UNIVERSITY OF NAIROBI

ENHANCING FOOD SECURITY THROUGH CROP AND LIVELIHOOD DIVERSIFICATION AMONG KIMANDI-WANYAGA COMMUNITY IN MURANG'A COUNTY, KENYA

BY

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I85/93062/2013

A Thesis Submitted in Partial Fulfilment of the Requirements for Award of the Degree of Doctor of Philosophy in Climate Change and Adaptation of the University of Nairobi

2021

DECLARATION

This Thesis is my original work and has not been submitted in any other university. Where other people's work has been used, this has properly acknowledged and referenced in accordance with the University of Nairobi's requirements.

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DEDICATION

This work is dedicated to the Almighty God, my Ebenezer. I also dedicate this work to my husband and best friend, Mr. Njogu Gakuya for his unconditional financial and moral support. Not to forget my mother, Wambui Ngure for her relentless prayers, and my lovely children Nyakio, Macharia and Ngure.

ACKNOWLEDGEMENT

I thank God almighty for the wisdom, tenacity and grace to complete this study. I am sincerely humbled for the opportunity to stand on the shoulders of the academic giants who are my supervisors namely, Prof. Shem Wandiga, Prof. Daniel Olago, and Dr. Silas Oriaso. Your unrelenting support led to the successful completion of this study. My special thanks to the former and current ICCA Directors, Prof. Shem Wandiga, and Prof. Daniel Olago respectively for selfless leadership. To the ICCA academic fraternity namely: Prof. Dan Olago, Prof. William Ogara, Dr. Maggie Opondo, Dr. Gilbert Ouma, Dr. Lydia Olaka, Dr. Simeon Dulo, Dr. Christopher Oludhe, Dr. George Outa, Dr. Tobias Nyumba, Dr. Catherine Sang, Mrs Eunice Ongoro, Dr. James Kaoga, and Mrs. Rosemary Barasa, thank you for your academic empowerment. I sincerely thank all the ICCA support staff for the unparalleled support and

I appreciate the support and contribution of my colleagues in the 2013 Doctoral program, with whom we consulted throughout the study. To all the staff at the graduate library, University of Nairobi, and the Kenya Bureau of Statistics (KNBS) for all the assistance provided. May God bless you. Special thanks go to my interdisciplinary research team, Key Informants and Focus Group Discussion participants, and all the other stakeholders that contributed to the successful completion of this study. To my colleagues, Nthenya, Kimeu, Karienye and Julia, I sincerely appreciate your contribution to this study.

My special gratitudes go to my family, especially my husband, Mr. Njogu Gakuya, for your financial and moral support. Special thanks to my mother, Wambui Ngure for your relentless prayers. To my lovely children Nyakio, Macharia, and Ngure, thank you for your company when I was burning the midnight oil. Thank you to my brothers and sisters Wanjiru, Wanjiku, Waithira, Mugure, Shiku, Munga, and Maina for being there for me. To my dedicated house manager, Wa Macharia, you stood in the gap and kept nudging me to keep going even when I felt like giving up, may God bless you. Finally, I thank you all who offered support in one way or another for the successful completion of this study.

ABSTRACT

Climate change poses significant risks to food security globally with predictions of a 10-20% decline in rain-fed crop yields by 2050. In Kenya, climate change hazards including droughts and floods are affecting crop productivity and constraining smallholder farmers food security. Murang'a County in Kenya is affected by prolonged droughts and floods. The County's over-reliance on rain-fed farming predisposes smallholder farmers to climate-induced food insecurity. This study was conducted with Kimandi-Wanyaga, a forest-adjacent community in the Gatanga Sub-County in Murang'a County, Kenya whose main livelihood source is smallholder rain-fed farming. This transdisciplinary research aimed to enhance the community's food security through crop and livelihood diversification vis-à-vis climate change. The study analysed the observed and perceived rainfall and temperature trends, their association with food security, their perceived current and anticipated impacts on food crop production, and the challenges facing the community's climate change climate coping efforts. A mixed methods research design was applied. Through a systematic sampling method, 281 household heads were selected. Monthly rainfall and temperature data from Thika meteorological station were analysed for trends using the MAKESENS procedure. Community perceptions data were obtained through household survey, Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs). The study explored the potential of expanding the community's crops and income sources diversity by incorporating improved traditional vegetables under the Plantation Establishment and Livelihood Improvement Scheme (PELIS) program. Two on-farm demonstrations on traditional vegetable farming were conducted. The farmers replicated the cultivation of the vegetables on their farms for four seasons. Using the MS Excel and SPSS statistical packages, collected data were analysed through descriptive (frequencies, percentages). Inferential statistics (Chi-Square tests) examined the associations between, 1) the rainfall and temperature changes and the food security indicators, 2) the community's socioeconomic characteristic and the food security indicators. The results were presented in tables, figures, and direct quote formats. The study established that the community perceived inadequate rainfall during critical crop growth (79%) reduced rainfall intensity (77%) and late-onset and early cessation of seasonal rainfall (73%) had interrupted their food crop productivity. The community perceptions disagreed with MAKESENS rainfall data trends which showed normal rainfall variability ($\alpha > 0.1$). The community perceptions and observed maximum temperature data agreed that the study area was warming ($\alpha = 0.001$) posing serious risks on their crop production and food security. The household heads' gender, age, occupation, and the size of land under food crops were found to be significantly associated with the households' level of food security but the household heads' education level was not significantly associated with the households' food security. The community's climate adaptive capacity was challenged by inadequate finances, lack of reliable and prompt climate information, inadequate knowledge on viable climate coping technologies, shrinking farm sizes, infertile soils, and market inaccessibility. The PELIS emerged as a viable climate adaptation opportunity with potential to enhance the community's food security. The farmers could diversify their crops and income sources by incorporating traditional vegetables such as Amaranths, Black nightshade, and Cowpeas for food security. The PELIS has the benefits of climate adaptation through crop production and climate mitigation through afforestation.

Key Words: Adaptation, Climate Change, PELIS, Rainfall Trends, Temperature Trends, Transdisciplinary, Traditional Vegetables.

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DEFINITION OF KEY TERMS

It is important to define some key terms that have been used in this study to ensure that that their context of use is well captured. The definitions applied here in the study agree with those applicable by the Intergovernmental Panel on Climate Change (IPCC, 2018) and supported with alternative definitions where applicable.

Adaptive capacity: "This is the ability of a system to adjust its characteristics in order to expand its range under existing climate variability and future climate change." (IPCC, 2018).

Climate adaptation: "Adjustment in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects to moderate or offset potential damage or take advantage of opportunities associated with change in climate." (IPCC, 2018).

Climate change: "Climate change is a significant change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. Climate change may be a change in average weather conditions, or in the distribution of weather around the average conditions (i.e., more or fewer extreme weather events)." (IPCC, 2018).

Climate variability: "Refers to variations in the mean state and other statistics (such as standard deviation, occurrence of extremes, and others) of climate at all spatial and temporal scales beyond that of individual weather events." (IPCC, 2018).

Crop Diversification: "The addition of new crops or cropping systems to agricultural production on a particular farm considering the different returns from value-added crops with complementary marketing opportunities." (IPCC, 2018)

Food security: "When all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." (IPCC, 2018).

Household Dietary Diversity Score: "A qualitative measure of food consumption that reflects household access to a variety of foods." (IPCC, 2018).

Household: "Refers to a group of people living in the same compound consisting of an enclosed set of buildings, eating from the same pot and recognizing one head of household usually, a husband and father or guardian." (IPCC, 2018).

Livelihood Diversification: "The maintenance and continuous alteration of a highly varied range of activities and occupations to minimize household income variability, reduce the adverse impacts of seasonality, and provide employment or additional income". (IPCC, 2018).

Livelihood: "Refers to the capacities, goods such as capital and social, and the activities needed to live." (IPCC, 2018).

Perception: "It is the process by which we receive information or stimuli from our environment and transform it into psychological awareness." (IPCC, 2018).

Resilience: "The ability of a system to anticipate, absorb, accommodate or recover from the effect of a hazardous event in a timely and efficient manner, including through ensuring preservation, restoration, or improvement of its essential/basic structures and functions." (IPCC, 2018).

Transdisciplinary: "Refers to research that includes cooperation within the scientific community and a debate between research and society at large. Transdisciplinary research transgresses boundaries between scientific disciplines and between science and other societal fields to deliberate about facts, practices and values." (IPCC, 2018).

Vulnerability: "The degree to which a geophysical, biological and socioeconomic system are susceptible to, and unable to cope with adverse effects of climate change including variability and extremes." (IPCC, 2018).

LIST OF ABBREVIATIONS AND ACRONYMS

AAKNET	Africa Adaptation Knowledge Network
ASALs	Arid and Semi-Arid Lands
AWS	Athi Water Services
EbA	Ecosystem Based Approach.
FAO	Food and Agriculture Organization
FDA	Focal Development Area
FGDs	Focus Group Discussions
GDP	Gross Domestic Product
GOK	Government of Kenya
ICCA	Institute for Climate Change Adaptation
IPCC	Intergovernmental Panel on Climate Change
KIIs	Key Informant Interviews
KNBS	Kenya National Bureau of Statistics
KPHC	Kenya Population and Housing Census
KTDA	Kenya Tea Development Authority
LH	Lower Highlands
MCDP	Murang'a County Development Profile
MCIDP	Murang'a County Integrated Development Profile
MS EXCEL	Microsoft Excel
PELIS	Plantation Establishment and Livelihood Improvement Scheme
PRA	Participatory Rural Appraisal
SPSS	Statistical Package for Social Sciences
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WRMA	Water Resources Management Association
WRUA	Water Resource Users Association

CHAPTER ONE: INTRODUCTION

1.1 Background

According to the United Nations Framework Convention on Climate Change (UNFCCC, 2007) climate change is "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes". The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report asserts that climate change has harmful environmental and socio-economic repercussions. Altered weather conditions and eventual biophysical impacts directly affect agricultural production (Challinor *et al.,* 2014, Rosensweig *et al.,* 2014). Climate change exacerbates food security risks and erodes the efforts against hunger and malnutrition among the most vulnerable communities (IPCC, 2014). Global rise in temperature will reduce yields productivity of important crops by 3-13 % not considering CO2 fertilization and adaptations (Wang *et al.,* 2020). About 80% of Africa's agriculture is small-scale and rain-fed (Wiggins, 2009). High dependence of Africa on rural livelihoods, natural resources (Joos-Vandewalle *et al.,* 2018; Paumgarten *et al.,* 2020; Kangalawe *et al.,* 2017) and limited economic and institutional adaptive capacity (Chepkoech *et al.,* 2020) and inadequate safety nets, and low GDP (Mbiba *et al.,* 2019; Desanker & Justice 2001) raises the continent's susceptibility to the widespread disturbances and extreme climate occurrence. The rise in Africa's temperatures could exceed the global mean by about one and a half times at a range of 3°C - 4°C by end of the 21st Century (Collier *et al.,* 2008). In Sub-Saharan Africa (SSA) more than 95% of total cropland relies on rainfall (Calzadilla *et al.,* 2013; Usman & Reason, 2004). Approximately 23% of GDP in SSA is from Agriculture (Goedde *et al.,* 2019) and employs over 60% of the population (Schleussner *et al.,* 2016). Smallholder farmers contribute approximately 80% of the food produced in SSA (Lowder *et al.,* 2014). However, climate change significantly endangers their livelihoods and undermines the gains towards food security, poverty alleviation, and sustainable development (Vermulean *et al.,* 2012; Lipper *et al.,* 2014).

Food security is sensitive to climate since crop production is dependent on moderately foreseen temperatures, rainfall amount and timing during critical crop development. (Walthall *et al.,* 2013). For example, climate variability accounts for approximately 60% of crop yield variability impacting crop production farm income (Osborne & Wheeler 2013; Ray *et* *al.,* 2015; Matiu *et al.,* 2017). An approximated agricultural loss of 2-7% GDP is predicted in SSA by 2100 (Mendelsohn *et al.,* 2000b). The expected extensive rainfall rise in East Africa may not promote farming productivity due to its spatial-temporal fluctuations (Kurukulasuriya *et al.,* 2006). Climate change impacts on agriculture constrain food security of the poor in SSA because of the populations' low adaptive capacity (Kurukulasuriya *et al.,* 2006). The Food and Agriculture Organization (FAO) also notes that almost one in every three people in Africa is chronically starved, adding that many of the food insecure smallholder farmers consume own-produced foods or sell them locally. This exposes them to climate change impacts since low yields fetch low incomes and increase purchases. The majority of the smallholder farmers become net food buyers highly exposed to rising food prices hence low purchasing power which constrains their incomes, food accessibility, and calorie consumption (Ritzema *et al.,* 2017; FAO, 2008). Many studies show that climate change affects smallholder farmers and poses threats from anticipated future climate change (Conway and Schipper, 2011; Muller *et al.,* 2011). Crop yields under rainfed farming are likely to reduce by 10-20% by 2050, and income from crops could decline by 90% by 2100 (Thornton *et al.,* 2011). As the global population rises, there is a significant need to increase the food supply (Thornton *et al.,* 2011).

