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# PERCEIVED IMPACTS OF CLIMATE CHANGE ON AGRICULTURAL CROPS PRODUCTION AND ITS IMPLICATIONS ON FOOD SECURITY: INSIGHTS FROM KAHURO- MURANG'A COUNTY KENYA


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**Abstract**

Kahuro sub-county, Murang'a Kenya, is a rich agricultural area which falls within the Central Kenya highlands with a part of it being semi-arid. Within the sub-county, there has been significant impact of climate change on crop production, but minimal information exists on farmers' mitigation and adaptation strategies. The study was undertaken to identify the farmers' perceptions of climate change on crop production and its impacts on food security. Thirty farmers were purposively sampled and interviewed. The results showed that 90% of the farmers in the area depend on rainfed agriculture, with 73% of the interviewees reporting to have been in farming for over 10 years. Majority of the farmers in the area are in the know about climate change citing prolonged dry spells, extreme temperatures, extended wet periods, and crop failure as climate change indicators. 43% of the interviewees mentioned human activities such as land cover clearing and deforestation as the main contributors to climate change. Majority of the farmers intimated drought-tolerant crop farming, reduced crop yields, and observed changes in planting times as significant impacts of a changing climate on crop production. Climate change has impacted the state of food security in the area with the majority of farmers intimating that the previous year's harvest was lower and hence cannot last their households until the next harvest season. Hence, farmers in the area have resorted to planting early maturing crop varieties, crop diversification, and conservation techniques. Though farmers in Kahuro are aware of climate change and the impacts of such changes, there is a need for capacity building on the potential adaptation, coping, and mitigation strategies to enhance sustainable agriculture and ensuring food security.

**Keywords:** Climate change; Crop production; Adaptation to climate change; Food security, Small-scale farming

# 1.0 Introduction

## 1.1 Introduction

Climate change has been defined as "change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and /or the variability of its properties and that persists for an extended period, typically decades or longer" (*Glossary — Global warming of 1.5 ºC*, IPCC, n.d.). Changes in the climate are attributed to natural external forces or internal processes that range from volcanic eruptions, solar cycle modulations, and anthropogenic changes that are persistent in land use or atmospheric composition (Okoba, Dejene, and Mallo, 2011). Okoba et al., (2011) further note that human activities have been among the greatest contributors to climate change due to their role in increasing greenhouse gas emissions. Indeed, rising greenhouse gas emissions from human activities have led to greater food insecurity, and reduced biodiversity coupled with more species extinction. Further, greenhouse gas emissions are a significant contributor to adverse weather events.

Climate change has significant impacts on crop production. First, climate change through changing rainfall patterns has led to water shortages that have negatively affected crop growth and yields (Elijah and Odiyo, 2019). Additionally, rising temperatures resulting from climate change have affected planting seasons coupled with increased instances of pests as well as diseases. Traditional crops have also been affected by climate change noting that their survival threshold is surpassed by high temperatures leading to poor yields (Elijah and Odiyo, 2019). However, climate change is affecting different crop varieties unequally owing to the variances in climate zone (Waithaka, Nelson, Thomas, & Kyotalimye, 2013). In Kenya, for example, crops that are mainly favored by warm weather such as tomatoes and cabbages are exhibiting rising crop yields while crops such as tea and coffee are declining yield-wise (Waithaka et al., 2013).

Given the varying intensities of climatic change impacts across climatic zones, there have been propositions that there is a need to boost the adaptive capacities of all societies to face the potential present as well as future challenges emanating from climate change (Boko, 2007). Given these arguments, climate change emerges as a notable development policy topic as well as a global governance issue especially in the 21st Century (Akter & Bennett, 2011). Countries in the developing world are cited to be hardest hit by changes in climate because they are located mainly in the tropical as well as drought-affected regions and their inhabitants depend highly on natural resources for livelihoods coupled with the fact that they have the least capacity to respond to impacts and challenges that are climate change-related (Boko, 2007). Kenya is not an exception and is likely to suffer from climate change in a similar way as other developing countries (Bryan et al., 2013). Changes in climate in Kenya have impacted vegetation, land management, natural water resources, and forest cover. (IFRI Research Institute, 2008). These impacts have resulted in declining livestock productivity and reduced crop yields from rain-fed agriculture subsequently contributing to malnutrition and food insecurity both in the highlands as well as the arid and semi-arid areas of Kenya (Berck et al., 2018). Noting that the major livelihood source for the majority of rural communities in Kenya is agriculture, awareness of climate changes and possible adaptations are significant factors in enhancing resilience within the agricultural sector thus protecting livelihoods and boosting food security (Yaro & Hesselberg, 2016).

Among Kenyan regions, Murang'a County in the Central Kenya highlands, is an ideal case study as the impacts of climate changes have been very significant. The County has experienced changing seasons, infrastructural damage, extreme weather, and notable human-animal conflicts resulting from scarcity in water resources (Bryan et al., 2013). There are indications that farmers in the County have adopted numerous practices to adapt to changing climate (Bryan et al., 2013). These practices include the planting of drought-resistant food crops, growth as well as breeding of

pest-resistant crops and livestock, cultivation of early maturing crops, and changing the timing of crop seasons (Bryan et al., 2013). Additionally, farmers have been found to diversify their farming enterprises and resulted in employing meteorological weather forecasts (Bryan et al., 2013).

According to Kabubo-Mariara and Kabara (2018), climatic conditions alterations have been observed in Murang'a, but the understanding of these changes remains relatively low especially among the rural populations despite them being the most vulnerable to these changes. The susceptibility of these rural populations to climate change the impacts is as a result of their significantly high reliance on climate-sensitive natural resources as well as high poverty rates (Kabubo-Mariara & Kabara, 2018). In this light, it is critical to examine how farmers perceive the climate change impacts on the production of agricultural crops as well as the impacts that these changes have on food security.

