local conditions. Research should also be conducted on other variables of climate such as wind and humidity and how they impact beekeeping.
3. Beekeepers should prioritize forming or strengthening beekeeping groups to share knowledge and resources. At the apiary level, actions include diversifying forage with climate-resilient plants, implementing water conservation measures like small ponds, and adopting integrated pest management. Maintaining simple production records will also help individuals track their progress and make more informed management decisions.
4. Strengthen extension services for climate-smart beekeeping to increase investment in agricultural extension services with specialized training for officers on climate-adaptive beekeeping practices.

5. Government should establish financial support such as credit facilities, subsidies, or grant programs specifically targeting climate adaptation in apiculture. Integration of beekeepers into existing programs such as the Parish Development Model should be prioritized.

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## APPENDICES

### Appendix A: Research work plan

| DETAILED<br><br>WORK<br>PLAN              | DURATION (months)             |                      |              |                  |                      |              |                            |                           |             |              |             |
|-------------------------------------------|-------------------------------|----------------------|--------------|------------------|----------------------|--------------|----------------------------|---------------------------|-------------|--------------|-------------|
|                                           | ACTIVITIES                    |                      |              |                  |                      |              |                            |                           |             |              |             |
|                                           | JULY-<br>OCTO<br>BER,<br>2024 | NO<br>V<br>,202<br>4 | DEC,<br>2024 | JAN<br>,<br>2025 | FEB-<br>MAR,<br>2025 | APR,<br>2025 | MAY<br>-<br>JUNE<br>, 2025 | JUNE<br>-<br>JULY<br>2025 | AUG<br>2025 | SEPT<br>2026 | OCT<br>2026 |
| Proposal<br>writing                       |                               |                      |              |                  |                      |              |                            |                           |             |              |             |
| Developing<br>data<br>collection<br>tools |                               |                      |              |                  |                      |              |                            |                           |             |              |             |
| Submission to<br>GUREC and                |                               |                      |              |                  |                      |              |                            |                           |             |              |             |

|                                                        |  |  |  |  |  |  |  |  |  |  |  |
|--------------------------------------------------------|--|--|--|--|--|--|--|--|--|--|--|
| presentation<br>of proposal                            |  |  |  |  |  |  |  |  |  |  |  |
| Correcting<br>comments<br>from GUREC                   |  |  |  |  |  |  |  |  |  |  |  |
| Data<br>collection                                     |  |  |  |  |  |  |  |  |  |  |  |
| Data cleaning<br>and analysis                          |  |  |  |  |  |  |  |  |  |  |  |
| Report<br>drafting<br><br>Finalizing<br>report writing |  |  |  |  |  |  |  |  |  |  |  |
| Submission<br>of the report                            |  |  |  |  |  |  |  |  |  |  |  |
| Presentation<br>of report                              |  |  |  |  |  |  |  |  |  |  |  |
| Disseminatio<br>n of report                            |  |  |  |  |  |  |  |  |  |  |  |

|                            |  |  |  |  |  |  |  |  |  |  |  |  |
|----------------------------|--|--|--|--|--|--|--|--|--|--|--|--|
| findings and<br>publishing |  |  |  |  |  |  |  |  |  |  |  |  |
|----------------------------|--|--|--|--|--|--|--|--|--|--|--|--|

## Appendix B: Research budget

| ITEMS                                                | QUANTITY       | Unit cost             | COST          |
|------------------------------------------------------|----------------|-----------------------|---------------|
| PRINTING DATA<br>COLLECTION TOOLS                    | 127            | USD 0.2722@           | USD 34.56694  |
| FACILITATION FEE FOR<br>RESPONDENTS + FGD AND<br>KII | 127            | USD 0.5445@           | USD 201.3694  |
| FEEDING                                              | 14 days        | USD 4.0835 per<br>day | USD 57.1686   |
| METEREOLOGICAL DATA                                  | 2 Sub counties | USD 13.6116           | USD 27.22231  |
| TRANSPORT                                            | 14days         | USD 4.0567 per<br>day | USD 56.7944   |
| MISSELINEOUS                                         | lump sum       |                       | USD 54.0899   |
| MAKING MAP                                           | 1              | USD 13.5225           | USD 13.5225   |
| <b>GRANT TOTAL</b>                                   |                |                       | USD 566.31861 |

## Appendix C: Questionnaire (English version)

My name is Anywar Boniface, I am a master student pursuing a master's degree of science in Applied tropical Entomology and Parasitology in the department of Biology of Gulu University. I am interested in studying the impact of climate variability on honey production. A case study in Paicho and Palaro sub counties, Gulu district, Northern Uganda. The information which will be provided shall be used entirely for academic purposes and personal information of respondents will be kept confidential.