Kenya's economy is heavily reliant on rain-fed farming (Ogallo, 2010). Kenya's drought cycles have shortened (Maitima *et al.,* 2009). According to the Kenya Food Security Steering Group (KFSSG, 2017), Kenya has been experiencing food security hurdles that make most Kenyans unable to access the proper food variety and amount. Murang'a County in Kenya also heavily depends on smallholder rain-fed farming and is facing climate change repercussions exhibited in recurrent floods, droughts, and drying waterways that worsen agricultural production and weaken communities' food security as reported by the Murang'a County Integrated Development Plan (MCIDP, 2018) and Ovuka and Lindqvist (2000). Climate hazards derail the County's economic growth as scarce resources are used for emergency response and rehabilitation programs (MCIDP, 2018). Failure to adapt could worsen the situation in the face of climate change. Historically, humans have coped and adjusted to climate change and variability at varying spatial and temporal scales. However, climate change threatens their food security and incomes, challenging their adaptive capacity and necessitating them to be innovative and acquire other necessary adaptive resources (Marschke & Berks, 2006).This necessitates an understanding of the adaptation processes to achieve well-focused policies (Beilin*et al.,* 2012; Jha & Gupta, 2021; Nicholas & Durham, 2012). Smit *et al*. (2000) define adaptation as an "adjustment in natural or human systems in response to actual or expected climatic stimuli or other effects, which moderates harm or exploit beneficial opportunities". Studies link climate adaptive capacity, notably power to withstand livelihood shocks and stresses with vulnerability (Moser, 1998; Adger, 2000; Sokona & Denton, 2001; Beg *et al.,* 2002; Metz *et al.,* 2002; Few, 2003). Adaptation is necessary to reduce vulnerability (IPCC, 2014) and vulnerability absence is resilience (Klein *et al.,* 2003). Peoples' ability to control vulnerability drivers strengthens their adaptive capacity. Households with a secure income and diversified food supply are therefore unlikely to be poor or hungry (Kelly & Adgar, 2000; Luers, 2005; Smit & Wandel, 2006). According to Thornton *et al*. (2011) future climate interventions should be guided by farmers' adaptive resources and the integration of local strategies with scientific innovations. Hence the need to understand smallholder farmers' current climate coping strategies and the constraints faced while addressing the climate-related risks.

Climate change adaptation demands that farmers first perceive changes in the climate, identify useful adaptation measures and implement them (Maddison, 2006). The "Local perceptions" are, "the way people identify and interpret observations and concepts" (Byg & Salick 2009; Vignola *et al.,* 2010). They reflect a local concern on the actual climate change impacts on people's lives and are embedded in the local socio-cultural context that shapes the outcome of environmental changes (Bhatta *et al.,* 2019). Farmers' climate change risk perceptions directly inform climate policy responses (Niles *et al.,* 2013). They are shaped by experiential knowledge, use of statistical information and depend on their social amplifiers, the trust attributed to climate scientists, and are only useful when linked to actual adaptation strategies (Weber, 2010; Reilly & Schimmelpfennig 1999). An understanding of how farmers perceive, react, and adapt to climate changes and events at the micro-level is therefore necessary for sound policy and program options (Leagans, 1979; Edwards-Jones & McGregor, 1994; Wheeler *et al.,* 2013; Castellanos *et al.,* 2013). However, many development policies neglect smallholders' perceptions making them among the poorest and hungry globally (Dercon, 2009) calling for enhanced communication of the perceptions of local communities' undertaking autonomous adaptation to policymakers (IPCC, 2014). These necessitate improved knowledge of how smallholder farmers interpret current and anticipated climate change and its implications on their food security (Nhemachena & Hassan, 2007).

Many rural households in poor countries are net food consumers. They spend their non-farm income to buy what they cannot produce (Ritzema *et al.*, 2017). Therefore, they benefit when prices fall and suffer if climate change raises food prices. To respond to higher food prices, they can expand their production to other farms, therefore, becoming net food sellers and raising agricultural wage labour demand (Taylor and Adelman, 2003). Many rural households in poor countries are net food consumers. They spend their non-farm income to buy what they cannot produce (Ritzema *et al.,* 2017). Therefore, they benefit when prices fall and suffer if climate change raises food prices. To respond to higher food prices, they can expand their production to other farms, therefore, becoming net food sellers and raising agricultural wage labour demand (Taylor and Adelman, 2003). Given that farmers' entitlements are the available capital, land, and labor their food accessibility is assured if they can manage these resources for adequate food production (Eakin *et al.,* 2014). Forests form a key natural resource in Kenya that offers many opportunities and benefits both locally and nationally such as livelihood improvement among forest adjacent communities (GOK, 2007). To increase forest cover in Kenya, the Forests Act (2205) initiated the Participatory Forest Management (PFM) a popular forest management concept used in developing countries that involves forest adjacent communities in forest management (Agevi *et al.,* 2014). Under PELIS, the Kenya Forest Service (KFS) through Community Forest Associations (CFAs) allow forest adjacent communities (10km radius from the forest) to cultivate crops in the forests alongside tree seedlings for improved food security and livelihoods (Agevi, 2012). The strategy has proved successful for crops and livelihoods diversification among Kakamega forest adjacent communities (Agevi *et al.,* 2016). Given that the study community is adjacent to Kimakia forest, the study identified the existing but underutilized pilot PELIS program as a viable climate adaptation opportunity to diversify crops and livelihoods.

1.2 Problem Statement

Kenya's economy heavily depends on rain-fed agriculture (Ogallo, 2010). Overdependence on rain-fed farming exposes the country to climate-related food insecurity (WFP, FAO; IFAD, 2012). For example, there have been major decadal drought occurrences in Kenya and minor droughts every 3 to 4 years. The recent critical drought years include: 1984; 1995; 2000; 2005/2006 and; 2009 (UNEP/GOK, 2000; UNEP, 2006; Huho & Kosonei, 2014). The recent 2016/2017 drought was declared a national disaster. The droughts often precede torrential rainfall resulting in seasonal floods and river overflows (Otieno & Anyah, 2013). The shortening drought cycles (Maitima *et al.,* 2009) have resulted in food insecurity and denied many Kenyans the right food amounts and variety (KFSSG, 2017). Most Kenyan households are food consumers and others spend most of their earnings buying food (KFFSG, 2017).

Murang'a County in Kenya is heavily dependent on rain-fed farming (MCIDP, 2018). A household survey conducted in the county in 2004 indicated an increase in rainfall and longer rainfall seasons with the maximum mean annual rainfall reaching 2700mm at 2500m height above sea level (Jaetzold *et al.,* 2006). Recently, the County is experiencing climate change repercussions that decline their farming and worsen their' food security status. These undermine the County's economic growth as restricted resources go to crisis response and restoration programs. If the communities don't adapt, their food security situation could worsen in the changing climate. (MCIDP, 2018, Ovuka and Lindqvist, 2000).

Kimandi-Wanyaga community is in Ndakaini Location, Gatanga Sub-County in Murang'a County. It borders Kimakia forest and comprises predominantly small-scale subsistence rain-fed farmers who are mainly tea farmers. The farmers operate under the socio-economic difficulties of increasing population, reducing land resources, inadequate livelihood possibilities, and growing food insecurity. Local weather is increasingly becoming unpredictable, causing persistently reducing crop yields, sometimes entire seasonal crop loss, and food shortages. Despite the farmer's historical coping efforts, the adverse climate impacts continue to threaten their food security (MCIDP, 2018). This indicates an adaptation gap.

Smallholder farmers' high vulnerability to climate change has been established (Holland *et al.,* 2017; Donatti *et al.,* 2018; Cohn *et al.,* 2017). Although humans have historically coped and adjusted to climate change and variability at varying spatial-temporal scales, climate change threatens communities' incomes and food security, thus challenging their adaptive capacity (Marschke & Berks, 2006). Inadequate knowledge on smallholder farmers' climate change experiences and responses continue to hinder adaptation efforts. This requires communication to policy-makers on the context-specific climate change impacts on smallholder agriculture and the strategies employed to deal with the impacts (Castellanos *et al.,* 2013; Donatti *et al.,* 2017). It is also necessary to enhance communication of the perceptions of local communities' undertaking autonomous adaptation to policymakers. Furthermore, understanding how farmers comprehend, respond, and adjust to climate changes and shifts at the micro-level can achieve sound policy and programming (Castellanos *et al.,* 2013; Wheeler *et al.,* 2013).

This study analysed climate data for trends and compared them with the climate change perceptions of the Kimandi-Wanyaga community in Murang'a County. The study also analyzed the association between the perceived temperature and rainfall changes and the factors underlying the local farmers' food insecurity for the duration 1984 to 2014. The association between the community's socio-economic characteristics and the perceived food insecurity was also examined. The community's current and anticipated future (2014-2045) climate change risks on food crop production were also explored. The community's current coping strategies and the challenges the farmers faced while addressing rainfall and temperature impacts on food crop production were also analysed. The PELIS is a pilot Kenyan farming system model started by the ministries of Forestry, Agriculture, Water, and Irrigation under Participatory Forest Management (PFM) guidelines of the Forest Act (2005) to increase food production among communities living adjacent to forests. According to the Kenya Forest Research Institute (KEFRI, 2014) the PELIS pilot project in Kiambu County achieved over 75% tree seedling survival while the profitability of potato farming rose four times higher than beans and maize. Hence, the PELIS is a cost-effective strategy for forest conservation and improved food security.

The study established that the PELIS program is also being piloted among the Kimandi-Wanyaga community which is adjacent to Kimakia forest. Despite the PELIS model's proven success in enhancing food security among communities living near forests, most of the study respondents (89.0 %) were not involved in the program. Based on reported PELIS success in other Counties such as Kiambu (KEFRI, 2014) the study found PELIS a promising opportunity to diversify crops and livelihoods through the cultivation of selected traditional vegetables to enhance the community's food security. The study conducted on-farm demonstrations to promote cultivation of selected traditional vegetables. A comparison was done on the performance of the traditional vegetables cultivated under the PELIS program and those cultivated on farmers' farms.

1.3 Justification and Significance

1.3.1 Justification

A study by Kogo *et al*. (2020) shows that climate change impacts rainfall and temperature which are the main crop production inputs. This makes food security is particularly vulnerable to climate change (Walthall *et al.*, 2013). Murang'a County's purposeful selection was because the County is among the Kenyan regions highly prone to climate change exhibited in prolonged droughts and floods. The resultant impacts threaten the livelihoods and food security of smallholder farmers in the County who heavily depend on rain-fed farming (MCIDP, 2018).

Many studies conducted in the County have mainly focused on the County-level rainfall variability determination (Ovuka and Lindqvist 2016) climate and landslide events (Kamau, 1981) and potential evaporation estimation (Shilenje, 2015). Climate change risks in developing countries are local and very uncertain (Morton, 2007). Hence there exists knowledge paucity on the micro-level rainfall and temperature change impacts on household-level food security in the County. A gap in knowledge also exists on the nexus between smallholder farmers' perceptions of rainfall and temperature changes and household-level food security. It was also necessary to determine the association between the community's socio-economic characteristics and their food insecurity perceptions. This study addressed the knowledge gaps by eliciting an in-depth micro-level understanding of the scientific and community perspectives of rainfall and temperature variations and their perceived implications on food crop production and food security among the Kimandi-Wanyaga smallholder farming community in the County. The anticipated future rainfall and temperature change scenarios were also determined by the community's climate coping mechanisms and the challenges encountered while responding to climate change were also examined. The study promoted the cultivation of traditional vegetables under the pilot PELIS Program as an adaptation strategy to diversify crops and livelihoods for food security vis-à-vis climate change. The transdisciplinary approach was employed to enhance knowledge integration from different unrelated scientific disciplines, practice partners, and the local community (Spangenberg, 2011).

1.3.2 Significance

Climate change is certainly impacting Kimandi-Wanyaga community's food security given the rising temperature trends. This study worked with the community to enhance climate change awareness and identify how temperature and rainfall changes impact their food security. Given that the study community is adjacent to Kimakia forest, the study identified the pilot PELIS as a promising avenue for crop and livelihood diversification, also establishing that the residents were knowledgeable about the value of the traditional vegetables. The study findings benefitted the study area smallholder farmers through enhanced climate change awareness and knowledge transfer on the cultivation of the traditional vegetables under the PELIS program. The study findings also formed a basis for recommendations to the Murang'a County government for viable climate interventions. The study was also a significant contribution to the application of the transdisciplinary approach in the search for viable climate adaptation strategies for improved food security among the study community. The published work from this study contributed to the body of scientific knowledge. The adaptation barriers identified in the study set a basis for further research.

1.4 Research Objectives

1.4.1 Main objective

The main objective of the study was to enhance food security through crop and livelihood diversification among the Kimandi-Wanyaga community in Murang'a County.

1.4.2 Specific Objectives

1. To determine whether there are rainfall and temperature changes in Kimandi-Wanyaga sub-Location in Murang'a County, Kenya.
2. To determine whether the perceived rainfall and temperature changes have affected food security in Kimandi-Wanyaga sub-Location in Murang'a County, Kenya.
3. To examine the challenges that Kimandi-Wanyaga community in Murang'a County faces while responding to rainfall and temperature changes.
4. To explore the potential of the cultivation of traditional vegetables under the PELIS Program in enhancing crop and livelihood diversification among the Kimandi-Wanyaga community in Murang'a County.