Thus, the aims of this study were: -

a) To document the perceived climate change impacts on crop production by smallholder farmers
b) To analyze the effects of perceived climate change impacts on how farmers evaluate their food security
c) To analyze farmers mitigation and adaptive strategies to climate change impacts

## 2.0 Literature Review

### 2.1 The Importance of Agriculture in East Africa and state of Food Security

The East Africa Community countries comprising of Kenya, Uganda, and Tanzania rely heavily on agriculture for food security, foreign exchange earnings, employment, and economic growth (Kabubo-Mariara & Kabara, 2018). Approximately 80% of the population in these countries are rural residents, indirectly as well as directly relying on the agricultural sector for their livelihoods (Waithaka et al., 2013). Even though the contribution of agriculture to the national GDPs varies between countries, agriculture stands out as an important economic sector in the region. Cereals production in the region can be argued to have increased significantly from 1961 as a result of yield per unit area improvement as well as the expansion of the harvested area (Kabubo-Mariara & Kabara, 2018). However, as a result of the increasing population in the region, East Africa is still food insecure (Kihila, 2017). In addition, the region's food insecurity is further aggravated by recurrent climate shocks that include pests, diseases, floods, and drought (Kihila, 2017). It is worth noting that the agricultural sector in the region is predominantly rain-fed thus the changing climate disproportionately affects the rural populations who are mainly poor and marginalized groups (Bryan et al., 2013).

Kenya has for a long time worked towards achieving self-sufficiency in food commodities including maize, rice, wheat, beans, meat, and milk (Kabubo-Mariara & Mulwa, 2019). Achieving food self-sufficiency is in line with "Zero Hunger" and "No Poverty" Sustainable Development Goals (Ramutsindela & Mickler, 2019). This is because food insecurity emanating from self-insufficiency is among the indicators of poverty. Achieving "Zero Hunger" and "No Poverty" goals is to a significant extent hinged on the "Climate Action" goal noting that food production is largely influenced by climate (Ramutsindela & Mickler, 2019).

Self-sufficiency in maize in Kenya, according to Ramutsindela and Mickler (2019), was achieved in the 1970s when maize production was high with the surplus being exported. However,

attaining self-sufficiency does not automatically translate into household food security (Kangethe, 2000). The argument is premised on the empirical evidence that has shown that finding a solution to food security issues from a production perspective while downplaying the ability of the people to purchase does not offer a solution to challenges of food security most notably regarding accessing sufficient food by vulnerable groups (Kangethe, 2000). Further, the challenge of food self-sufficiency in Kenya has been contributed largely by climatic changes where drought cycles seem to have shortened occurring every 2-3 years compared to 5-7 years in the past (Kangethe, 2000).

Climate change has been propped as a significant factor driving the spread of diseases and pests (Ramutsindela & Mickler, 2019). Climate change affects the survival rate, population size, development in addition to geographical distribution of diseases and pests (Trębicki & Finlay, 2018). These phenomena are evidenced by the recent occurrence of fall armyworms and desert locusts affecting crops while livestock diseases including Rift-Valley Fever have been prevalent after periods of dry spells followed by heavy rainfall in Kenya ultimately impacting on food security in the country (Okoba et al., 2011).

## 2.2 Climate Variability in East Africa

The East Africa region has been found to already be subject to climate extremes and variability ranging from floods to droughts in most cases having severe social as well as economic implications (Castro et al., 2019). Recent climate predictions are indicating that these countries potentially will face long-term and near-term variations in climate that include changes in intensity and frequency of extreme events, warmer temperatures, and declining precipitations (Castro et al., 2019). Further, Omambia, Shemsanga, and Sanchez Hernandez (2015) notes that the impacts of the projected climate change are bound to have a lasting impact adding to the toll

of the climate extremes and variability being experienced thus making the communities depending on natural resources for livelihoods and well-being more vulnerable.

In Kenya, there has been a series of floods and droughts which have resulted in devastating environmental and socio-economic consequences. Chronologically, in January 1997, a national disaster was declared by the Kenyan government because of a severe drought that posed a threat to approximately 2 million people (Mackay, 2008). Further, in 1997/98, heavy rainfall (El Nino) was experienced causing destructive floods in the country (Mackay, 2008). Additionally, in 2000, the nation was faced with another drought that was arguably the worst in 37 years with over 1.7 million people needing food assistance (Bryan et al., 2013). The numbers escalated with over 4 million people requiring food assistance in the same year leading to the government appealing for food aid assistance from the international community. Two years later in 2002, the country was again hit by devastating floods that culminated in the displacement of people, loss of properties, landslides, and death of people through drowning (Bryan et al., 2013; Adger et al., 2003). In 2004, the country did not experience the long rains which resulted in farmers experiencing subsequent crop failure with more than 2 million people needing food aid. The situation was similar in 2005 where it was estimated that over 2 million people mainly from the arid and semi-arid areas required food assistance as a result of failed rains. Prolonged drought was experienced in Kenya in 2017 and 2018 which was characterized by below-average precipitation in the seasonal long and short rains (Castro et al., 2019). The drought led to deteriorating pastures and farmlands, livestock loss, reduced water availability, and subsequent food price increases. In contrast, according to Science Africa (2020, December 14), the country experienced prolonged wet seasons in 2019 extending into 2020.

Climate change in Murang'a, just like in many other parts of Kenya has been significant. Farmers experienced crop failure in 2004 and 2005 owing to the failure of the long rains which

significantly impacted food crop production (Wakhungu & Nyukuri, 2009). During droughts, there have been numerous cases of primates-farmers' conflict while competing for scarce water resources in addition to the primates feeding on growing food crops (Wakhungu & Nyukuri, 2009). Additionally, in 2019 for example, farmers in the county were faced with numerous landslides owing to the heavy downpour which led to the loss of crops with subsequent impact on food production and security (Daily Nation, 2019). These landslides created a significant reduction in livestock productivity noting that livestock fodder was swept away in addition to making the livestock prone to pests and diseases. 2020 saw the onset of desert locusts into the county which was attributed to climate change with the tropical cyclones in the Arabian Peninsula providing suitable warm and wet conditions for desert locusts to breed (Owidhi, 2020).