### Section 1: Detail of study area.

|            |  |           |  |
|------------|--|-----------|--|
| sub county |  | Latitude  |  |
| Parish     |  | Longitude |  |
| Village    |  |           |  |

### Section 2: Demography

|                                        |                                     |                                   |                                    |                                      |                                   |                                     |                                 |
|----------------------------------------|-------------------------------------|-----------------------------------|------------------------------------|--------------------------------------|-----------------------------------|-------------------------------------|---------------------------------|
| 1.Name of the respondent<br>(optional) |                                     |                                   |                                    |                                      |                                   |                                     |                                 |
| 2.Gender of the respondent             | Male <input type="checkbox"/>       |                                   |                                    | Female <input type="checkbox"/>      |                                   |                                     |                                 |
| 3.Age of the respondent                | 15-20<br><input type="checkbox"/>   | 21-26<br><input type="checkbox"/> | 27-32<br><input type="checkbox"/>  | 33-38<br><input type="checkbox"/>    | 39-44<br><input type="checkbox"/> | 45-50<br><input type="checkbox"/>   | 51+<br><input type="checkbox"/> |
| 4.Marital status                       | Married<br><input type="checkbox"/> |                                   | Single<br><input type="checkbox"/> | divorced<br><input type="checkbox"/> |                                   | widowed<br><input type="checkbox"/> |                                 |

|                      |                                                    |                                     |                                               |                                      |
|----------------------|----------------------------------------------------|-------------------------------------|-----------------------------------------------|--------------------------------------|
| 5.Educational status | No formal<br>education<br><input type="checkbox"/> | Primary<br><input type="checkbox"/> | Secondary<br><input type="checkbox"/>         | Tertiary<br><input type="checkbox"/> |
| 6.Occupation         | Farmer<br><input type="checkbox"/>                 | Teacher<br><input type="checkbox"/> | Extension<br>officer <input type="checkbox"/> | Other<br><input type="checkbox"/>    |

7. How many years have you been involved in beekeeping?

☐ Less than 1 year

☐ 1–3 years

☐ 4–6 years

☐ 7–10 years

☐ Over 10 years

## SECTION B: BEEKEEPING PRACTICES

8. What type of beehives do you use? (Select all that apply)

☐ Traditional hives

☐ Modern hives (e.g., Langstroth, Top-bar)

☐ Both

9. How many beehives do you currently manage? \_\_\_\_\_

10. How did you start beekeeping?

☐ Personal interest

☐ Family tradition

☐ Encouragement from neighbors/friends

☐ Training from agricultural extension officers

☐ Other (Specify): \_\_\_\_\_

**11. Where do you keep your beehives? (Select all that apply)**

☐ Homestead

☐ Forest/bush area

☐ Backyard garden

☐ Near water bodies

☐ Other (Specify): \_\_\_\_\_

**12. How many times do you harvest honey from a single hive per year?**

☐ Once

☐ Twice

☐ Three times

☐ More than three times

☐ No harvest in some years

**SECTION C: PERCEPTIONS OF CLIMATE VARIABILITY**

**13. Have you noticed changes in weather patterns in the past 10–20 years?**

☐ Yes

☐ No

**14.** If yes, which of the following changes have you observed? (Select all that apply)

☐ Increased temperature

☐ Decreased temperature

☐ Increased rainfall

☐ Decreased rainfall

☐ Unpredictable rainfall patterns

☐ More frequent droughts

☐ Stronger or more frequent storms

**15.** How do you identify that the climate has changed? (Select all that apply)

☐ Drying of rivers/streams

☐ Delayed or early rainfall

☐ Reduction in flowering plants

☐ Extended dry or wet seasons

☐ Loss of biodiversity

☐ Others (Specify): \_\_\_\_\_

**16.** On a scale of 1–5, how would you rate the impact of climate variability on honeybee production?

☐ 1 - No impact

☐ 2 - Minimal impact

☐ 3 - Moderate impact

☐ 4 - Significant impact

☐ 5 - Severe impact

#### **SECTION D: IMPACT OF CLIMATE VARIABILITY ON HONEY PRODUCTION**

**17.** Has climate variability affected your honey production?

☐ Yes

☐ No

**18.** If yes, how has it affected honey yield?

☐ Decreased significantly

☐ Decreased slightly

☐ No change

☐ Increased

**19.** What are the main factors you believe are causing these changes in honey production?

(Select all that apply)