1.5 Research Questions

The following research questions guided the study:

1. Has rainfall and temperature changed in Kimandi-Wanyaga sub-Location in Murang'a County, Kenya?
2. Are there existing and potential future rainfall and temperature change impacts on food security among the Kimandi-Wanyaga community in Murang'a County?
3. Does the Kimandi-Wanyaga community in Murang'a County face any challenges while responding to rainfall and temperature change climate stressors on food security?
4. Does the cultivation of traditional vegetables under the PELIS Programme enhance crop and livelihood diversification among the Kimandi-Wanyaga community in Murang'a County?

1.6 Scope and Limitations of the Study

This study analysed rainfall and temperature data for trends and compared it with the community perceptions. The study also examined the perceived current and long-term (2014-2045) impacts on food crop production and food security. Also explored were the community's coping mechanisms, the opportunities, and the challenges faced while coping with rainfall and temperature changes on their food crop production. The study examined the factors underlying the community's food shortage and the potential of the pilot PELIS program as a climate adaptation strategy for food security among the forest adjacent community. The study, therefore, aimed to promote the cultivation of selected traditional vegetables under the PELIS as a strategy for crop and livelihood diversification for food security under the changing climate. The vegetables were Cowpeas *(Vigna ungucuilata) Managu (Black nightshade) Terere (Amaranth spp.) Saget (Cleome gynandra)* and *Murenda (Corchorus olitorius).*

The study had several limitations which were navigated around as follows: 1) The first was lack of up-to-date rainfall and temperature data for local volunteer weather stations. More up-to-date daily data was obtained from Thika Meteorological Station. 2) Secondly, cultural orientations on food acceptability challenged the acceptance of traditional vegetables which were historically regarded as "wild vegetables only eaten during famine". The attitude slowly changed through intensive community involvement during field trials and FGDs. 3) Other challenges included the reluctance of some community members to participate in the study seeking assurance for tangible benefits. The inclusion of trusted area administrators helped in convincing respondents to participate. The interviewers probed further through the use of more familiar events. 4) Unavailability of some sampled household heads within the survey period and some respondents' inability to recall the chronology of climate events also posed a challenge. Unavailable households were recalled until a response was obtained. In case of refusal to participate, the next household was interviewed. 5) Farmers' preoccupation with tea picking also limited farmers' participation in demonstrations. Hence demonstrations were planned to fall on days free of tea picking. 6) Another challenge was inadequate baseline data on household income and consumption patterns. Expenditure data and income sources were used as a proxy to income data.

1.7 Layout of the Thesis

The thesis is divided into eight chapters. Chapter one gives a detailed background of the work addressed in the study including the study problem statement, research objectives, questions, significance, justification, and the study scope. Chapter two presents a detailed and systematic review of current literature on climate change and variability and how other researchers are addressing the phenomena. Also addressed are climate change and variability implications on food security at global, Africa, Kenya, and Murang'a County levels. It highlights the adaptation mechanisms adopted in Africa and Kenya and summarizes the key research gaps identified. Chapter three describes the location of the study area including the biophysical and socio-economic settings and their vulnerabilities. The study research methods are also presented describing the process of data collection, processing, and analysis. A graphical and narrative conceptual framework is presented detailing presumed relationships between key concepts, factors, and variables in the study. Chapter four analyses the temperature and rainfall changes in Kimandi-Wanyaga sub-Location in Murang'a County. It presents the MAKESENS results for the observed community perceptions of the rainfall and temperature changes.

Chapter five presents and discusses data on the second objective which examines prevailing and potential future climate change impacts on food security among the study community. It addresses both scientific and the community indigenous perspectives. Chapter six addresses the study's third objective which analyses challenges facing climate change coping and adaptation mechanisms among the smallholder farmers. Chapter seven focuses on the last objective of the study which analyses the potential of expanding diet and income sources diversity by incorporating traditional vegetable farming under the pilot PELIS program to enhance food security under climate change among Kimandi-Wanyaga community in Murang'a County. It examines the level of the PELIS program uptake and the prevailing knowledge on the value of traditional vegetables among the community. It also presents results of on-farm demonstrations conducted to promote uptake of improved traditional vegetables for crops and livelihoods diversification for food security. Chapter nine summarizes the study findings by giving general conclusions and recommendations for solutions to problems identified in the study. Also presented are recommendations for further research.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

According to the article 1 of the United Nations Framework Convention on Climate Change (UNFCCC) climate change is "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes" (Kabir & Serrao-Neumann, 2020). The Intergovernmental Panel on Climate Change (IPCC) a growing body of extensive studies on climate change, asserts that climate change is unequivocal by pointing out the rising global temperatures and sea levels (IPCC, 2014). The IPCC (2019) notes that global average surface temperatures will degrade land, leading to soil erosion and loss of vegetation, and food insecurity due to decreased crop yields and unstable food supply systems. This process will lead to unfavorable changes to food systems and livelihoods, land value, and the health of humans and the ecosystem in general. The IPCC confidently emphasizes the risks of climate change on food security. They note that the effects on crop yields will surpass the benefits as indicated by declining global total wheat and maize production (Choo, 2021). Fan *et al.* (2021) predict increased frequencies and severity of climate shocks adversely affecting agricultural systems hence increased challenges to resilience. More studies indicate evidence of climate change impacts aggravating current livelihood and socio-economic vulnerabilities. They pinpoint food insecurity as a complex and persistent threat to the survival of many global poor communities adding that soon rural impacts will significantly worsen availability and supply of water, food security, agricultural incomes, and alter food and non-food crop production ecosystems (Davenport *et al.*, 2017). Additionally, tropical production of major cereals like wheat, rice, and maize will reduce if the temperature rises at 2 ^{o}C or above pre-industrial levels, raising food prices and vulnerability of net food buyers (Davenport *et al.*, 2017). Other studies have established that resource-poor farmers with low adaptive capacity to climate shifts, natural calamities, and socioeconomic risks are most vulnerable (Pereira, 2017; Makuvaro *et al.*, 2018; Barbier & Hochard, 2018; Mulungu & Ng'ombe, 2019). Sub-Saharan Africa has experienced a significant drop in agricultural production due to frequent droughts and floods (Njoka, 2019; Nikoloski *et al.*, 2018).

2.2 Climate Change in Africa

Climate variations across Africa range from hyper-arid Sahara to humid tropics due to complex interaction between land and surrounding water masses (Cuthbert *et al.*, 2019). Three main macro factors drive Africa's climate including Inter-Tropical Convergence Zone (ITCZ) the West African Monsoon, and the El Niño-Southern Oscillation (ENSO) though clarity on their interactions and how they relate with climate change is not absolute (Sylla *et al.,* 2019). Africa's landmass diversity results in highly diverse warming trends with some areas getting wetter as other areas get drier (Haile *et al.,* 2020).

2.2.1 Africa Temperature Variations

Africa's temperatures have risen more than one decade ago. The trend is likely to accelerate in most parts (Hulme *et al.,* 2001; IPCC, 2007) at a minimum of 4°C temperature rise in North and Southern Africa. Figure 2.1 indicates that despite variations, Africa's temperature rise has accelerated since the 1960s (Hulme *et al.,* 2001). Some examples include tropical forests decadal warming rates of 0.29°C (Malhi & Wright, 2004) South Africa's above maximum average temperature rise of 0.1-0.3ºC, and rise in the rate of Ethiopia's minimum temperature (Kruger & Shongwe, 2004; Conway *et al.,* 2011). From 1960 to 2000, West and Southern Africa drought frequencies rose while extremely cold spells reduced (New *et al.,* 2006). Temperatures have also been dropping along Eastern African coastlines and areas near extensive water masses (King'uyu *et al.,* 2000).

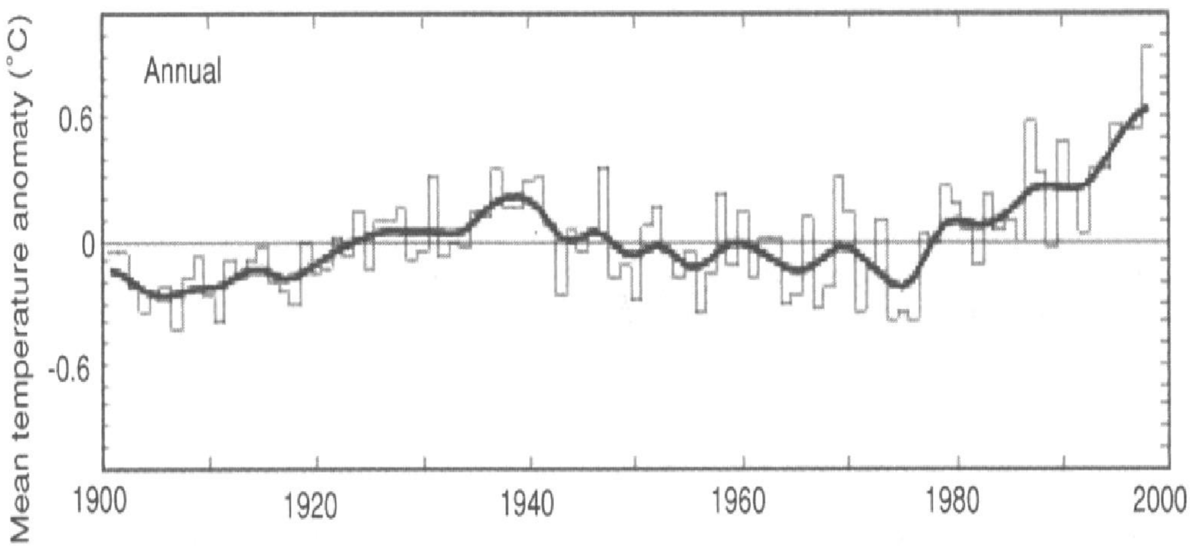


Figure 2.1: African Annual Mean Temperature Anomalies (°C) for the past 100 Years (1900-2000). Source: Hulme *et al.* (2001).

2.2.2 Africa Rainfall Variations

Rainfall being an important natural asset for the majority of the rain-fed farmers is key to the continent's economic development (Glantz, 2019). Figure 2.2 shows IPCC projected precipitation changes for Africa from 1980-99 to 2080-99. African rainfall generally exhibits inter-annual or multi-decadal spatial-temporal variations (Muthoni, 2019). For example, between 1931 to 1960 and 1968 to 1990, West African rainfall decreased by 20 - 40% (Buba *et al.*, 2018; Amadou & Diakarya, 2021; Lèye *et al.*, 2021) and mean annual rainfall in the tropical rain-forests decreased by 4% in W. Africa, 2% in S. Congo and 3% in N. Congo (Ahmed *et al.*, 2017). Also witnessed from 1960 to 1998 was a 10% annual rainfall rise in Guinean coast (Buba *et al.*, 2018), increased inter-annual rainfall variability, widespread droughts, and heightened heavy precipitation frequency in Southern Africa (Mbiriri *et al.*, 2018; Nicholson *et al.*, 2018; Nhamo *et al.*, 2019; Malherbe *et al.*, 2020). A minimum 10-20 % rainfall decrease is likely in North and Southern Africa. Eastern Africa experiences a dipole decadal-scale rainfall pattern where northern parts receive more rainfall than lower parts (Nicholson, 2017).