## 2.3 Climate Change Projections

There are projections that farmers will continue to bear the brunt of continued climate change. According to Hashemi (2018), the current trend in the rise of average temperature is projected to continue in all seasons with the degree of temperature increase varying across the regions. Kenya's plateaus and highlands where Murang'a county falls are expected to experience higher temperature increase rates (Hashemi, 2018). Most notably, the projection for precipitation is becoming more uncertain in part due to the regional climate's natural variability (Okoba et al., 2011). However, it is projected that precipitation may increase in the highlands especially during the long rain seasons (Okoba et al., 2011; Omambia et al., 2015). These projected climatic changes will ultimately influence farmers' crop production and subsequently their food security.

## 2.4 Farmers' Adaptation Strategies to Climate Change

Governments both at national and county levels have initiated projects geared towards climate change adaptations and mitigation (Ongugo et al., 2014). According to the National Adaptation Plan, there is a need to institute climate change adaptation strategies in agriculture to

ensure food security (Ongugo et al., 2014; Kenya, 2013). The County Government of Murang'a through its County Integrated Development Plan notes that livestock coupled with agricultural production in the county is highly dependent on agriculture (Ministry of Devolution and Planning, 2013). The plan notes that the provision of extension services in agriculture to farmers is a critical step in enhancing farmer adaptation to climate change.

Farmers in the county have adopted planting crops that are early maturing in addition to being drought-resistant to cope with the crop production challenges brought about by climate change (Waithaka et al., 2013). Further, farmers have been shown preferences for growing and breeding pest and disease-resistant crops and livestock while also changing the timing of crop seasons (Bryan, 2013; Kabubo-Mariara, & Kabara, 2018; Kabubo-Mariara, & Mulwa, 2019). The diversification of farming enterprises as a climate adaptation measure cannot be overlooked with many farmers employing meteorological weather forecasts to inform alternative enterprise choices (Bryan et al., 2013). However, climate adaptation is hindered by high costs associated with adaptation, poor access to credit, and inadequate access to meteorological forecasts as well as extension services coupled with limited potential for irrigation (Onoja et al., 2019).

## 3.0 Methodology

### 3.1 Study Area

Kahuro is a sub-county of Muranga County in the Central region of Kenya standing at an average elevation of 1645 metres a.s.l. The area is known for its fertile soils suitable for agricultural crop and livestock production which is enhanced by a good climate (Jätzold, 1987). The area experiences March to May long rains while the short rains are experienced from October to November (Jätzold, 1987). Farming is the main economic activity in this area being favored by the fertile soils coupled with the good climate. Farmers primarily grow food crops including *Zea mays, Musa paradisiaca, Phaseolus vulgaris, Maranta arundinacea, Lopmoea batatas,* and *Cucurbita spp*. among other crops. *Camellia sinensis and Coffea spp.* form part of the cash crops grown in the area while *Persea americana* and macadamia are emerging crops. Kahuro sub-county has an estimated population of over 80,000 according to the 2019 Kenya Population and Housing Census. Further, the average household size is estimated at 3 people.


Figure 1. A map of Kahuro sub-county
**Source:** Google Earth

### 3.2 Data Collection

Data collection was done between January and March 2021. Semi-structured interviews were used to collect the data with 30 farmers being interviewed where 20 were male while 10 were female. The interviewees were small-scale farmers within the Kahuro area with the choice of the area being informed by the fact that it is a high potential agricultural area. The choice of semi-structured interviews was founded on the fact that they allow new ideas to be brought on board by the interviewee. This method was deemed appropriate to give the interviewees more opportunities to express themselves fully. Noting that the interviewer needed to capture the perceptions of farmers on climate change and the impacts such changes have had on agricultural crop production and food security, semi-structured interviews provide more reliable as well as comparable qualitative data (Bazeley, 2020). As such, individual interviewees give an in-depth understanding of their experiences with climate change. Interviewed farmers are primarily Kikuyus hence the interviews were conducted in Kikuyu which is the local dialect.

Convenience sampling was done to arrive at the respondent farmers where those who were available and willing to participate in the study were interviewed. Further, while informing the participants of the study and its purpose, the principle of "Confidentiality" in addition to "Diligence" especially noting that the study was conducted amid the COVID-19 global pandemic. During this study, data was collected offline using the "KoboCollect" tool. The data collection tool enables data collection in a safe mode where third parties cannot access it hence promoting confidentiality. Additionally, the tool has strong safeguards against data loss hence suitable for conducting long interviews. Finally, the choice of the tool was advised by the fact that the data is available immediately after it is collected hence the researcher has an opportunity to ensure that he has complete information before leaving the interviewee.

### 3.3 Data Analysis

Data collected was exported to Microsoft Excel and all non-numerical data was given codes. All respondents were given IDs and listed on the first column of the spreadsheet. Interview questions were divided into three sections with each section having an independent worksheet. Responses from the field were entered in the corresponding IDs. Additionally, titled columns across the page were used to ease the generation of bar and circle graphs. During the analysis, it was critical to effectively move around the worksheet to ensure that no additional data was entered while the existing data was not altered.

### 3.4 Limitations of the Study

The study proves critical in understanding the views of farmers on climate change and its impact on crop production and food security. During the study, the researcher faced several challenges including the COVID-19 pandemic and subsequent lockdown which largely hindered movement as well as creating possible exposure to the researcher and interviewees. Due to previous experiences, some 5 farmers were unwilling to participate in the study especially with the recording of their answers, however with the enumerator explaining the concept and reason for the study, these farmers accepted to participate Moreover, the interviewers intimated that significant numbers of studies conducted previously by other actors such as NGOs included financial handouts for respondents. As such, 5 respondents declined to participate without financial handouts which necessitated the inclusion of a similar number of respondents to maintain the sample.