☐ Droughts

☐ Temperature changes

☐ Reduced flowering plants

- ☐ Lack of water sources
- ☐ Pests and diseases
- ☐ Other (Specify): \_\_\_\_\_

20. What is the average honey yield per hive per year (in kilograms)? \_\_\_\_\_

21. Which season do you experience the most challenges in honey production?

- ☐ Dry season
- ☐ Rainy season
- ☐ Both seasons

#### **SECTION E: COPING STRATEGIES FOR CLIMATE VARIABILITY**

22. What strategies have you adopted to cope with climate variability in beekeeping? (Select all that apply)

- ☐ Relocating hives to cooler/shadier areas
- ☐ Providing supplementary feeding (sugar syrup, pollen substitutes)
- ☐ Planting more flowering plants/trees
- ☐ Using modern hives with better insulation
- ☐ Adjusting hive placement (shade, wind protection)
- ☐ Planting resistant forage plants
- ☐ Water provision for bees

☐ Other (Specify): \_\_\_\_\_

**23.** Which of the above strategies has been the most effective for you?

---

**24.** What challenges do you face in implementing these coping strategies? (Select all that apply)

☐ Lack of resources (money, equipment)

☐ Limited knowledge/training

☐ Poor access to agricultural extension services

☐ Climate conditions too severe

☐ Other (Specify): \_\_\_\_\_

## **SECTION F: SUPPORT NEEDED AND RECOMMENDATIONS**

**25.** What type of support would help improve your beekeeping amidst climate variability?  
(Select all that apply)

☐ Training on climate-smart beekeeping practices

☐ Access to modern beekeeping equipment

☐ Financial support or credit facilities

☐ Government/NGO programs for beekeepers

☐ Access to climate information (weather forecasts, etc.)

☐ Other (Specify): \_\_\_\_\_

**26.** Do you receive information or advice on beekeeping from any of the following sources?

(Select all that apply)

☐ Agricultural extension officers

☐ Local beekeeping associations

☐ Radio/TV programs

☐ Mobile phone alerts or apps

☐ Other beekeepers (peer-to-peer learning)

☐ None

**27.** What additional recommendations do you have for improving honeybee production in the face of climate variability?

Thank you for participating in this survey! Your responses are highly valued and will contribute significantly to the success of this research.

## Appendix D: Questionnaire (Luo version)

An nyinga Anywar Boniface, atye Latin Kwan I rwom mamalo me unibaciti matye ka Kwan lok anyai mayelo lee, dano karacel ki Jami apita. Pi man, atye katimo kikweda I kit ma aloka loka piny yelo kwede ki kic I Paicho ki Palaro cab-kanti, I Gulu district, I kumalo me Uganda. Lagam ma yin I bimiyo ki tic kwede me lok me Kwan man kiken dok bene ki bigwoko maber

Dul me acel: kabedo ma kwed otime iye:

|           |  |           |  |
|-----------|--|-----------|--|
| Cab-kanti |  | Latitude  |  |
| Caro      |  | Longitude |  |

Dul me aryo: lok kom lagam lapeny matut

|                      |                                   |                               |                                   |                                          |                                |                                        |                             |
|----------------------|-----------------------------------|-------------------------------|-----------------------------------|------------------------------------------|--------------------------------|----------------------------------------|-----------------------------|
| 1.nying lagam lapeny | Gwet I yii bok                    |                               |                                   |                                          |                                |                                        |                             |
| 2.Dako nyo lacoo     | lacoo <input type="text"/>        |                               |                                   | <input type="text"/> dako                |                                |                                        |                             |
| 3.Mwaka              | <input type="text"/><br>15-20     | 21-26<br><input type="text"/> | 27-32<br><input type="text"/>     | 33-38<br><input type="text"/>            | 39-44<br><input type="text"/>  | 45-50<br><input type="text"/>          | 51+<br><input type="text"/> |
| 4.Kit me nyom        | anyome<br><input type="text"/>    |                               | pe nyome<br><input type="text"/>  | kin wa opoke<br><input type="text"/>     |                                | Coo too/da too<br><input type="text"/> |                             |
| 5.Kwan               | pe akwano<br><input type="text"/> |                               | puraimari<br><input type="text"/> | cinia <input type="text"/>               | unibaciti <input type="text"/> |                                        |                             |
| 6.Tic atiya          | lapur <input type="text"/>        |                               | <input type="text"/><br>lapwony   | lapwony<br>pa lupur <input type="text"/> |                                | mukene <input type="text"/>            |                             |