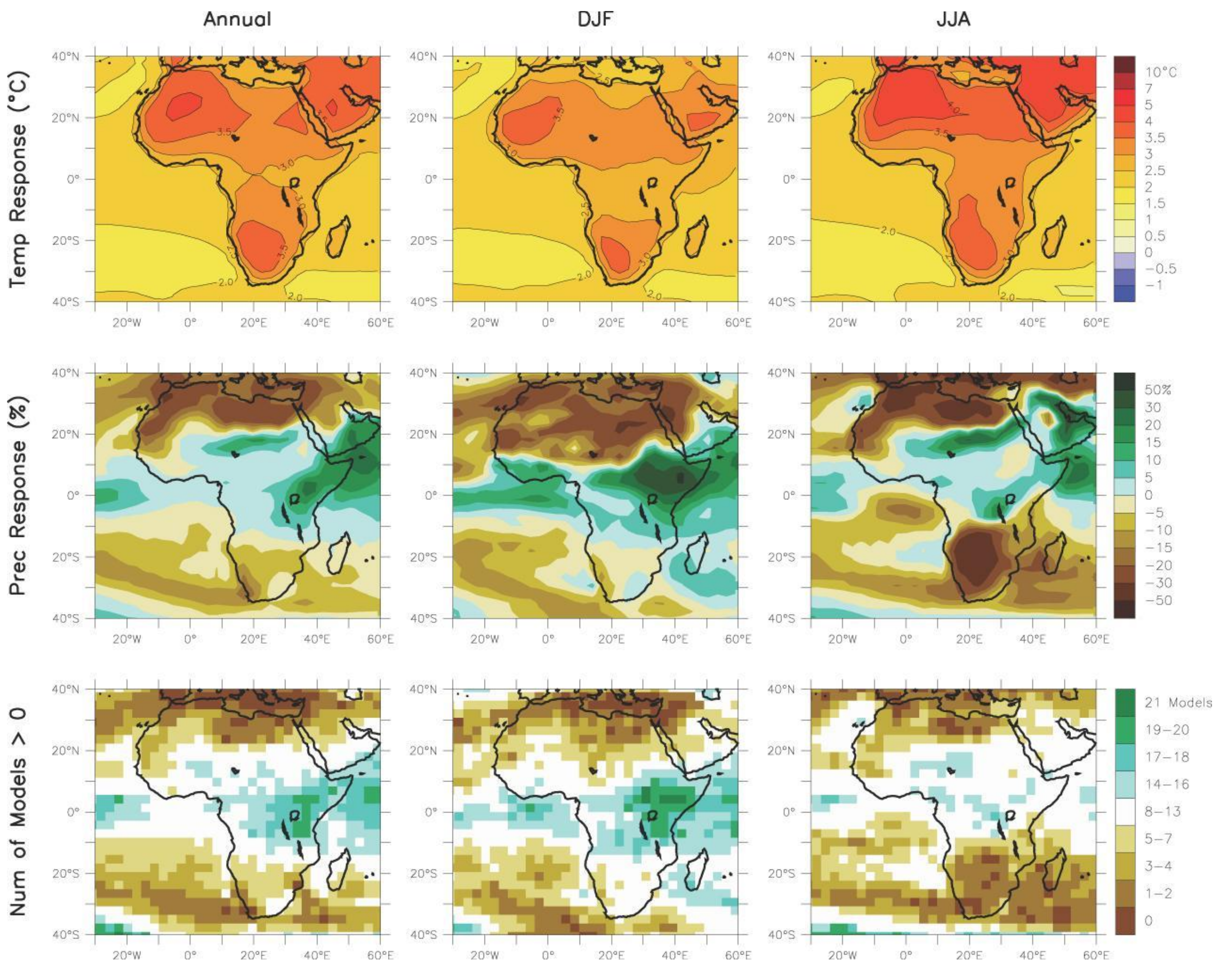


Figure 2.2: Temperature (top row) and rainfall (middle row) projections for Africa: change from 1980-99 to 2080-99 for IPCC Scenario A1B with number out of 21 Atmosphere-Ocean General Circulation Models (bottom row); (annual average (left) December-February (centre) June-August (right). Source: IPCC (2007).

Rainfall variability in East Africa (EA) is becoming more intense, affecting smallholder farmers (Bryan *et al.,* 2013; Bekele *et al.,* 2019; Gebrechorkos *et al.,* 2019). Rainfall variability is high in EA because of the El Niño Southern Oscillation (ENSO), although there has been a recent increase in more extreme rainfall and temperature trends (Gebrechorkos *et al.,* 2019; Saalu Faith *et al.,* 2020)

2.3 Africa's Agriculture Vulnerability to Climate Change and Variability

Africa's farming and livelihoods are highly climate-based. Above 95% of SSAs total crop land being rain-fed (Abou Zaki *et al.,* 2018) and above 60% of population employed in the farming sector (Pais *et al.,* 2020). Agriculture contributes an average of 32% of national GDP (Abou Zaki *et al.,* 2018) with 90% being small-scale. Temperate agriculture is mainly temperature and rainfall dependent. Tropical agriculture relies on rainfall which varies in quantity and reliability resulting in prolonged floods preceding prolonged droughts (Lehmann, 2018; Mujumdar *et al.,* 2020; Onyutha, 2021). The vulnerability of the Sahel results from exposure to recurrent droughts and floods, reliance on climate sensitive natural resources, limited economic opportunities, low adaptive capacity, inequitable markets, inaccessible services and poor governance (Abberton *et al.,* 2021). Expected widespread rainfall increase in East Africa is unlikely to translate into improved agricultural productivity due to its variation in space and distribution. Agriculture over-dependence, high temperatures, insufficient and highly variable rainfall and minimal modern technology adoption exacerbate developing countries' vulnerability and weaken their adaptive capacity (Singh & Nayak, 2018; Awazi *et al.,* 2020). Therefore, climate induced crop yield variations can highly impact most of Africa's population (Hummel, 2018).

Africa livelihoods heavily dependent on climate-sensitive natural resources risk the threats of extreme climate events because of their over-reliance on natural resources and rural livelihoods, low GDP insufficient, economic and institutional adaptive capability, and inadequacy of safety nets (Nyiwul, 2021; Mafongoya *et al.,* 2017; Nyiwul, 2021; Issar, 2020; Maja & Ayano, 2021; Ringler & Rosegrant, 2020). Various assessments predict that SSA will be the most climate-vulnerable by 2100, with an estimated agricultural loss of 2- 7% GDP, followed by Western and Central Africa at 2 - 4%, and Northern and Southern Africa at 0.4 - 1.3% (Adjei, 2021). The projected 5-8% enlargement of Arid and Semi-Arid Lands (ASALs) and water resource depletion will worsen chronic hunger and directly lower ASAL frontiers' crop yields due to a decrease in farming land, yield potential and length of growing season.

Individual crops have a specific temperature range for optimum production but climate change is already pushing them beyond their tolerance limits. At risk are the majority of African crops whose survival is near their heat tolerance limit. For example, a few days of warming just before flowering causes significant drop in crop yields of groundnuts, fruit trees, soybean and wheat (Cohen *et al.,* 2021).

Despite growing consensus on Africa's historical coping with climate variability and uncertainty impacts such as drought (Tiana, 2020; Bahta, 2020; Nembilwi *et al.*, 2021) vulnerability to natural resource change raises susceptibility to climate change (Nyiwul, 2021). Low soil fertility, crop and animal pests and diseases and inaccessible improved farm inputs continue to afflict majority of African farmers a situation being worsened by climate impacts like recurrent droughts, floods and El Nino occurrences (Nakawuka *et al.*, 2018; Muchuru & Nhamo 2019; Abate *et al.,* 2020; Kusangaya *et al.,* 2021). Vulnerability reduction requires positive actions that enhance livelihood resilience against shocks and stresses (Bryan *et al.,* 2017; Opiyo *et al.,* 2018; Saito *et al.,* 2018; Oriangi, 2019; Ulrichs *et al.,* 2019; Barret *et al.,* 2020; Gebremichael *et al.,* 2020; Gwiriri *et al.*, 2021; Leal Filho *et al.*, 2021).

Owen (2020) reports with high confidence that communities are embracing adaptation mechanisms such as livelihood diversification, infrastructure and technology adjustment and ecosystem-based approaches (EbA). However, the vulnerability of the African farmers to climate change and natural hazards is by poverty, inaccessibility to information, technologies, and social services that make their climate change adaptation challenging (Chirambo, 2016). These indicate an adaptation gap and call for enhanced adaptive capacity to impacts of climate change and other extreme events that undermine Africa's poverty eradication efforts.

2.4 Kenya Climate Change and Variability.

2.4.1 Rainfall

Constant droughts and floods in Kenya disrupt agricultural production causing massive food imports (Mathenge, 2020). The main determinant of Kenya's climate is the Inter-Tropical Convergence Zone (ITCZ). The ITCZ is a broad low-pressure area caused by an intersection of northeast and southeast trade winds. Three air masses influence Kenya's climate including, the Western region November-March Sudan dry winds, Eastern region dry northeast trade winds from Arabian Peninsula, and coastal ocean winds. A shift in the April – August wind system makes the southeast monsoon winds from the Indian Ocean cause rainfall in the eastern, southern, and central of Kenya (Camberlin, 2018; Cook & Vizy, 2019). In July, a stream of strong, high and extremely unstable southwest trade winds (Congo air stream) cut across equatorial Africa causing convectional storms mainly in Western Kenya. This disaggregates Kenya's rainfall regime into four distinguishable patterns: the coastal belt (April to June maximum rainfall) the central Kenya (bimodal rainfall of March-May and October-December) the southwestern Kenya (without a definite dry month) and the northwestern Kenya (March and May maximum rainfall). The significant temporal and spatial variations result from topography complexity, the presence of many lakes, and other regional factors (Camberlin, 2018; Mumo & Yu, 2020).

2.4.2 Temperature

Kenya's temperature is equatorial, manifested in minimal mean monthly temperatures. The approximate diurnal average temperature in central and Nairobi areas is 15°C, Rift Valley and the coast is 25°C. Northern Kenya experiences the highest temperature where the maximum commonly surpasses 35°C (Muhati *et al*., 2018). The mean annual average temperature very closely corresponds with height above sea level. Most areas experience above 0°C. Ground frost hardly occurs below 2500m. The daily temperature variations range between 9°C and 13°C. The temperature range in the highlands above 2200 m is 14 to 17°C. Those in the coast and island areas lie between 5°C and 9°C (Camberlin, 2018).

2.4.3 Evaporation

Evaporation rates are mainly a function of solar radiation rather than temperature (Tao *et al.*, 2018). They mainly indicate cloud cover frequencies rather than temperature reduction with altitude. Drier northern and eastern Kenya evaporation rates rise above 2500 mm per year while cloudy parts at 3000 m also experience 1100 mm and below (Camberlin, 2018).

2.4.4 Vulnerability of Kenya's Agriculture to Climate Change and Variability

Kenya's food production will need to rise by 75% from 2015 levels to match consumption by 2030 (Cilliers *et al.,* 2018). However, Kenya's agricultural production is highly susceptible to the climate change risk. For instance, there have been major decadal drought occurrences in Kenya with minor droughts every 3 to 4 years. Kenya's recent critical drought years include 1984; 1995; 2000; 2005/2006 and; 2009 (Okal *et al.,* 2019). Mohtasin (2021) has also observed a shortening of drought cycles in Kenya. A record 28 drought periods have happened in the last 10 decades with three happening within the last ten years causing massive economic losses, energy and water supply disruptions, and serious food insecurity in the arid and semi-arid lands (ASALs). The recent 2016/2017 drought was declared a national disaster. Such droughts often precede torrential rainfall causing seasonal floods and river overflows (Rateb & Hermas, 2020). Gewa *et al.* (2021) also indicate severe challenges to food security among most Kenyans.

Radeny *et al.* (2020) note that the changing climatic conditions pose great threats to the agricultural based livelihoods in Kenya. Rainfall and temperature variations will affect both crops and livestock activities negatively due to emergent diseases, pests, and weeds leading to significant yield losses. Kalele *et al.* (2021) also identified the ASALs as vulnerable to climate change with drought and crop pests as the most common adverse effects and risking household food security. Amwata (2020) concurs that during the past three decades, droughts and floods frequency have increased, leading to crop failures, emerging livestock diseases, and loss of livestock and fisheries.

2.5 Climate Change Adaptation in Muranga County

Dry periods and low moisture levels characterize Muranga's lower-middle areas than the upper areas of the county where more flooding and soil erosion has higher occurrence (MoALFC, 2021). Various adaptation measures have been attempted in the County. Residents engage in harvesting rainwater which is stored for productive activities. Farmers also engage in conservation agriculture and planting crops that can withstand drought stress. Climate Smart farming involving minimal tilling of land, use of cover crops, nitrogen improvement, and crop rotation have also been encouraged (Betemariam *et al.*, 2019). Farmers are also encouraged to adhere to the right time to plant crops and breed livestock to maximize production and decrease pest occurrence. They also engage in fodder conservation and usage of certified farming inputs. The farmers are also starting to engage in value chain promotion of their products to get better returns from crop production (MCIDP, 2018).

Activities that sustain soil and land management also occur in Muranga County. Terracing is a widely practiced measure for conserving soil for crop production across the county (Gachie *et al.*, 2020). Other measures include planting grass strips to manage soil erosion. Trash lines are also practiced which involves placing farm residue in lines to inhibit eroding soil. Napier grass planting on hedges is a popular practice by farmers as it acts in soil retention as well as livestock feeding. Cross-slope barrier soil and water conservation measures are also practiced including *fanya juu* which refers to throwing soil uphill. Retention ditches are also dug to prevent run off. While an advantage may be gained by usage of these measures, Wolka *et al*. (2018) caution that they use considerable portions of the available arable land which necessitates proper design and usage. Irrigation is also practiced particularly in the rivers that occur in the county forming the South West Upper Tana Basin (Mwendwa *et al.,* 2019).

There have been efforts towards agroforestry in the county (Betemariam *et al.,* 2019). Farmers are also encouraged to mix crops and trees for increased resilience. The Kenya Forest Service is also encouraging a participatory forest management approach through the PELIS. Communities neighbouring forest are able to grow crops within the forest reserve while conserving the trees cover (Ayiemba *et al.,* 2014). There have been concerted efforts to encourage planting of trees especially on farms to curb soil erosion. They also act as wind breakers and enhance soil fertility through their foliage which converts to humus (Gachie *et al.,* 2020). Hedgerows are also planted to assist in soil water retention.