## 4.0 Results

### 4.1 Crops Grown and Farming Duration

This chapter provides an in-depth look at the responses given by the respondents while trying to determine the perceptions that they held regarding climate change and the impact that such changes have had on food security. Out of the 30 interviewees, 3 farmers had been in farming for less than 5 years while a similar number had been in farming for over 5 years but less than 10 years. The majority of the respondents showed that they had been farming within the study area for over 10 years but less than 20 years. Only 1 respondent had been farming in the study area for over 20 years. 29 indicated that they grow maize on their farms while 14 respondents grow bananas. Additionally, 11 of these farmers grow coffee and 5 grow avocados, tea, and beans. Further, only 2 farmers indicated to be growing tomatoes and macadamia with fodder and cabbages being grown by 1 farmer each (Figure 2).

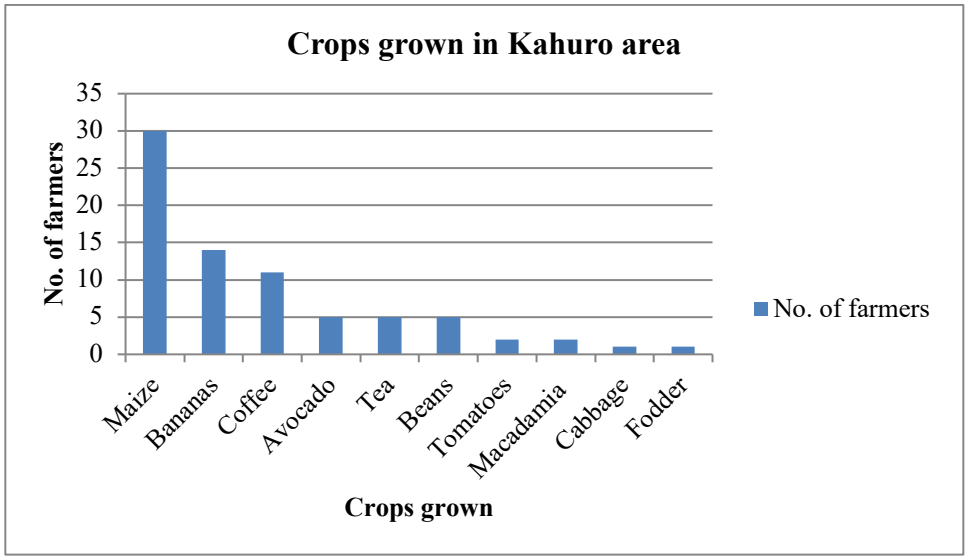


Figure 2. **Graph showing the crops grown by the interviewed farmers**

In sum, 23 farmers (76.67%) affirmed that their land sizes had changed while only 7 (23.33%) farmers reported no change in the farm sizes. Farmers indicated that there were significant land

size changes that were impacting food crop production. 10 farmers affirmed that their land under crop production had changed. These farmers pointed that the reasons for these changes were land subdivision, landslides, and destruction by wild animals. Additionally, 6 interviewees intimated that they have used up their productive land for construction of rental and residential houses. Farmer KH007 noted that: *"Much of my productive land has been taken up by construction. I want to become a landlord with an assured monthly income rather than doing farming. The money I will get from rent will be used to buy food for my family".* Farmer KH004 indicated that his land size had changed owing to landslides. He stated: *"My land is very prone to landslides. In 2002 is when there was the first landslide on my land.* 13 respondents noted that their land under crop production had increased. The increase was attributed to the leasing of land from other farmers which in turn was a result of continued land subdivision. Farmer noted KHO16 stated that: *"We divided our father's land amongst ourselves which led me to lease land from neighbors so that I can produce enough food for my family".* 9 farmers reported that their land under crop production had not changed.

Figure 3. **Crop production land used for construction of rental and residential houses**

### 4.2 Source of Water for Crop Production and Sustainability of Crop Yield into the Next Season

Farmers would often attribute their changes in production to climatic trends. 90% of the interviewed farmers indicated that they depended on rainfall to continue growing their crops while only 10% produced crops under both irrigation and rain-fed agriculture. The respondents were also asked whether their crop production had been on the decline, improving, or remained the same. Out of the 30 interviewees, 26 pointed out that their crop production had declined over the last one year. 4 farmers opined that their production had improved over the last one year while no farmer indicated to have maintained their crop production.

When the farmers were asked whether the crop yield from the last harvest would be able to sustain the family until the next harvest, 9 farmers pointed out that the harvest would be adequate. The respondents reported that the previous harvest was adequate since they had engaged in irrigation farming hence their production was not affected by changes in weather patterns. Further, the household size was also a significant factor that determined how long the previous harvest would last.

2 households with three members had reported that the harvest would keep them until the next harvest. On the other hand, 21 farmers indicated that the previous harvest would not last until the next harvest season. Households that reported having more than three members and who experienced low yields indicated that their harvest would not last till another harvest season. A male farmer aged 63 noted that: *"I live with my wife and 8 dependents so the 4 bags of maize harvested cannot last for the next 4 months"*.

### 4.3 Causes of Declining Crop Yields

86.67% of the interviewed farmers had posted declining crop yields in the last year. 8 Respondents cited unreliable rainfall, frequent droughts, extended cold seasons, and flooding as the major climatic events that affected their crop yields. Additionally, pests and diseases that

included Fall Armyworms (FAW), as well as Maize Lethal Necrosis Disease (MLND), also affected the quantity and quality of the crop yields. It is worth noting that human-wildlife conflict resulted in crops being destroyed by wildlife subsequently leading to a decline in the yields. Farmer KHO23 stated that: *"When the rains fail, monkeys invade our shambas (land) and feed on our maize. When you attempt to chase them they imitate you and continue feeding."* Despite the study area being a relatively high potential agricultural production zone only 9 respondents indicated to have a harvest that would last to the next harvest season pointing out the possibility of food insecurity.