7. Mwaka adii dong ma I gwoko ki kic

Pud pe otyeko mwaka acel

☐ 1-3

☐ 4-6

☐ 7-10

☐ Okato dong mwaka apaa

**Dul me adek: tic me gwoko kic**

8. I gwoko kic I kit bong mene

☐ Ogoo/agulu

☐ Bong kic manyen (KTB)

☐ Aryo weng

9. Itye ki bong kic gin adii.....

10. Icaiko gwoko kic pi tyen lok mene

☐ Obedo mitina

☐ Obedo tic ma gang wa

☐ Lowota aye ocuka cwinya me cako gwoko ne

☐ Acaiko gwoko ne ma aa ki pwony pa lapwony pa lupur

☐ Onyoo mene ni.....

11. Iketo/I gwoko bong kic ka kwene?

☐ I nget gang

☐ I bunga

☐ Poto ma inget gang

☐ Cok kip ii

☐ Onyo ka kwene.....

12. itoto kic mamegi wang adaa I mwaka acel

Wang acel

☐ Wang aryo

☐ Wang adek

☐ Makato wang adek

☐ Pe atoto

**Dul me agwen: tam ki ngec ikom aloka loka piny**

13. Ineno dong aloka loka piny in nge mwaka ma okato 10 me oo I 20

☐ Aneno

☐ Pe aneno

14. Ka I neno, aloka loka mene enoni (itwero cimo weng ka ineno)

☐ Lyeto ma lamal

☐ Lyeto ma lapiny

☐ Kot mapol

☐ Kot manok

☐ Kot cwee ma pe byeke

☐ Two pa piny kare ki kare

☐ Kot macwee ki yamo mapol

15. Ineno nining ka aloka loka piny otime

☐ Two pa kulu

☐ Cwee pa kot ma rii onyo cake con

☐ Pot yat ma turu doko cen

☐ Rii pa two pa piny ki kot macwee

☐ Rwenyo pa jami nakwo

☐ Onyo mukene

16. Ket nyig lok magi I kit ma pire tek kwede ki I acel wa I abic, itwero Waco ni aloka loka piny obedo ki peko madit tutwal I kom kic?

☐ Peke ki peko

☐ kelo peko matidi

☐ kelo peko ma ladyere

☐ kelo peko madit

☐ kelo peko madit adada.

**Dul me abic: adwoki pa aloka loka piny I kom tic pa kic**

17. Aloka loka piny oyelo kici matek?

☐ Oyelo

☐ Pe oyelo

18. Ka oyelo, ci otimo nining I kit ma ikwanyo kwede ki I bong?

☐ Moo kic obedo manok adada

☐ Moo kic obedo manok

☐ Pe oloke

☐ Omede ameda

18. Tit alokaloka piny mene ma ineno obalo kic mamegi matek kwede?

- ☐ Two pa piny
- ☐ Aloka loka pa lyeto
- ☐ Nok pa pot yat ma turu ki kic
- ☐ Peke pa pii ki kic
- ☐ Anyai ki two pa kic
- ☐ Onyoo mukene .....

20. Inongo kic kilo adii I mwaka acel ki I kom bong mamegi...

21. I kare me ma I nongo peko madit tutwal I gwoko kic mamegi?

- ☐ Oroo
- ☐ Cwii
- ☐ Oroo wa ki cwii weng

**Dul me Abicel: tic me gwoke ki kom aloka loka piny ma yelo kic.**

22. Tic /gin ango ma itimo we aloka loka piny pe oyel kic mamegi?

- ☐ Keto kic kama ngic/ kama tipu yen tye iye
- ☐ Cwalo cam ki kic
- ☐ Pito yen mature
- ☐ Tic ki bong kic manyen ma lyeto pe yelo
- ☐ Keto kic kama yamo ki kot pe yelo
- ☐ Pito yen ma rii naka naka
- ☐ Cwalo pii ki kic

☐ Onyoo jami mukene.....