Off-farm strategies are also being employed by stakeholders in climate change adaptation in Muranga County. The current climate early warning system is inadequate because its managed by one person. This necessitates a robust monitoring system with proper instruments for detecting ground movements (MoALFC, 2021) to combat landslides which continue to be a problem in the county (Schade, 2017). Periodic weather advisories are given by the Kenya Meteorological Department. Government and NGOs also avail extension services to farmers to help in better crop production. There have also been efforts to extend credit services to Muranga farmers (Kamau *et al.,* 2017). Muranga County Government acknowledges that current adaptation measures practiced are inadequate to deal with the increasing climate impact risks (MCIDP, 2018) suggesting better strategies including more research on climate-resilient crop varieties. Shinbrot *et al*. (2019) state that key decision-makers should adopt a multi-targeted framework to enhance farmers' well-being through specific enabling adaptation measures such as crop and livelihood diversification which this study sought to establish in Kimandi Wanyaga area in Muranga County.

2.6 Climate Change Effects on Food Security

2.6.1 Food Security Concept

Food security definitions are diverse. In this study food security is, "when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (El Bilali *et al.,* 2019). This occurs when everybody has constant physical, social, and financial access to adequate, safe and nutritious food for their own food preferences and dietary needs to actively engage in a healthy life (Sassi *et al.,* 2018). Individual's food needs and wants are therefore met. Three food security key pillars are food availability, food access, and food utilization (Lestari, 2021). Food availability is the physical presence of food. Access is being able to acquire food through production or buying. Utilization is having food with the right nutritional composition and effective body ability to utilize it. Factors such as household income, health, government policy, conflicts, globalization, market deficiencies, and environment determine an individual or household's food security status. Adequate food security determination should be based on the ability of livelihoods to adequately supply food to families and individuals (Babatunde, 2020; Galiè *et al.*, 2019). The consequences of climate change such as extended floods and droughts directly, or indirectly affect the food security pillars (Sweileh, 2020). Potential climate change impacts on key food security pillars are as discussed below.

2.6.2 Food Availability

This refers to the physical presence of food. Rural households often produce and sell surplus to local markets. Floods often damage road infrastructure (Njogu, 2021) hampering farmers' market accessibility. This impedes ability to sell surplus farm produce, acquire necessary foods and farm inputs and restrains livelihood strategies consequently diminishing available food varieties and nutritional intake (Mavhura, 2017). Climate change is undoubtedly modifying pest dynamics (Trebicki, 2020) and increasing yield losses from weeds, pathogens, viruses and animal pests. Studies estimate an annual loss of approximately 30–40% global production of major food crops (Sharma *et al.*, 2017). Examples of direct climate risks affecting agricultural systems include seasonal rainfall and temperature variations, altered evapotranspiration, photosynthesis and biomass production and altered suitability of agricultural land for crop production. These affect agro-climatic conditions and change sowing and harvesting calendars, growing seasons, water availability, weeds, pests, and disease populations (Malhi *et al.*, 2021).

2.6.3 Food Accessibility

This concerns food affordability or the ability to acquire food through production or buying. With an estimated 60% of Africa's livelihoods highly reliant on rain-fed farming and most food being accessed by buying, agriculture remains a significant food security determinant (Ayanlade & Radeny, 2020). However, 'deagrarianisation' is altering this trend in rural sub-Saharan Africa as livelihoods diversify to off-farm options (Bryceson, 2018). To determine the climate change effects on household food access necessitates the determination of the extent of dependence on agriculture for income. Livelihoods based on farming are more highly sensitive to the impacts of climate change on agriculture. The majority of households are net consumers of food and some spend more than half of their non-farm earnings on the food they cannot produce. They benefit when food prices are low and are hurt when climate change makes food more expensive. Hence, changes in food prices seriously affect the sizes and variety of food consumed.

2.6.4 Food Utilization and Nutrient Access

Food utilization concerns an individual's ability to effectively use available nutrients. It closely interlinks overall food safety to an individual's health. Health status's primary role in food security is threatened by most climate change manifestations such as warming, drought, or floods due to their potential negative impact on human health that compromise food utilization (Philipsborn *et al.,* 2021). Undoubtedly, climate change will modify pest dynamics despite uncertainties on the actual changes (Trebicki & Finlay, 2019). Pests and pathogens affect the quality of many food crops leading to health risks. For example, carcinogenic aflatoxins in maize and groundnuts thrive in hot and dry conditions (Rushing & Selim, 2019). By 2100, climate change is predicted to enlarge malaria vectors' ecology to zones traditionally unsuitable for malaria transmission (Semakula *et al.,* 2017).

Combined climate stresses and conflicts disrupt sanitation and drinking water systems, raising human susceptibility to malnutrition and diarrheal diseases like cholera (Fadda, 2020). Diarrheal diseases, a leading cause of child mortality and impaired nutrient absorption are most common during floods, prolonged drought and extreme high temperatures. Rise in droughts increase meningitis outbreak while extreme rainfall events favour cholera outbreaks (Houedegnon *et al.,* 2019). Malnutrition predisposes humans to increased infection, energy loss and dismal productivity. Higher disease burden further worsens food accessibility (Wolfson & Leung, 2020). Other possible direct climate change effects on micronutrient availability include yield variations in key micronutrient crop sources, altered nutritional content of specific crops and influence on crop choices (Soares *et al.,* 2019). Poor countries with inadequate public health infrastructure will be hardest hit. Children will bear the biggest health burden. According to Abegunde *et al.* (2019) failure to adapt will worsen food insecurity, deteriorate ecosystems, raise crop losses, and lower food production.

2.7 Food Security and Climate Adaptation Mechanisms in Africa

2018). It is projected that the recurrence and magnitude of extreme weather occurrences like desiccations and floods which negatively affect farming and food security will increase soon. Population and food demand will also rise and put the poor in less developed countries at risk of severe food shortage as recently witnessed in the Horn of Africa famine (Hussain & Sulaimon, 2018). Durodola (2019) has noted drastic agricultural production reduction in sub-Saharan Africa, from extreme climate change occurrences such as recurrent droughts and floods. Other consequences are human and livestock mortality (Ojija, 2017). According to Chaloner (2021) some of the adverse climate impacts in East Africa include reduced rainfall; alterations in cropping seasons; higher incidences of fungal diseases and pests as humidity and temperatures vary; low crop and biomass production and; food insecurity and hunger. Nkengasong (2019) projects a doubling of Africa's population to 2 billion people by 2050. Sub-Saharan Africa is expected to have the fastest growth rate globally with over 60% of the population depending on farming for livelihoods. However, agriculture in SSA are almost entirely rain-fed rendering them highly vulnerable to climate change and variability. Additionally, a 15-20% reduction of Africa's food production per head is projected by 2050. These predictions therefore necessitate robust agricultural oriented innovations that strengthen climate change resilience while increasing production.

IPCC defines adaptation as an "adjustment in natural or human systems in response to actual or expected climatic stimuli or other effects, which moderates harm or exploits beneficial opportunities" (Taylor, 2019). Historically, humans have coped and adjusted to climate change and variability at varying spatial and temporal scales. Climate change is threatening communities' incomes and food security, thus challenging their adaptive capacity and necessitating them to be innovative and acquire other necessary adaptive resources (Muricho, 2019). Furthermore, local climate variability influences people's decisions and determines their social, political, economic and general livelihoods (Kabir & Serrao-Neumann, 2020). Studies link climate adaptive capacity, notably power to withstand livelihood shocks and stresses with vulnerability (Amuzu *et al.,* 2018; Dendir & Simane, 2019). Adaptation is necessary to reduce vulnerability and vulnerability absence is resilience (Ford *et al.,* 2020). Thus, adaptation reduces vulnerability by enhancing resilience. Under enabling livelihood change conditions, societies' positive actions can enhance resilience (Cinner & Barnes, 2019). Peoples' ability to control vulnerability drivers strengthens their adaptive capacity. Households with a secure income source and a diverse food supply are, therefore, unlikely to be hungry or poor.

Various factors determine people's vulnerability, adaptive capacity and adaptation choices (Ford *et al.,* 2020). Worsening adverse climate change effects on economies, communities, households and natural resources in many regions depict deficiencies and gaps in existing adaptation pathways. Although individuals, communities, states and organizations benefit from adaptation actions, competing demands, poverty, lack of skills, weak institutions, land degradation, poor infrastructure, inadequate finances and poor governance hamper such actions. Adaptation interventions mainly resemble or build on existing ones (Eriksen *et al.,* 2021). Local level adaptation involves: strengthening communities; enhancing existing coping mechanisms and enabling involvement in climate change policy planning and development (Mcleod *et al.,* 2019). Although adaptation is highly contextual, its value is often overlooked in development of many adaptation strategies. Many African national governments have realized that impacts actualization on the ground requires enhanced local actors' participation and are making efforts to incorporate adaptation governance systems in their vulnerability reduction plans with livelihood diversification as a key strategy (EbA).

Concerted efforts are needed to enhance adaptive capacity to climate change impacts and other extreme events. For resilience, systems relationships must persist and absorb shocks without altering their original state. A community's resilience is therefore determined by availability of necessary resources and ability to prepare and respond to changes which necessitates robust mechanisms that enable absorption of climate shocks (Agarwal *et al.,* 2021). Barnes (2020) agrees that livelihood assets largely determine people's climate change response, and, therefore, this could be a major consideration for adaptation interventions. Efforts to lower vulnerability and strengthen livelihood resilience of natural resource dependent communities include livelihood diversification, equal key resource access, innovation and closing of information gaps (Makate, 2019). For direct climate adaptation, food security should be enhanced by improving food production, enhancing market and resource accessibility and reducing disaster risk.

2.8 The Food Security Situation in Kenya and Murang'a County

2.8.1 Food Security in Kenya

The country's economy is heavily dependent on rain-fed agriculture (Muema *et al.,* 2018) making agriculture a key pillar in the country's development (Kogo *et al.,* 2021). Agriculture drives Kenya's economy by directly accounting for 24% GDP and 27% of GDP indirectly through manufacture, distribution and other related services. Specific contributions include about 45% of government income, over 75% of industrial raw materials, over half of the exports, 60 % of total employment, and support to over 80% of livelihoods in rural areas. Recently, beginning in 2008, Kenya has been experiencing food insecurity challenges rendering a high proportion of the population unable to have access to food in the required quality and amounts. Approximately over 10 million people suffer from food insecurity, as most rely on relief food. Rising food prices and a short supply of preferred staples mainly, maize also reduce households buying power and limit foodstuff choices (Njiru & Letema, 2018). The challenges attributed to frequent droughts, high cost of domestic food production due to high input costs, internal conflicts leading to displacement in high agricultural potential areas, and low buying power due to poverty. Kenya reports reduced rainfall, forage shortage, proliferation of waterborne diseases in humid areas and poor nutrition to rank among imminent climate change impacts (Bonzemo, 2018). The country's food security continues to decline gradually as supply of food commodities to markets dwindle and commodity demand rises. This results from below-average 2016 crop production due to poor long and short rains adversely affecting cropping activities and reduced regional imports from neighbouring countries. With an estimated 10 % below five-year average drop in 2016 long rains maize production, the staple food prices, notably maize, increased across most markets by approximately 10-25 % above five-year average (Davenport *et al.,* 2019). Other impacts include: significant drop in on-farm casual labour opportunities and household income and, high demand petty trading, non-farm casual labour and remittances from relatives. A 2017 short rains assessment estimated over 2.5 million people especially in the ASALs to be acutely food insecure as households' stocks deplete and incomes reduce, their food security is bound to deteriorate (Funk *et al.*, 2018).

2.8.2 Food Security in Murang'a County

Murang'a County is among Kenyan regions facing climatic and environmental challenges resulting in food insecurity. Despite agriculture employing 57 % of the County's labour force, the sectors' employment potential is being undermined by pressure from a soaring population sizes resulting in: land subdivision to uneconomical sizes, resource scarcity, forests encroachment, increased bare land highly susceptible to soil erosion, soil nutrient loss, landslides and land degradation. Moreover, climate change impacts such as frequent droughts, floods, and drying waterways have deteriorated farming and worsened food insecurity among communities. Approximately 23% of the county's population is food poor, 19% of the children below 5 years are stunted, and 1% of the county's children below 5 years is wasted (KNBS, 2015).

The county has responded by mainstreaming climate change in the County's Integrated Development Plan (CIDP) and recommended agricultural diversification as a key development strategy (MCIDP, 2018). Specific safety nets by the National and County governments to build local communities' capacity and cushion households hard hit by droughts against food insecurity include relief food distribution, provision of drought tolerant seeds of maize (*Zea mays*) beans *(Phaseolus vulgaris)* avocadoes (*Persea americana*) tissue culture bananas *(Musa spp.)* cow peas *(Vigna unguiculata)* sweet potato *(Ipomea batata)* vines and establishment of irrigation schemes for mass food crop production. However, dealing with climate disasters like drought, poor crop performance, famine, landslides, human-wildlife conflict, frost, water pollution and forest fires slow the county's economic development (Murang'a County Development Plan, 2018). Furthermore, under a changing climate, concerns are rife that current food insecurity is bound to worsen. These necessitate a better knowledge of climate change impacts and adaptation at the household level to identify more viable solutions for food security. On this basis, this transdisciplinary research project sought to collaborate with the Kimandi-Wanyaga community in Murang'a County to identify climate stressors responsible for driving local food insecurity and some viable solutions to address food insecurity. Particular emphasis was on the promotion of improved traditional vegetable farming to diversify crops and livelihoods and improve food security.