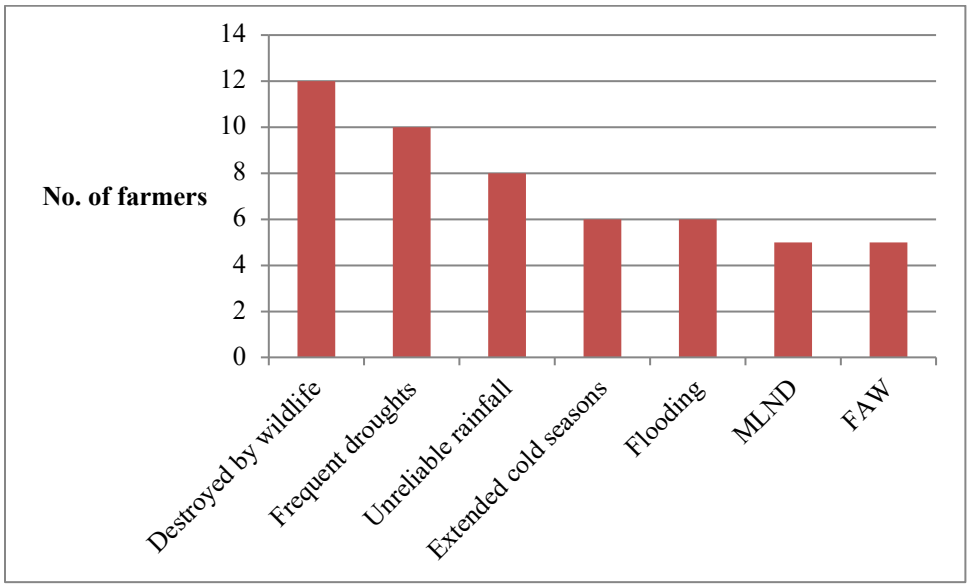


Figure 4. **Graph showing the causes of declining crop yields**

### 4.4 Crop Growing Seasons for Food Crops Grown

While seeking to determine the number of crop seasons for each food crop grown, maize, beans, and bananas farmers reported having 2 seasons while avocado farmers reported 1 crop season. Interviewed tomato and cabbage farmers indicated that they have 3 seasons within which they grow. It was noted that while the cropping seasons may have remained the same in number, the planting and harvesting time had changed significantly. Interviewed farmers noted that there was a gradual shift in the onset and duration of rainfalls with some years including 2000 and 2006

experiencing drought. Additionally, there were reported incidences of extended wet periods. Framer KH002 noted that: *"In the past, maize was planted at the beginning of April and mid-October when the rains set. These days we plant as late as the beginning of May and November when the rains are delayed. Other times when the rains set early, we plant in mid-March and early October. The planting seasons have been affected very much".*

Table 1. Table showing the regular crop seasons for the major crops

| **Crop** | **Regular crop seasons** |
|---|---|
| Tomatoes | 3 |
| Cabbage | 3 |
| Fodder | 3 |
| Maize | 2 |
| Bananas | 2 |
| Beans | 2 |
| Coffee | 1 |
| Avocado | 1 |
| Tea | Continuous |
| Macadamia | 1 |

Farmers interviewed during the study pointed out that they had experienced shifts as well as extended crop growing periods at different times over the duration they have been in farming. In 1984, 2000, 2001, 2006, and 2016, farmers reported incidences of drought. In addition, years that reported floods, as well as prolonged short rains and prolonged long rains, included 2018, 2019, and 2020.

## 4.5 Changes in Crop Yields in the Last 10 Years

When asked how individual farmer's crop yields have changed over the last 10 years, interviewed farmers responded decline, as well as increasing yields, was witnessed. 9 farmers who had indicated that the current harvest would last them to the next harvest cited that the increase in crop yields was as a result of using improved crop varieties that were drought, pests, and disease resistant. Additionally, these farmers indicated that they had adopted conservation agriculture which contributed significantly to maintaining soil fertility while the use of irrigation reduced the over-reliance on rains for growing crops. Farmer KH002 noted that: *"Since the weather has become very unpredictable, I dug a water pan with assistance from the ward extension officers. With this, I can harvest water and farm without relying very much on the rain".*

Figure 5. **Pictures of water harvesting structures for irrigation purposes in Kahuro**

Farmers who posted declining crop yields pointed out that the unreliability of rainfall in distribution, amount, and timeliness has contributed to reducing yields. In addition, soil fertility has declined with fertilizers and other farm inputs becoming expensive. Further, the interviewees indicated that the emergence of new pests and diseases such as Fall Armyworms, MLND, as well as the advent of desert locusts have negatively impacted crop yields.

## 4.6 Changes in Land Cover and Land Use Impacting Food Security

Interviewees posted that land use and land cover had changed over time. To begin with, there was a notable land subdivision that reduced the land available for crop production. Noting that the farmers realized reduced crop yields and subsequent decline in crop farming profitability, they tended to diversify from crop production to dairy farming and constructions of residential as well as rental houses. In addition, interviewees noted that some lands have been overused impacting their productivity. Reduced productivity coupled with unreliable rainfall has led to farms being abandoned consequently affecting food security. Where interviewed farmers have been able to harness water for irrigation, it has been noted that land vegetation cover has been cleared to create more land for farming thus enhancing food security.