23. Tic mene ma I nongo tiyo boti maber tutwal

.....

24. Peko angoma inongo ka itye ka timo tic mamaloni?

☐ Peke pa jami mogo calo cente ki jami tic makonyo tic

☐ Ngec manok

☐ Peke pa kony ma aa ki bot lupwonye pa lupur

☐ Peko madwong ma aa ki I aloka loka

☐ Onyoo gin mukene.....

**Dul me abiro: kony mamite ki jami mamite atima**

25. Kony angoma I mito wek okonyi kwede me gwoko kic ki kom aloka loka piny?

Pwonye mdok I lok kom alokloloka piny ki gwoko kic

☐ Bedo ki kero me nongo jami lagwok kic

☐ Kony me cente

☐ Kony ki bot gamente ki dul ma pe jenge I kom gamente bot lugwok kic

☐ Bedo ki kero me nongo ngec I kom alokaloka piny

☐ Onyoo mukene.....

26. I nongo ngec onyo kony me tam madok I lok kom gwoko kic ki bot jo magi?

☐ Lapwony pa lupur

☐ Gurup pa dul lugwok kic

☐ Radio ki TV

☐ Cim

☐ Both lupur kic mukene

☐ Onyoo kuu

27. Tye tam mo ma itwero kati kwede me nenoni ki yilo kero me gwoko kic ki i kom ayela yela me alokaloka piny?

*Apwoyo matek pi gamo lapeny mago. Ajolo dok aworo tami I kom lapeny magi tutwal em neno ni kwed man owoto maber.*

## **Appendix E: Interview Guide for key informant (English version)**

**Title:** *climate Variability and its impact on Honeybee Production in Paicho and Palaro Sub-Counties, Gulu District*

*Dear Participant,*

I am Anywar Boniface, a Master's student at Gulu University, researching the impact of climate variability on honeybee production. A case study of Paicho and Palaro Sub-counties. This interview aims to gather detailed insights into your experiences and perceptions related to climate variability and its impact on honey production. Your responses will remain confidential and will be used solely for academic purposes. Thank you for your time and cooperation.

### **Interview Structure:**

- **Type:** Semi-structured interview
- **Duration:** 30–45 minutes
- **Format:** Face-to-face or virtual (depending on participant availability)
- **Recording:** Audio recording (with participant consent) for accuracy in data analysis

### **SECTION A: Introduction and Background**

1. Can you briefly introduce yourself?

- *Name (Optional):* \_\_\_\_\_
- *Role in beekeeping (e.g., beekeeper, agricultural officer, cooperative leader):*  
\_\_\_\_\_
- *How long have you been involved in beekeeping?*

2. How did you start your beekeeping journey?

- *What motivated you to engage in beekeeping?*
- *Describe the scale of your beekeeping operations (number of hives, types of hives used).*

## **SECTION B: Perceptions of Climate Variability**

3. Have you observed any changes in the weather patterns over the past 10–20 years?

- *What specific changes have you noticed (e.g., rainfall, temperature, droughts)?*
- *How do these changes differ from what you experienced in the past?*

4. What signs or indicators do you personally use to identify that the climate is changing?

5. Do you think climate variability is affecting honeybee production in your area?

- If yes, how? (Prompt for specific examples such as decreased honey yield, bee colony behavior changes, etc.)

## **SECTION C: Impact of Climate Variability on Honey Production**

6. In what ways has climate variability impacted your honey production?

7. Have you experienced any seasons where honey production was particularly poor?

- What do you think caused this?
- How did it affect your income or livelihood?

8. What challenges do you face as a beekeeper related to changing climate conditions?

## **SECTION D: Coping and Adaptation Strategies**

9. What strategies have you adopted to cope with the effects of climate variability on your beekeeping activities?
10. Which strategies have been most effective for you? Why do you think they worked well?
11. Have you received any training or support related to climate-smart beekeeping practices?
  - If yes, who provided the training (government, NGOs, cooperatives)?
  - Was it helpful?
12. Are there traditional or local practices in your community that help cope with climate changes in beekeeping?