2.9 Climate Change Perceptions.

Farmers' perception on adaptation strategies and climate change significantly affect how they adopted adaptation measures (Kalele *et al.,* 2021). Farmers who are able to perceive climate change are in a better position to adopt climate adaptation measures (Hasan & Kumar, 2019). Dry periods and rising temperatures will have an impact on farmers' perception that the weather conditions are changing which motivates them to take up adaptive measures. Shinbrot *et al*. (2019) observed that local weather conditions will affect how farmers' climate change awareness will evolve and how they will adopt measures that align with their vulnerability experience. The degree to which farmers are aware and perceive changes in climate change will have a big influence on the adaptive strategies employed by farmers (Ado *et al.,* 2019). Farmers' perceptions greatly determine the usage of climate-smart farming practices, and ecological factors strongly influence climate change adaptation strategies (Mairura *et al.,* 2021).

Farmer’s perception of the evolving climatic conditions should be considered through a social process by decision makers as key stakeholders when designing adaptation policies that target them especially for smallholder farmers. Farmer’s perceptions will meaningfully impact the usage of sustainable farming measures (Makate *et al.,* 2017). It is therefore important that when making climate adaptation policies, consideration of farmers' perceptions is essential. Policymakers should engage to influence farmer perceptions through workshops and farmer training on climatic risks and threats while increasing their participation in groupings to increase their adaptation capacity (Shinbrot *et al.,* 2019). Makuvaro *et al.* (2018) found farmers' responses to perception on climatic conditions compared favorably with research data. Farmers are sensitive to climatic changes due to the adverse effects on food security and their wellbeing and will adapt strategies that are mostly similar to accepted practices. Hasan & Kumar (2019) also found that how farmers perceive weather conditions will often align with observed climate data. These conditions will include precipitation, temperature, flooding, drought events that will affect crop production. Farmer observations and climate data will mostly align with the climate impacts, exposure to vulnerability, and even adaptation practices. Callo-Concha *et al.* (2018) contend that farmer responses regarding climatic perception and adaptation are mostly conditional, speculative, and unpredictable. This necessitates scientific data research to enhance their adaptive capacity. Weather-related data is important in shaping farmers’ perception of climatic threats as it affects the effectiveness of adaptation measures. Ado *et al.,* noted that entities that target households’ income improvement and decision-making on climate adaptation need to target the use of media in spreading even in their vernacular languages. Water-use efficiency for irrigation should be improved for effective and lasting climate adaptation. Farmers' range of awareness of changing climate conditions, threats, vulnerability, and adaptation strategies can increase by involving farmers in agricultural training. They can have better access to awareness programs on climate changes in farmers' associations which may quicken adaptive measures to sustain crop production (Hasan and Kumar, 2019). Extension services are an important focal point for farmer knowledge on issues that affect them including climatic threats and adaptation measures (Callo-Concha *et al.,* 2018).

Perception of climatic conditions and adaptation among farmers is also determined by whether the weather threats are short-term or long-term. Farmers will mostly be concerned by long-term threats to crop production like increasing temperatures because the investment to adapt will be higher (Shinbrot *et al.,* 2019). Callo-Concha *et al.* (2018) found that adaptation measures may not respond adequately to the particular threats or impacts they perceive but will focus on society-wide demands like household food security, livelihoods, and marketing issues which may not be effective. Shukla *et al.* (2019) note that the extent of threats that farmers experience and how they perceive them will vary according to differences in their demographic and socio-economic conditions. The range of their farm holdings will play a big part in how their perception will affect their vulnerability context (Shinbrot *et al.,* 2019). It is important to appreciate how farmers with varying household and farm resources will perceive climatic threats. Poorer farmers will perceive greater risks to their household food security and livelihoods than richer farmers (Shukla *et al.,* 2019). The greater context of the differences in perception of threats has big consequences when formulating policies. It calls for the enactment of adaptive measures that are flexible towards different farmer segments rather than generalized policies that may bring about inequalities in different farming conditions. Makuvaro *et al*. (2018) in their research found there were no considerable variances in farmer responses despite differences in their wealth categories.

Callo-Concha *et al.* (2018) found that crucial elements of effective adaptive measures should have short-term economic gains and be compatible with local environmental, societal, and recognized situations while supporting farming traditions. This will help in supporting farming communities to adapt and increase households' wellbeing. Farmers who are aware of and adopt various adaptation measures will have higher returns than those who use narrower /single measures or even don't try to adapt at all. (Asayehegn *et al.*, 2017). Kalele *et al.* (2021) found that farmer perception is important in adaptation measures undertaken. This necessitates an understanding of the adaptation processes to achieve well-focused policies (Beilin*et al.*, 2012; Jha & Gupta, 2021; Nicholas & Durham, 2012). It is also necessary to enhance communication of the perceptions of local communities' undertaking autonomous adaptation to policymakers. Furthermore, knowing the way farmers perceive, respond, and adapt to climate changes and events at the micro-level can be a robust policy and programming decision (Castellanos *et al.,* 2013; Wheeler *et al.,* 2013).

2.10 The PELIS Program

The PELIS is a pilot Kenyan farming model started by the Ministries of Forestry, Agriculture, Water, and Irrigation based on Participatory Forest Management (PFM) guidelines of the Forest Act (2005) to improve food production among communities living near forests (Agevi *et al.,* 2016) and secured in Kenya's Forest Management and Conservation Act of 2016. It is meant to engage meaningfully with surrounding communities in forest management and also improve their livelihoods. It seeks to improve Kenya's forest cover through participatory forest management. Forest conservation and management are devolved to the adjacent communities through a collaborative arrangement where benefits are shared between the Kenya Forestry Service and community-based groups called Community Forest Associations (CFA) (Okumu & Muchapondwa, 2017). The CFAs are formed by nearby residents who border the forest and they register the group with the state. The Kenya Forest Service then comes in and engages them on best forest management practices and transfer of skills. Tree nurseries are established by the CFA. Community members are allocated plots within the forest where they can plant crops while conserving and adding to existing trees. They engage in tree planting to enhance the forest cover while also planting their crops. This continues until the forest cover is adequate and more crop farming is no longer tenable. PELIS has been used by the state to target previously degraded forest areas as a win-win situation for both forest conservation and improving livelihoods among the nearby communities (Wanjira & Muriuki, 2020).

The program has raised food production for the farmers and engaged them in tree planting activities (Odwori *et al.,* 2017; Musyoka *et al.,* 2019). Crop cultivation ends when the tree canopy closes and the farmers are allocated a different area (Wanjira & Muriuki, 2020). Cutting trees for charcoal continues to be a major problem in forest conservation in the country and it has even been argued that PELIS can be further used to enhance sustainable charcoal production with specific areas being allocated to grow trees for the activity (Jepng'etich, 2020). Okumu & Muchapondwa (2020) researched the PELIS program in the Mau forest conservancy and identified a need for exploration on training affected communities on diversifying the products. This study sought to enhance food security among the Kimandi Wanyaga community by expanding their diet and income sources diversity under the PELIS program.

2.11 Traditional Vegetables

African indigenous Vegetables are those vegetables originating from Africa (Abukutsa-Onyango, 2015). Traditional vegetables are the indigenous or introduced vegetable species whose consumption has made them part of a culture. Vegetables are a significant component of the human diet because they contain required micronutrients for proper body development and good health (Owade *et al.,* 2020; Abukutsa-Onyango, 2010, Kamga *et al.,* 2013). African indigenous vegetables have the potential to earn income and therefore, can enable the poorest rural communities to improve livelihoods (Schippers, 2000, Abukutsa-Onyango, 2003). The vegetables are important for household food security and income generation among the rural people (Abukutsa-Onyango, 2003; Legwaila *et al.*, 2011)). Their demand in cities and major towns is also rising. The vegetables are affordable, improve dietary diversity, and can improve food security (Gido *et al.,* 2017). The smallholder farmers' integration into high-value agriculture food systems presents a viable pathway for food security, poverty reduction, employment, women empowerment, and climate resilience in developing countries (FAO, 2016). These necessitate intensive production and marketing of the vegetables for enhanced household income sources (Mwanga *et al.*, 2020).

In Kenya, traditional vegetables can expand the local food base, improve food security and household incomes, and improve health (Kamga *et al.*, 2013). The vegetables adapt to local climatic conditions, are resistant to diseases and pests, are high-yielding, and can easily be intercropped (Gitau *et al.,* 2016). However, they remain under-utilized, with most people preferring exotic vegetables such as cabbages or kales (Muriithi and Matz, 2015). Despite their potential benefits, researchers and national agricultural programs generally neglect and regard them as a low-status food often associated with poor rural lifestyles (Kinyuru *et al.*, 2012). Food insecurity mitigation during drought requires improved production, consumption, and marketing of traditional vegetables.

2.12 Transdisciplinary Research

Transdisciplinary definitions are heterogeneous. This study defines transdisciplinary as, "research that includes cooperation within the scientific community and a debate between research and society at large. Transdisciplinary research transgresses boundaries between scientific disciplines and between science and other societal fields to deliberate about facts, practices and values" (Hardon *et al.*,2008).

2.12.1 Transdisciplinary Emergence

The advent of one-way knowledge transfer from academia "experts" to users 'ignorant" disregarding "users' knowledge, scientific knowledge uncertainty, and application context resulted in science disintegration into burgeoning distinctive disciplines or interdisciplinary sub-disciplines. Science specialization enhances efficiency but causes negative outcomes which do not follow disciplinary lines. Monodisciplinary research solves societal problems through a single lens limiting complexity inherent in emerging life-world difficulties such as poverty, sickness, crime, environmental degradation, and growing food insecurity which require knowledge-based solutions. Although monodisciplinary science illuminates pressing environmental problems, it overlooks complexity hence its capacity to address them becomes insufficient (Green & Andersen, 2019). Interdisciplinary integrates several disciplinary methods to create new applications, analyses, and disciplines. New synergy results from knowledge transfer (Chen *et al.,* 2020).

However, the reality is an organized whole constituting many layers. Studying one problem aspect should not ignore the whole (Lehtonen, 2018). Furthermore, societal problems are too complex to be tackled from a single point of view hence the need for scientific knowledge reorientation to emerging world problems needs. It calls for disciplinary boundary transcendence and shedding of rationality bounds to cross through to the real (Beavis & Gibbs, 2020). Current sustainability science that replaces ‘‘unity of nature’’ with ‘‘resilience of inextricably coupled human-environment systems’’, their dynamics, ontology and governance call for transdisciplinary that reorients reductionist science "science for society" to "science with society" (Scholz, 2018). Transdisciplinary is a "specific kind of interdisciplinary research involving scientific and non-scientific sources or practice" or "a new form of learning and problem-solving involving cooperation among different parts of society, including academia, to meet complex society challenges." It bridges the historical gap between interdisciplinary and problem orientation and a disciplinary practical policy of support for natural sciences and technology (Hummel *et al.,* 2017).

2.12.2 Transdisciplinary Scope and Relevance

Three existing knowledge types include systems, target, and transformation knowledge. Systems knowledge analyses describe, interpret empirical problem-influencing processes and project the future. Target knowledge encompasses direct or indirect interests of other stakeholders including necessary adjustments at private, public, and personal levels for transformation. Transformation knowledge acknowledges established social, cultural, technical, and legal practices and transforms them into desired ones. The mutual linkage between the three knowledge types is required to adequately address life-world knowledge requirements for effective transformation while circumventing unforeseen challenges and unintended risks (Schneider *et al.,* 2019).

Emphasis on the development and implementation of "socially robust knowledge" for "socially robust orientations" renders transdisciplinary the most appropriate research paradigm for sustainability science (Scholz, 2017). For transformation, there is a need to acknowledge personal, academic, and professional knowledge and its diversity (Sellberg, 2021. However, various epistemological divides across academic knowledge create a dilemma on whose reality counts (Martinazzo *et al.*, 2020). Despite challenges, excluded lay understandings or 'citizen science' should be collaborated with expert academic and professional knowledge due to their differences, non-substitution, and value in comprehending particular contexts. These echo calls to widen our minds on what embodies sound knowledge creation, particularly when tackling complexity and contextualizing societal issues (Scholz, 2020).

2.12.3 Transdisciplinary Tenets

Transdisciplinary tenets remain unchanged though heterogeneously practiced and understood. They are (a) problem-orientation (b) participation of stakeholders from diverse disciplines and non-academia (c) research approach and not a methodology or theory (d) emergent science research founded on internal reflexivity and (e) mutual learning between disciplines and with society. Transdisciplinary collaborates among the scientific community and between science and society. Disciplinary boundaries are transgressed to embrace complexity, diversity, uncertainty, values, and societal knowledge for the perceived common good. Disciplinary codes are preserved but adapted to different research questions formulated through interdisciplinary (da Rocha *et al.*, 2020). Transdisciplinary is problem, practice, process, and solution-oriented (Zscheischler *et al.*, 2017) generating knowledge that is unique from within mono discipline or temporary disciplinary alliances. It addresses complex problems transcending various interlinked life domains (Said *et al.*, 2019). Multi-stakeholder collaboration enables knowledge integration from natural, social sciences, humanities (Schneider *et al.*, 2019) practice partners, and local community for scientifically sound, socially robust, and politically feasible problem-solving solutions (Bergmann *et al.*, 2021). Transdisciplinary legitimizes non-researcher experiential knowledge from daily practices and cultural backgrounds (Méndez *et al.*, 2017).