## 4.7 Farmer's Perception of Climate Change

The study sought to evaluate the perceptions that farmers had regarding climate change. In efforts to have this insight, farmers were asked what they have heard about climate change. Interviewed farmers identified human activities such as deforestation and clearing of land cover as the major cause of climate change. In addition, interviewees noted that changes in weather patterns such as having prolonged dry spells, experiencing too much rainfall, and having extended wet periods with extreme temperatures as part of what they know about climate change. Additionally, there were indications that the adoption of wrong farming activities by farmers was to blame for changes in the climate where such changes resulted in rainfall and water shortages. Farmers also felt that the ozone layer which protects the earth against the UV rays has been depleted causing global warming which has significantly changed the climate of the study area. These findings point out that the majority of the farmers within the study area are aware of climate change. The awareness of farmers about climate change is further cemented by the views that they hold regarding how the climate is changing. According to interviewees' responses, an increase in

temperatures in comparison to previous years is a pointer to changes in climate. Moreover, the farmers reported having experienced more frequent drought periods, extended wet seasons with frequent flooding, coupled with the emergence of new crop pests as key indicators of a changing climate. These observations can be argued to have been inconsistent in their occurrence previously but are now more pronounced. Despite temperatures increasing over time, farmers pointed at extremely low temperatures that were being experienced during the cold months of July and August in the area. Finally, the ultimate indicator of how the climate is changing from the farmers' perspective was incidences of crop failure which they opined was not as frequent in the past.

### 4.8 Impacts of Climate Change on Crop Yield/Production

About 73% of the farmers interviewed have been engaging in crop production for over 10 years. As such, they have studied the crop yield patterns for a period where they can conclude the impact that climate change has had on crop production. 17 farmers reported declining crop yields resulting from prolonged droughts, prolonged wet seasons, the unreliability of rainfall, and gradual changes in temperatures. 1 farmer, however, noted that the climate changes have favored banana production while 3 farmers indicated that they have reduced the scale of crop production due to the unpredictability of climate. 4 farmers attributed poor quality yields to climate change. This may be connected to the invasion of crop fields by pests and diseases, low soil moisture, and extreme temperatures that have notable impacts on the quality of produce. Additionally, 5 farmers indicated that a changing climate has led to farmers changing their planting patterns. Usually, the onset of rainfall determines the time of planting thus delays in planting caused by delayed rains negatively affected crop yields. On the other hand, farmers who have adopted irrigation farming reported that they were able to undertake dry planting which not only increased the crop yields but also the planting seasons. Most of these impacts that have been identified suggest that climate variability has an immense effect on crop production and subsequently food security. 7 farmers

also noted that climate change has led to changing of cropping systems from mono-cropping to intercropping as well as mixed cropping. Additionally, the introduction of disease and pest-resistant crop varieties such as "Duma 43" maize by 5 farmers was reported while 4 farmers intimated that they had changed from maize and coffee farming to modern crops farming such as macadamia and avocado.

### 4.9 Farmers Adaptation and Mitigation Measures to Climate Change

With the majority of the farmers showing that there are prone to the effects of climate change, the study delved into determining whether they were taking precautionary measures to reduce their exposure to climate change impacts. It is worth mentioning that respondents reported having initiated mitigation measures such as the growing of drought-tolerant crops that include sorghum and green grams. However, the adaptation of these crops has not been widespread noting that a majority of the respondents argued that they do not have adequate knowledge on their husbandry and thus opted to continue growing crops that have been traditionally grown in the study area. Further, the farmers pointed out that they have engaged in the farming of early maturing drought-resilient crop varieties. Maize farmers, for example, singled out the 'Duma 43' maize variety as one that matured early and adequately withstood drought. Farmer KH001 stated: *"After experiencing dropping yields, I started planting 'Duma 43" maize variety after it was recommended to me by the ward extension officer".* Diversification in production has been noted as key in assisting farmers to withstand the changes of weather. In this light, interviewed farmers reported to have diversified their crop production embracing macadamia and avocado farming which are strong emerging crops in the study area. Money fetched from the sale of these crops was reported by respondents to be used in purchasing foods from the market if the previous harvests could not last to the next harvest. Farmer KH010 intimated: "*Because the maize yields have reduced, I have to buy food from Soko (market) so that I can feed my family until we harvest*

*again".* Further, farmers posted that they were engaging in water harvesting during the rainy seasons for use in the dry seasons. As such, respondents pointed out that they were harvesting surface water runoff using retention ditches that they have established with the assistance of extension staff from the Murang'a County Department of Agriculture. Additionally, farmers have embraced digging of water pans to tap and conserve runoff water to assist them in farming during the dry seasons. The intervention is in congruence with activities that Murang'a County Department of Agriculture has been engaging farmers with within the study area through the National Agricultural and Rural Inclusive Growth Project. It should be noted that respondents indicated to have adopted mulching in coffee, avocado, and macadamia farms as a water conservation measure since mulching reduces the rate of soil moisture loss, especially during dry spells. Respondents reported having engaged in using indigenous technical knowledge in fighting pests and diseases. The use of ash to control Fall Armyworms was especially most noticeable while 3 farmers also reported using push-pull technology in maize farming by growing *Desmodium incanum* and *Brachiaria mutica* grass which was effective in wading off maize stalk borers.

### 4.10 Informing people about climatic change

About 12 of the farmers interviewed noted that conducting farmers' field days as well as convening public meetings is critical in helping disseminate information regarding climate change. Moreover, 13 other farmers intimated to have learned much about climate change through vernacular radio stations thus suggesting that it was a god medium of passing information to other people given the popularity of these radio stations within the region. Another critical avenue identified as potentially useful in reaching out to people on matters of climate change was church congregations, conducting farmers' group training, peer training, and printing advisory brochures as well as newspaper bulletins which should be timely. Also, 20 respondents within the study area also indicated that agricultural extension staff would come in handy working hand in hand with

the meteorological department in spearheading participatory scenario planning and establishing an early warning system of weather forecasting that would benefit farmers.

## 5.0 Discussion

### 5.1 The Perceived Impacts of Climate Change on Crop Production by Smallholder Farmers

The study reveals that the farmers in the Kahuro sub-county are aware of climate change and the potential causes of such changes. Farmers also noted that they have been witnessing climate change for an average of 10 years with most of them have been in farming for a similar period. Farmers pointed out that the unreliability of rainfall, increase in pests and diseases, landslides, and frequent droughts are indicators of a climate that has changed. Further, the respondents noted that these changes in the climate have affected crop production given that unreliability of rainfall has often led to crop failure translating into poor yields. Moreover, the increase in pests and diseases has not only affected the quantity but also the quality of harvests while landslides have been shown to lead to loss of crop. The fact that there are farmers who have adopted irrigation farming is an indicator that farmers in the study area have experienced climate change hence seeking mitigation measures for the vagaries of weather. In addition, the respondents intimated that they had inclined towards farming crop varieties that were relatively tolerant to drought, pests, and diseases.