## **SECTION E: Support Systems and Recommendations**

13. What kind of support do you think beekeepers in your area need to adapt better to climate variability?
14. Do you think government policies or local organizations are doing enough to support beekeepers in dealing with climate change?
  - If no, what improvements would you suggest?
15. What recommendations would you give to new beekeepers to help them cope with climate-related challenges?
16. Is there anything else you'd like to add about the relationship between climate variability and honeybee production that we haven't discussed?

**Closing:** *Thank you very much for your time and valuable insights. Your responses will significantly contribute to the success of this research. If you have any questions or would like to receive a summary of the study results, please feel free to let me know.*

## **Appendix F: Interview guide for key informants (Luo version)**

Lapeny pa jo madongo ma ki yero gi me gamo lok me kwed man.

Wiye madite: alokaloka piny ki adwoki ne I kom tic pa kic makelo moo in Paicho ki Palaro cab-kanti

Bot lagam lapeny,

An nyinga Anywar Boniface, latin me macta I Gulu Unibaciti, tye ka timo kwed I kit ma alokaloka piny tye kwede ki adwoki ne I kom kic makelo moo. Lapeny man tye me gamo ngec matut ki boti kit yin itamo dok ineno kwede alokaloka piny kit ma yelo kwede ki kic. Tami ducu ma ibimiyone ki bitiyi kwede I lok me Kwan ki kwed man kiken. Apwoyi pi jalo cawa ni me gamo lapeny man.

Kit ma lapeny biwot kwede.

Kit lapeny, tye ma itwero medo tami matut iye.

Cawa: dakika 30-45

Obibedo wang ki wang ki dong twero bedo I yamo pa munu lubu ki kit ma ngat moni tye iye.

Mako dwon. Mako dwon dano ki nynonyo pa munu ki twero pa lagam lapeny pi mako lok ada.

### **Dul me acel: Nyute**

#### **1. Itwero nyute Kong?**

- Nyingi, tic ma itiyo malube ki gwoko kic, ki dong I gwoko kic pi kare marom mene

#### **2. Icako gwoko kic nining?**

- Ngo ma oweko icako gwoko kic?
- Itwero waca matut kit itye kwede ka gwoko kic (wel bong ki kit bong)

### **Dul me aryo: tam ki ngec ikom alokaloka piny**

#### **3. I bedo dong ki lanen malube ki kit ma piny loke kwede I kare ma okato anged maromo mwaki 10-20?**

Lanen mene ma yin ineno dong (cwee pa kot, lyeto, kede oroo)

Aloka loka piny man pat nining ki kare ma okato anged

4. Ngo manyutu ni alokaloka piny tye katime?
5. Itamo ni alokaloka piny tye ka yelo kit ma kic tiyo kwede me cweno moo I kabedo ma orumu yin?
  - Katye kit eno, nining (moo kic nonge manok, kic loko kit me kwo gi woko)

**Dul me adek: adwoki pa alokaloka piny ikom kic macweyo moo**

6. Iyoo mene ma ineno ni alokaloka piny oyelo kic mamegi?
7. Ibedo ki kare moo ma ineno ni kit moo kic nonge kwede obedo rac tutwal?
  - Itamo ni ngo makelo gin man?
  - Oyelo kit ma omyero inong kwede ki cente?
8. Peko mene ma yin inongo malube ki kit ma alokaloka piny bedo kwede?

**Dul me agwen: tic ma tye katiine me lweny I kom alokaloka piny ma yelo kic**

9. Tic mene dong ma yin itimo wek okonyi kwede me lweny I kom rac pa laokaloka piny?
10. Tic mene ma yin inongo tiyo maber maloyo mukeneni I lweny I kom alokaloka piny?
11. Ibedo dong ki kero me nongo pwonye maneno kit me gwoko kic I kare ma nongo alokaloka piny tye?
  - Ka I nongo pwonye magi, ngat mene ma omini (gamente kede NGO, onyo I gurup)?
  - Okonyi matek tutwal?
12. Itye ki tic mogo malube ki tekwaro makonyo I kit me lweny I kom alokaloka piny?