Dialogue between academia and society enhances stakeholder awareness and participation for feasible results (Dick *et al.*, 2017). Based on the transdisciplinary perspective, new learning and interaction form new visions and reality in the search for solutions to intricately interwoven societal problems (Bibri, 2019). It is context-specific through social interaction of various collaborating partners with diverse skills and understandings in a joint venture for better situations. Learning becomes a process of collaboratively creating new rich knowledge undetectable through monodisciplinary lenses (Tempelhoff, 2018). Transformation occurs through the integration of different perspectives or 'thought styles' (Tobias *et al.*, 2018) and scales of reality in a shared discussion of approaches and assumptions to synthesize ideas for new knowledge of nature and reality. (McGregor, 2018). It is not a new super discipline because it is nourished by single disciplinary knowledge. It simplifies, expands, updates, and augments disciplinary research by digging deeper for the underlying complexity of world reality (Bibri, 2019). It complements disciplinary knowledge forming a “new intellectual space” through a steady cross-fertilization of converging different paths (Tillu, 2020).

The transdisciplinary ultimate agenda is to attain a broader perception of different realities of world complexity which requires uniting knowledge from different layers of reality. Melting disciplinary boundaries grows and expands the fertile middle ground between and beyond disciplines yielding a new united mindset and space. Transdisciplinary blooms in the middle, full, vibrant, and fertile ground between disciplines where all different viewpoints are valid. New coherent structures, patterns, concepts, and properties emerge from the web of relationships between people (Uher, 2018). Different world views create similarity patterns that beget unity. Sound intellectual outer space from various disciplines collectively creates an amalgamated embodied knowledge (Bibri, 2019). It permits the assumption of concurrent existence of independent realities only apparent through interaction (Uher, 2018).

Solution searching requires transdisciplinary that involves shared dialogue of approaches and assumptions for a joint analysis crisscrossing idea with new approaches to form a new web of world knowledge (Torrens *et al.*, 2019) that understand the profound complexity of current real-world problems. Transdisciplinary comprises lived experiences and additional vision whose four pillars include: learning to know, to be, to be with, and to do (Nicolescu, 2018). Learning to know involves reigning in constant questioning of theories and linkages construction resulting in a continually interlinked reality. Learning to do comprises creating own potential through a profession that genuinely blends several abilities while creating an adaptable, inner, individual core. Learning to be, determines how we have been accustomed to establish any conflicts between our inner-self and social life and questioning the basis of our persuasions. Learning to be with, embrace others' opinions while defending our own persuasions to attain complex plurality (Nicolescu, 2018).

2.12.4 Transdisciplinary Limitations

Studies rarely realize an interdisciplinary level of disciplinary boundaries transgression for new integrative theory outcomes due to differences in disciplines’ languages, sampling approaches, and data constitution. Inadequate comprehensive reports on ‘real transdisciplinary processes force Trans-disciplinarians to undergo complex and highly unclear methodological and epistemic transdisciplinary practical challenges faltering in locating the right transdisciplinary path without an effective roadmap (Scholz, 2020). Researchers, therefore, adhere to interdisciplinary or transdisciplinarity without a clear grasp of their meanings (Nicolescu, 2018). Transdisciplinary processes, therefore, require practice to encompass reflection and theory development.

Subtle conflicts between disciplinary conceptual and analytical frameworks also complicate the formulation of shared tools on methodology and context analysis of the inquiry. The difficulty of combining findings from participating disciplines arises from researchers' dilemma to disown their knowledge systems, culture, and communities. The closest we can get is a better appreciation of insights and analysis of landscape issues by various knowledge societies. The need to embrace and understand diverse perspectives arising in transdisciplinary processes requires clarification of antagonistic opinions, criticism, major differences, and disagreements. To achieve realistic workable decisions demands democratic legitimacy, identification of common ground and, quelling the lure of only involving willing participants. This calls for careful analysis for mutual learning (Scholz, 2020).

2.12.5 Transdisciplinary Rationale in the Study

Agricultural activities exist within a complex mess of multiple scales and dimension interactions. Food insecurity is a complex problem transcending various fields (Tolk *et al.,* 2021). Various disciplines understand and describe it at spatial-temporal scales leading to different outcomes. Climate-induced food insecurity is a nexus of context-dependent phenomena irreducible to a mono discipline. To capture multiple realities requires an integrated holistic approach that transcends disciplinary confines (Tolk *et al.,* 2021) and an 'eye towards the holistic complex of interrelationships' such as transdisciplinary (Beavis & Gibbs, 2020). Transdisciplinary is an expansive viewpoint approach unfeasible through monodisciplinary or society. Therefore, it is required to achieve high quality, sustainable and acceptable knowledge-based solutions for highly complex climate change causes and impacts engulfed by "factual uncertainties, value loads, and societal stakes" (Hellin *et al.,* 2020). Transdisciplinary comprises lived experiences and additional vision whose four pillars include: learning to know, do, be, and be with (Nicolescu, 2018). The transdisciplinary approach was employed in this study to integrate knowledge from different researchers and non-researchers, problem perceptions, and interests in searching for solutions to Kimandi-Wanyaga community climate-induced food insecurity. The researchers comprised the academic team, the interdisciplinary team, and the non-researchers were the community and local actors. The aim was to capture the multi-dimensional realities of climate-induced food insecurity through an integrated, holistic approach that transcended disciplinary confines. The resultant win-win partnerships embraced the existing situation, melted between the different stakeholders, and cross-fertilized the knowledge structure to transform the community's food security through diet and income sources diversity under the PELIS program.

2.13 Summary

Progressive climate rise is causing inter-annual crop yield variability raising crop demand, crop prices, and food insecurity adversely affecting poor people's livelihoods. The temperatures in Africa have risen than the past ten years. This is predicted to continuously increase with agricultural loss in Sub-Saharan Africa estimated at 2 - 7% GDP. The erratic timing and spacing of East Africa's anticipated rainfall rise is unlikely to benefit agricultural productivity. Kenya is experiencing shorter drought cycles. Frequent droughts, costly domestic food production, costly inputs, internal conflicts in high agricultural potential areas, low buying power, high poverty make approximately over 10 million Kenyans food insecure. In Murang'a County, frequent droughts and floods undermine agricultural production rendering communities' food secure while slowing down economic growth. Climate change adaptation requires that farmers first perceive climate change, identify viable adaptation measures and implement them. To achieve well-focused climate adaptation policies requires knowledge of farmers' climate change perceptions, choice of adaptation measures, and the challenges affecting their climate adaptation efforts. The PELIS program has raised food production for the farmers and cost-effectively conserved forests. Therefore, there is a need to sensitize forest adjacent communities' on expanding their crop diversity in the face of climate change.

Traditional vegetables are important in enhancing food security, employment, and income generation for the rural poor. The demand for vegetables is also rising. Therefore, food insecurity mitigation, especially during drought, requires enhanced cultivation, consumption, and marketing of traditional vegetables. The study community faces the socioeconomic challenges of a growing population, diminishing land resources, unpredictable tea prices, inadequate livelihood opportunities, and food insecurity. The intersection of the underlying socioeconomic challenges and climate change hazards threatens the community's livelihoods and food security. Hence this study sought to enhance the community's food security by diversifying crops and livelihoods. Available larger parcels of land under the pilot PELIS program presented a climate adaptation opportunity that could significantly expand the community's diet and income sources diversity through the cultivation of traditional vegetables such as Amaranths, Black nightshade, and Cowpeas. The study applied a transdisciplinary research approach to grasp the expansive viewpoints of various scientific disciplines and non-researchers for enhanced food security under a changing climate.

CHAPTER THREE: STUDY AREA AND METHODS

3.1 Introduction

This chapter describes the study area and data collection methods used to realize the study objectives. Also provided are detailed study area maps and photographs taken. The study applied a mixed methods research design to collect both quantitative and qualitative data. Multiple data collection tools were used for data triangulation and to ensure the validity of the study findings. The study applied a transdisciplinary approach to integrating scientific perspectives of diverse unrelated disciplines and knowledge of non-researcher user-group participants to enhance food security. Households were chosen as units of analysis because it is mainly the level where major livelihood decisions occur (Thomas *et al.,* 2008). Locally appropriate food security indicators included the households' number of daily meals, diet diversity and the number of months households consumed own-produced foods. Due to the sensitivity of the household income question, proxy indicators such as household expenditure and a list of income sources were used (Pretty *et al.*, 1995).

3.2 Study Area Location

The study area is Kimandi-Wanyaga Sub-Location, Ndakaini Location, Kariara Ward, Gatanga sub-County in Murang'a County (See Figures 3.1, 3.2) covering an area of approximately 9.169km2. It borders Makomboki Sub-Location to the North, Mbugiti Sub-Location to the South, Karangi Sub-Location to the West, Ndakaini Sub-Location to the East, and Kimakia Sub-Location to the Northwest. It comprises five villages of Kigundu, Kimandi/Ngerechi, Wanyaga, Kimandi/Muraya, and Tuguru (KNBS 2009 Census Report). The main occupants are the Kikuyu community practicing small-scale rain-fed subsistence farming. One main tarmac road connects the study area to Thika town (Thika-Gatanga road), and there are several other feeder roads (Ndaki FDA-PRA, 2014).

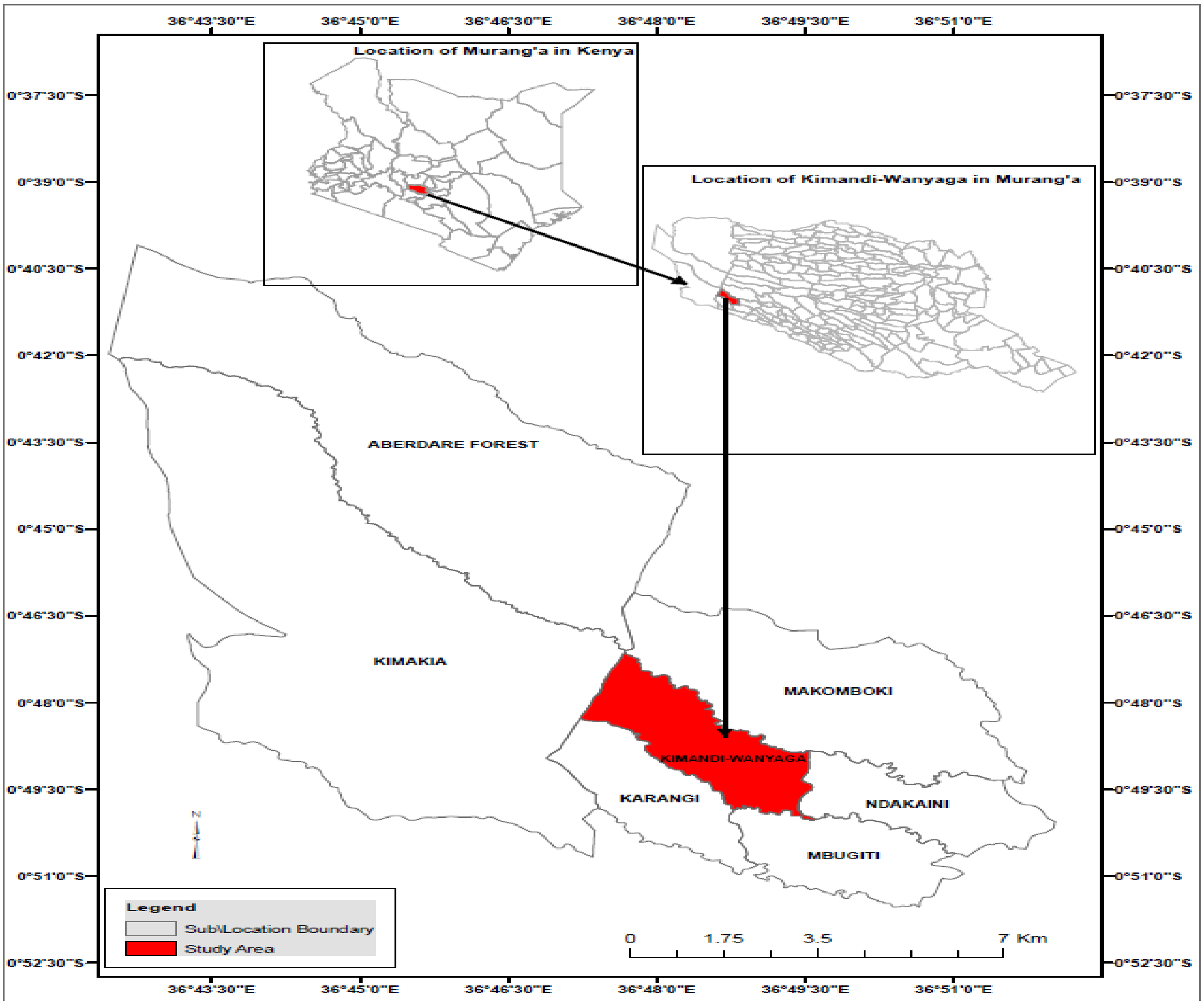


Figure 3.1: Map of Kimandi-Wanyaga Sub-Location (shaded area) within Ndakaini Location. Inset: Map of Kenya showing Location of Murang'a County; Map of Murang'a County Sub-Location Boundaries showing Location of Kimandi-Wanyaga Sub-Location.