These findings are in tandem with research in Calderone, Headey, and Maystadt, (2014), that point out that over 90% of the farmers in Kenya have noted climatic changes. Noting that Kahuro sub-county is highly dependent on rain-fed agriculture with the majority of the farmers relying on agriculture as the major income source, it would follow that any climate changes would be noticed by the resident farmers in the area. Studies conducted across the country have pointed out that extreme temperature, erratic rainfall patterns, unusually early rains that are often followed by weeks of dryness, long dry spells, and flooding are key indicators of a changing climate (Castro et al., 2019). It is also worth noting that long-term temperature and rainfall trends form critical pointers of variability in climate in the drylands and

as such have an impact on the effectiveness of rainfall and subsequently availability of water for sustaining crop production (Camberlin et al., 2012). This study affirms that the farmers in the area perceive prolonged droughts and changes in rainfall as significant pointers of climate change which corroborates with the area's historical climate data. A series of drought incidents show that there is increased climate change in Kenya (Boitt, Albright, & Kipkulei, 2020).

Castro et al. (2019) and Boitt et al. (2020) indicated that climatic change in Kenya has been experienced for the last 30 years with significant changes being witnesses in the arid and semi-arid areas, where part of the study area falls. Within the central highlands of Kenya, where a large part of the Kahuro sub-county lies, long rains have been on the decline with over 150 millimeters over the last 35 years. The study also confirmed studies pointing at a general decline in March to April long rains which have become significantly unreliable (Castro et al., 2019; Karienye & Macharia, 2020).

Given the low and unreliable rainfall that is being witnessed, intense efforts have been aimed at developing crop varieties that are suited for different climatic conditions. Despite these efforts, gaining optimum yields from these crop varieties require water and nutrients to be supplied at optimum levels devoid of which they would post low yields. However, farmers are often forced to take time waiting for the onset of rain to start planting rather than having a specific planting time. Studies by Kassam et al., (2016) and Benkeblia et al., (2018), notes that a change in planting dates, crop varieties, and type of crop is a critical indicator of the awareness of climate change and the impacts of climate change on crop production. The emergence of new crop varieties and traits such as 'Duma 43' in maize, F1 tomato varieties, Murang'a 20 macadamia, and Hass as well as Fuerte avocado varieties have helped in improving agricultural productivity thus working to improve incomes and enhance food security among the residents of the study area. While the development and use of new crop varieties may be considered a gain,

there are valid concerns on the impacts of such crops in the ecosystem. First, there may arise uncontrolled spreading of pollen from these crops to autochthonous species where experts suggest that this could lead to destruction of species and ecosystems diversities (Tao & Ai, 2014) Additionally, there is a risk of evolution of plant pests and diseases that are more destructive hence leading to crop losses. For example, with most of the new crop varieties being resistant to herbicides, farmers are tending to use herbicides more without fear of harming their crops (Gupta & Ram, 2004). However, this has led to emergence of weeds that are resistant to herbicides leading to use of stronger herbicides since such weeds have an impact of crop harvests consequently affecting beneficial insects.

While interviewed farmers have shown that they are aware of climate change, the approaches used to disseminate information on climate change shows there is a need for intensified awareness creation. Farmers indicated that they access information on climate change from vernacular radio stations, public gatherings, and farmer field days. Conradie (2020), observes that the extension staff play a vital role in climate change information dissemination while proving useful in training on mitigation measures. Lee, An, and Kim (2020) cites that extension visits help to inform farmers about contemporary climate associated issues hence playing a pivotal role in helping farmers improve their knowledge about the best adaptation practices. Further, extension visits have been found to assist farmers in coming up with decisions that are founded on substantial information that ranges from when to sow to what crop variety to use in efforts to respond to climate change (Lotze-Campen, 2011). In the context of the study area, extension services will provide the much-needed interventions to support adaptation and coping interventions to climate change. Such interventions would include the promotion of irrigated agriculture, enhanced technical and financial support to drought tolerant crops, conservation agriculture, and provision of climate information.

## 5.2 The effects of Perceived Impacts of Climate Change on How Farmers Evaluate Their Food Security

The household interviews indicated that the farmers are tying changing climate with food security. Notably, a changing climate has led to farmers abandoning farming activities and converting arable land into alternative use such as developing real estates. Consequently, crop production would decline on this note and have significant impact on food security in the area.

Moreover, farming seasons have reduced with crops that previously had more than one cropping seasons having only one season. Farmers allude to the fact that their crop productivity has declined with the immediate previous harvests unable to last the families to the next harvest hence posing a threat to the household food security. The major contributors of the declining crop production were identified during the study as drought, unreliable rainfall, extreme temperatures, and flooding which caused landslides. Further, the occurrence of invasive pests coupled with emergent crop diseases has significantly affected crop production. Similar findings in Benkeblia et al. (2018), demonstrate that crop production in East Africa and across the globe has been on the decline with changes in climate as the major contributor. The study cites low as well as unreliable rainfall, changes in temperatures, and land degradation as notable climate changes with immense effect on crop production. With extreme high temperatures being felt, precipitation has declined while on the other hand, extremely low temperatures have slowed the maturity of crops. Research in Owidhi (2020), shows that crop yields are affected by numerous factors that include rainfall, temperature, climate variability, extreme weather events, and atmospheric carbon dioxide concentration which has been particularly identified as having major impacts on crop production. Additionally, this study's findings are further supported by Kassam, Mkomwa, and Friedrich (2016), who report that there is witnessed changes in planting time, notable crop yield decline, increases in incidences of pests and diseases, and crop failure which has been attributed to climatic changes within Sub-Saharan Africa, where Kenya falls.