**Dul me abic: Kony ki jami mamite atima.**

13. Itamo kit kony ango ma kitwero konyi kwede me lweny I kom alokaloka piny?
14. Itamo ni cik ma gamente ki dul ma pi jenge I kom gamente tye kwede nit ye ka kelo kony ma weko lweny I kom alokaloka piny bedo yot?
  - Ka peke ka nyako nyige, ci itamo ni kitwero timo gin ango?
15. Tam ango am itwero minone ki jo ma gin pwod odonya adonya ka gwoko kic?
16. Itye ki gin mo ma itwero medo malube ki kit ma alokaloka piny yelo kwede ki kic?

Apwoyo tutwal me mina ngec matut man. Lagam mamegi pire tek dok binyako nyige I kom kwed man. Ka itye ki lapeny mo malube ki kikweda man, bed agony me penya.

## **Appendix G: Informed consent document (English version)**

**Title of the study:** Climate variability and its impact on Honeybee Production in Gulu District, Northern Uganda

**Investigator(s):** Anywar Boniface

**Institution(s):** Gulu University

### **Introduction**

My name is **Anywar Boniface**, and I am a master's student at Gulu University. This informed consent document explains the study regarding the influence of climate variability on honeybee production in Paicho and Palaro sub-counties of Gulu District. After I explain the study to you, I will answer any questions you may have. If you choose to participate in the study, you will be asked to sign this consent form, and you will receive a copy to keep.

### **Purpose:**

The study seeks to investigate how microclimate variability affects honey production and the coping strategies employed by local beekeepers. The findings of this study will help to enhance understanding of climate impacts on honeybee production and inform strategies for improving beekeeping practices in changing climatic conditions.

### **Procedures:**

Your participation in this study will involve answering questions through structured interviews and possibly participating in focus group discussions about your experiences with beekeeping and climate variability. The interview will last approximately 30-45 minutes. It is anticipated that a total of 191 including those who will be involved in focus group discussion participants will take part in this study.

### **Risks/Discomforts:**

There is no foreseeable risk of harm or discomfort that will arise from your participation in this study. The only potential inconvenience may be the time spent during the interview.

### **Benefits:**

Your participation may help contribute to the development of adaptive strategies for beekeepers in your community. Additionally, participants will receive feedback on the findings and progress of the study, and any new information that may affect participants will be shared.

### **Confidentiality:**

Your identity will not be revealed to anyone, as we will use codes to identify participants. Information obtained will only be accessible by the research team. Soft copies of the data will be protected by password, and hard copy files will be kept in a locked location. Confidential information will only be accessed by the principal investigator.

**Alternatives:**

You do not have to participate in this study if you are not interested. You will not lose any benefits if you choose not to participate.

**Cost:** There will not be any additional costs incurred as a result of participating in this study. However, you will be provided with UGX 5000 for respondents and UGX10000 for Key informants as compensation for your time.

**Questions:**

If you have any questions related to the study, you can contact the principal investigator, Anywar Boniface at 0787094748/0777406468 or via email at bonifaceanywar96@gmail.com

**Statement of Voluntariness:** Participation in this research study is voluntary, and you may choose to join on your own free will. You have the right to withdraw from the study at any time without penalty. If you have any concerns regarding your rights and participation in the study, please contact the Chairperson, Gulu University Research Ethics Committee, Dr. Julaina A. Obika at Tel: 0772964491; email: j.obika@gu.ac.ug ; or the Uganda National Council for Science and Technology, Plot 6 Kimera Road, Ntinda, Kampala at Tel: 0414705500.

**Statement of Consent:** I..... have been informed about the study, including the risks, benefits, and my rights as a participant. I understand that my decision to participate will not affect me in any way and that my identity will be concealed in any published results. I am aware that I may withdraw at any time. By signing this form, I do not waive any of my legal rights but indicate that I have been informed about the research study in which I am agreeing to participate voluntarily and take recording (for KII) of the conversation. I will receive a copy of this form.

Name.....

Signature/thumbprint of participant: .....

Date: .....

Name and Signature of witness.....

Date: .....

Name and Signature of interviewer.....

Date: .....

## **Appendix H: Informed consent (Luo version)**

### **Karatac me gamo twero**

**WII LOK ME KWAN MADIT:** Adwogi pa aloka loka piny I kom kic I Gulu dictrik

**Latim kwed:** Anywar Boniface

**Gang Kwan:** Gulu Unibaciti

Wii lok ma okwongo

An nyinga Anywar Boniface, Atye Latin Kwan me rwom mamalo in Gulu Unibaciti. Karatac man me gamo twero tito kit ma aloka loka piny yelo kwede ki kic I Palaro ki Paicho cab-kanti, I Gulu Distrik. Ka atito ki yin lok me Kwan man, abibedo ki lagam I kom lapeny mo kiken ma I bipenya kwede. Ka I yee me bedo I kin jo ma gin obibedo ka gamo lapeny I lok me kwan man, abipenyi me keto cingi I karatac man and I bibedo ki karatac acel mamegi.