Interviewed farmers showed there are differing opinions on the extent of the impact of climate changes. A section of the farmers indicates that changing climate has led to increased crop productivity. However, this observation can be largely attributed to the introduction of new crops that include macadamia and avocado in the area. Despite the introduction of these new crops, the study found out that majority of the drought tolerant crops such as *Manihot esculenta, Eleusine coracana, Dioscorea spp.,* and arrowroots that are suited for the lower part of the study area have been abandoned giving higher preference to modern crops including tomatoes, cabbages, and maize. In spite of the worrying trend, Kassam et al. (2016) notes that these abandoned crops are hardy hence survive dry climates in comparison to the modern crops that do not perform well in the semi-arid environments despite being economically attractive. The introduction of avocado, macadamia, tomatoes, and cabbages within the study area has been within the past twenty years. It is also during this period that interviewed farmers cited they started experiencing drastic climate changes. They noted that the climate became warmer which provided a conducive environment for pests and diseases to thrive hence increasing the cost of production leading to some getting abandoned. This coupled with the fact that interviewees had transformed arable land into real estate indicates that the livelihood and economic importance superseded aspects of climate change.

### 5.3 Farmers' Mitigation and Adaptive Strategies to Climate Change Impacts in Murang'a County

Interviewed farmers indicated that they have initiated measures to curb the vagaries of climate change while there are farmers who have decided to do nothing in view of climate change. As such, the failure to do anything in efforts to cope with changing climate is an indication that farmer perceptions of climate change do not necessarily lead to adoption measures (Lotze-Campen, 2011). While interrogating the failure of adaptation by farmers, Hashemi (2018), observes high costs, poor access to credit, and inadequate access to meteorological

forecasts as well as extension services coupled with limited potential for irrigation as key factors that hinder adaptations to climate change. In cementing this argument, Karienye and Macharia (2020), show that the awareness or perception of climate change and instituting adaptive measures is largely influenced by varying environmental as well as socio-economic factors. Such factors range from shortage of land, the inadequacy of financial resources, lack of information, and poor potential for irrigation combined with climate variability, volatile large scale and local markets short term changes, and extreme weather conditions. These findings show that despite the fact that climate change is an integral crop production factor to consider, socio-economic factors are a force to reckon with in influencing whether farmers adopt the various climate change adaptation measures. In absence of adaptation, the agricultural sector would be widely affected by climate change, however, with adaptation it is possible to bring down vulnerability significantly.

## 6.0 Conclusion

Farmers in Kahuro are aware of climate change which is evidenced by the perceptions that they hold towards climate change. They attribute occurrences such as invasion of pests and diseases as well as landslides and frequent droughts as key indicators of a changing climate. Additionally, they also believe that the continued rainfall unreliability is a direct impact of changes in the climate. These farmers are also holding the views that these impacts of climate change have an implication on crop production and hence food security. The frequent droughts, pests and diseases as well as rainfall unreliability are resulting in crop failure and subsequent poor yields. Further, pests and diseases are affecting the quality as well as quantity of produce. On the other hand, landslides are leading to loss of crop. These impacts of climate change are having a toll on food security noting that the harvests are inadequate to last the households till the next harvest. With the farmers aware that the climate is changing and the subsequent implications that those changes have on food security, they have initiated mitigation and adaptation measures. Farmers are engaging in early planting, planting crop varieties that are drought, pests, and diseases tolerant in addition to adopting irrigation farming.

However, there are farmers who have not adopted any mitigation strategies despite being aware of their importance. This is attributed to monetary challenges as well as inadequate capacity. This is an indication of existing mismatch between acquisition of knowledge and practical application of this knowledge in climate resilience practices as this is tied to capital requirement, in which they have a deficiency. In addition, the findings also show that correlation between climate resilience ability and economic sense of the techniques. This explains the continued decline in total farm yield and deterioration of food security in the study area.

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## Appendices

**Semi-Structure Questionnaire**

Code of interview …… Date ……

**Part A**

**a) To document the perceived impacts of climate change on crop production by smallholder farmers**

1. What crops do you grow in your farm?

2. Is it under irrigation or rain fed?

3. How long have you grown the crops in 1 above? .....Years/Months

4. How is your crop yields/ production over the last one year?

5. Is the harvest enough to last until the next season? If no? why? What measures have you employed to minimize the exposure?

**Part B**

**To discuss the effects of perceived impacts of climate change on how farmers evaluate their food security**

1. How many crop growing seasons you have per year for each food crop you grow?
2. Are the above-named crops growing seasons regular annually or they have changed over the years? Why?
3. Which specific years have you for the first time experienced shift or extended crop growing season? Why?
4. Has the farm size area changed? Why? How did you (how did you adapt?)
5. Land size under crop production in the last year? […….. Acres]

6. In your opinion, what do you think will be the size of your farm next year? [Acres]

7. How has the crop yield from your farm been changing over time in the last ten years?

8. What affects changes in your yield in 7 above?

9. What is your opinion about the land cover/land use changes in your area regarding food security?

**Part C**

**Perception questions/ Household Questionnaire**

1. What have you heard about climate change?

2. How, in your opinion, the climate is changing? .....

3. How the changing climate has impacted crop production patterns/ yields in your ward/village? .....

4. How should people be informed a little about the changing climate? .....

5. Is there any activity to adapt to the impact of climate change on food security in your area?.....

6. In 5 above, what activities have you engaged in

7. Do you think climatic changes and food shortages are interconnected? Why and how? ….....

8. How should be people warned to prevent the loss of crops?

9. Do you agree that changes in the climate are not to blame for reduced crop production in your ward/ village? ……

10. Is there anything that farmers can do to mitigate the effects of climate change? Please describe what you do and/or would like to do?