### **Ber pa kwed man**

Kikweda man nenone matut tye me neno kit ma aloka loka piny yelo kwede ki kic ki dok kit ma lugwok kic gin kanyo kwede gwoko kic I kare ma nongo aloka loka piny tye katime kwede. Adwoki pa kikweda man bikonyo me niang kit ma aloka loka piny ma lube ki cwer pa kot ki lyeto yelo kwede ki kic ci bibedo ki kare me niango kit ma lupur twero kwede ki gengo ne wek pe oyel kic gi.

### **Kit ma ki timo kwede kore ki kore**

Donyo ni I lok me kwan man bibedo pole me gamo lapeny kun nongo I twero gamo ne calo ngat acel onyo I gurup malube ki kit me gwoko kic I kare ma nongo piny loke.lapeny man bi cwalo dakika maromo 30-45, ki dong I gurup bicwalo dakika 60-90. I lapeny mandano maromo 127 twero gamo ne.

### **Gin marac ma twero time**

Gin mo marac ma obitme matwero kelo awano I lok man me kikweda ni obibedo peke malube ki lapeny ma yin ibigamoni. Lapeny man twero cwalo cawa aye madwong.

### **Ber ne**

Gamo lapeny magi konyo me yilo rwom konyo lupur kic weko bedo ki yo maber onyo kit ma kiromo kanyo aloka loka piny kadi bed nongo tye.

### **Mung**

Lok komi mo kiken pe ki cwalo ki ngato mo kun nongo wa gwoko maber. Lok mo kiken ma ki bigamo ki boti eni ki bigwoko I lok me kwan man kiken. Ngec man ki bigwoko ne I nyonyo pa muno maber manongo ngati mo kiken pe twero nongo ne mapat ki latim kwed.

### **Gin mukene:**

Pe I twero gamo lapeny magi ka I pe ki mite I yee. Pe tye gin moo ma I twero rwenyo ne k ape I gamo lapeny magi.

**Cul.** Cul me 5000 ki bimiyo bot ngat ma bigamo lapeny ki dong bene 10,000 bot lodito madongo ka inen I gamo lapeny I lok me kikweda wek okony yin ki wot ki dong pi cawa ma obale.

**Lapeny.** Ka itye ki lapeny mo, ci I twero kube kweda and lakwed Anywar Boniface I number magi 0787094748/ 0777406468 onyo bonifaceanywar96@gmail.com

**Lok me dyere.** Bedo ki kero me gamo lapeny I kwed man tye miti ni dok bene I twero yee onyo pe I twero yee. Ki dong I tye ki twero weko gamo lapeny magi labongo dic mo kiken. Ka itye ki lok mo malube ki tweroni I lagam ki lapeny I kwed man, ci itwero mino lok man bot wonkom maloyo lok me kikweda I Gulu unibaciti Dr.Julaina A Obika I numba 0772964491, onyo j.obika@gu.ac.ug Onyo I twero I twero bene mino ngec bot dul madit ma neno lok me cayan ki nyonyo pa munu I Uganda (UNCST), pulot numba 6 I yoo Kimera, Ntinda, Kampala, I numba cim 0414705500.

### **Lok me yeo**

An.....ki tyeko tita lok me kikweda man, kacel ki jami matwero time rac, ber ne, ki twero mamega macalo lagam lapeny. Aniang ni lapeny man pe twero kelo gin mo marach I kom an ki dong bene lok koma makwao lapeny magi bene ki bigwoko maber. Atye bene ki ngec ni atwero weko gamo lapeny magi. Keto cinga I karatac man nyuto ni aye me gamo lapeny magi dok beneki tyeko niango an I kom lok me kwed man oweko aye me gamo lapeny. Aye me gamo pot karatac man me bedo kwede.

Nying.....

Cing pa lagam lapeny.....

Nino dwe .....

Cing pa lacaden.....

Nying lakwed: Anywar Boniface

Nino dwe.....