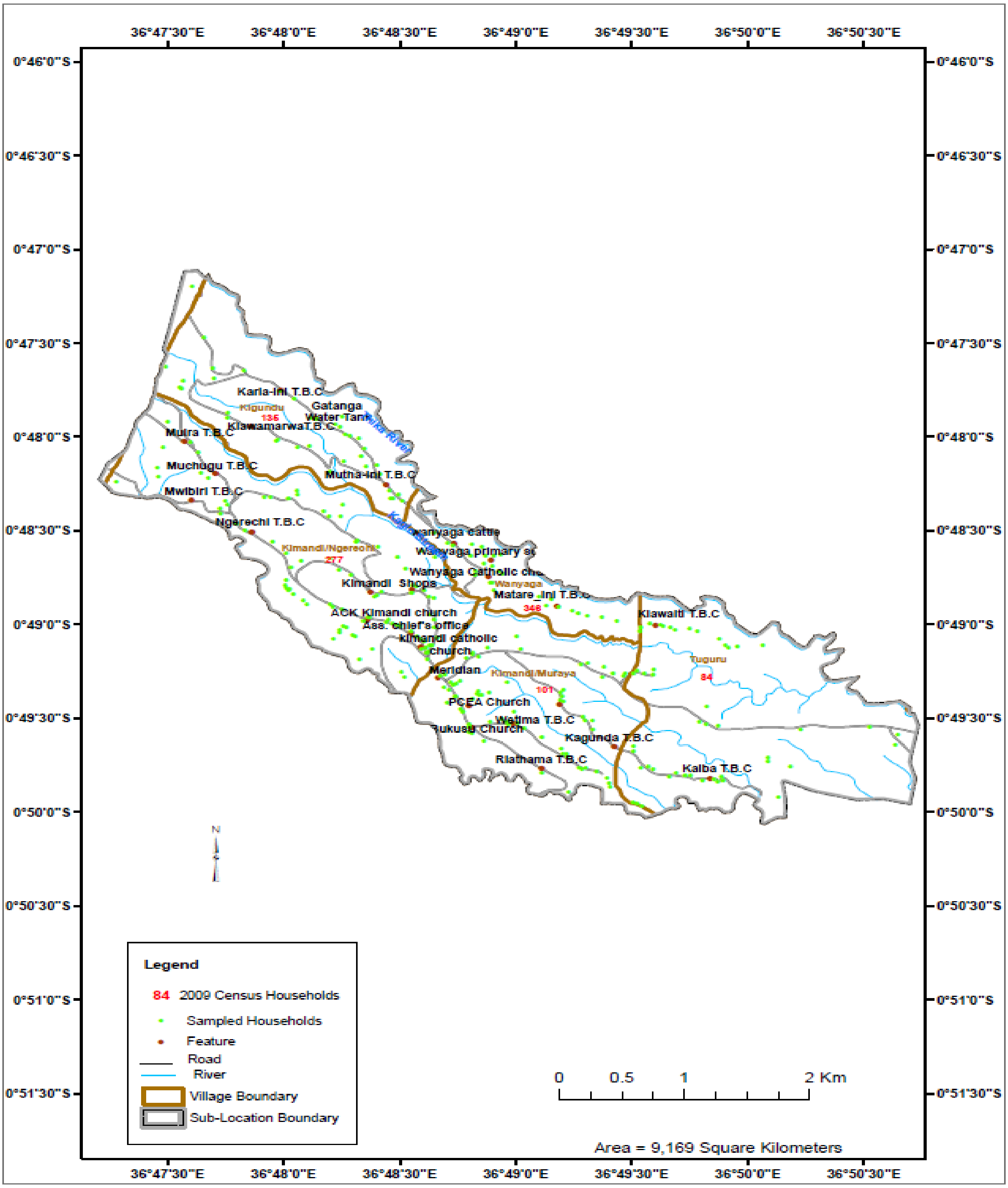


Figure 3.2: Map of Kimandi-Wanyaga Sub-Location and Component Villages

3.3 Biophysical Setting

3.3.1 Climate

The area is at an altitude of 2040 m above sea level within the Lower Highland (LH1) agro-ecological zone known as the Tea-Dairy Zone, characterized by permanent cropping possibilities divisible in a long to very long cropping season followed by a medium one. The average annual temperatures range from 15ºC to 18ºC with a mean yearly rainfall of 1700-2400 mm. The closeness to the Aberdares and Mt. Kenya forests makes the climate commonly wet and humid therefore fit for tea and dairy farming. The rainfall pattern is bimodal. Long rains fall from March to May and short rains from November, December to early January. April rainfall is the highest in amount and reliability (Jaetzold *et al.*, 2006).

3.3.2 Vegetation

The vegetation is predominantly tea bushes, with patches of trees as border markers and wood lots. Popular tree species are Eucalyptus (*Eucalyptus spp*.) and grevillea (*Grevillea robusta*) trees due to their fast growth hence quick return on investment. A leeway of 10 ft. from the riverbank is allowed when planting Eucalyptus trees since they consume large water volumes which can drain rivers. A few grazing areas have Kikuyu grass (*Desmodium Pennisetum*). Food crops are planted near homesteads, kitchen gardens, and river valleys (Ndaki FDA-PRA, 2014).

3.3.3 Land Uses and Resources

Residents are mainly small-scale subsistence rain-fed tea farmers. Over 95% of arable land is under tea. Low attention is given to food crop production. Popular food crops produced are maize (*Zea mays*) beans (*Phaseolus vulgaris*) Irish potatoes (*Solanum tuberosum*) sweet potatoes (Ipomea batata) cabbages (Brassica oleracea) Sukuma wiki (*Brassica oleracea var. viridis*) and avocados (*Persea americana*). Some farmers were venturing into growing short-season crops such as courgette (*Cucurbita pepo*). Livestock reared include cows, goats, chickens, rabbits, and a few sheep. Bucket irrigation is common along river valleys. Woodlots and trees planted along boundaries supply timber and firewood for sale and household use. Some farmers participate in the PELIS program practiced in the nearby Kimakia forest to cultivate food crops (Ndaki FDA-PRA, 2014).

3.3.4 Physiography and Soils

Over 35% of the landscape is steep, covered with friable soils susceptible to soil erosion and landslides. Tea bushes provide complete soil protection and minimize soil erosion except during flash floods. Soil fertility is generally low judging by crop performance level and vegetation type such as weeds (Ndaki FDA-PRA, 2014).

3.3.5 Water Resources

The volcanic rock system has disconformities and porous beds that collect and move groundwater and regulate water supply from wells and boreholes (Jaetzold *et al.*, 2006). Permanent rivers in the area are Kayuyu, Thika, Githika, and Gitabiki draining into the adjacent Ndakaini Dam. Nearly 60% of the community uses piped water from Kandara Water Project and 40% depend on river and rainwater harvesting using gutters and tanks. Water service providers forbid the use of tap water for irrigation by imposing hefty penalties on defaulters (Ndaki FDA-PRA, 2014).

3.3.6 Biophysical Vulnerabilities

During 2004, the area recorded longer rainfall seasons and increased rainfall that saw the maximum mean annual rainfall reaching 2700mm at 2500m height above sea level (Jaetzold *et al.,* 2006). Currently, the area is experiencing erratic weather patterns causing river flow recession, reduced crop productivity, crop season loss, and food insecurity. The steep terrain and fragile soils subject the area susceptible to flash floods, soil erosion, landslides, river and dam siltation, and water eutrophication. Eroded soils are less productive hence low crop productivity. Landslides lead to loss of livestock, human, crops and arable land. Reduced rainfall and encroachment of water catchment areas have reduced perennial river water flow (Ndaki FDA-PRA, 2014).

3.4 Socio-economic Setting

3.4.1 Political and Administrative Context

Kimandi-Wanyaga Sub-Location is in Ndakaini Location, Kariara Ward, Gatanga Sub-County, Murang’a County in Kenya. A Member of Parliament (MP) represents Gatanga Constituency, Member of County Assembly (MCA) represents Kariara Ward and Ndakaini Chief heads the location. Kimandi-Wanyaga Assistant Chief heads the Sub-Location and village elders head five villages constituting Kimandi-Wanyaga Sub-Location (Ndaki FDA-PRA, 2014).

3.4.2 Local Economic Setting

Tea farming employs about 30% of local unskilled labor. The rest of labour comes from outside the County. About 40% of skilled residents work outside the area government institutions, local institutions such as schools, hospitals, and Ndakaini Dam, while others operate small businesses. The average household farm acreage is 1.4 acres. Most farmers produce food only for home consumption with little to store or sell. Most youths are unemployed resulting in idleness, indulgence in drug/substance abuse, and crime (Ndaki FDA-PRA, 2014). According to the Kenya Integrated Household Budget Survey (KIHBS, 2005/2006) the County's poverty index is 36%.

3.4.3 Demographics

Kimandi-Wanyaga Sub-Location covers 9.2 km2 with a total population of 3479 people (1685 males, 1794 females) 943 households, and a population density of 379 persons per km2 (see Table 3.1). The gender imbalance is attributed to male out migration to urban centers in search of work. The highest education level achieved by the majority of male residents (60.2%) and female residents (59.7%) was the primary level (see Tables 3.2 & 3.3) (KNBS, 2009).

Table 3.1: Kimandi-Wanyaga Sub-Location Population by Sex, Number of Households, Population Density and Area in Sq. Km

Population					
Male	**Female**	**Total**	**Number of Households**	**Area in Sq. Km**	**Households Density**
1685	1794	3479	943	9.2	379

Source: KNBS, 2013

Table 3.2: Gatanga District Rural Population Aged 3 Years and Above by Sex and School Attendance Status.

	At school	**%**	**Left school**	**%**	**Never attended**	**%**	**Not stated**	**%**	**Total**
Total	39,547	38.4	54,557	52.9	7,746	7.5	1,222	1.2	103,072
Male	20,388	40.2	26,938	53.1	2,741	5.4	629	1.2	50,696
Female	19,159	36.6	27,619	52.7	5,005	9.6	593	1.1	52,376

Source: KNBS, 2013

Table 3.3: Gatanga District Rural population aged 3 Years and Above by Sex, and Highest Level of Education Reached.

	Never attended	Pre-Primary	Primary	Seco-ndary	Tertiary	University	Youth Poly-technic	Basic Literacy	Madrasa	Total
Total	8,740	4,406	61,755	23,575	3,064	778	291	416	8	103,033
Male	3,242	2,294	30,516	12,244	1,592	492	177	107	-	50,664
Female	5,498	2,112	31,239	11,331	1,472	286	114	309	8	52,369

Source: KNBS, 2013

3.4.4 Health Setting

The community access government health services from nearby Gatura, Kangari, and Ndakaini dispensaries. Church-owned Gituru and Githumu dispensaries also existed. Wanyaga mobile clinic was also offering outpatient services for common ailments. Others were private clinics and chemists at nearby shopping centres (Ndaki FDA-PRA, 2014).

3.4.5 Regulatory Framework

There are two Community Forest Associations (CFAs) namely Kimakia and Gatare, participating in the management of Kimakia and Gatare forests respectively. The Kenya Forest Service (KFS) implements the PELIS program where residents are allowed controlled crop cultivation in the nearby Kimakia forest while rehabilitating the forest by replanting trees in opened-up areas. The PELIS is a pilot Kenyan farming system by the Ministries of Forestry, Agriculture, Water, and Irrigation under Participatory Forest Management (PFM) guidelines of the Forest Act (2005) to enhance food security among forest-adjacent communities (GOK, 2007). PELIS participation in the study area, participants require a yearly enrollment fee of 700 Kenya shillings to the Kenya Forest Service (KFS) and 200 Kenya shillings to Kimakia Community Forest Association (CFA). Participants are allotted land parcels by balloting. Each ballot is equal to an acre and farmers can have more than one ballot based on land availability and affordability. Farmers use the land for one year after which, KFS gives them tree seedlings and technical skills to plant and manage alongside together with their crops. The commonly planted trees are cypress (*Cypressus lusitanica*) and Pine (*Pinus pinea*). Crops planted are maize, carrots, peas, beans, and potatoes. The crops are cultivated until the trees develop a canopy after which, they are left to grow uninterrupted. The community also engages in other activities such as fighting forest fires and control of illegal forest activities. The Kenya Tea

Development Agency (KTDA) manages tea production and marketing and the New Kenya Cooperative Creameries (KCC) buys milk from the farmers (Ndaki FDA-PRA, 2014).

3.4.6 Socio-Economic Vulnerabilities

The soaring population has fragmented land parcels forcing farmers to expand tea production which covers over 95% of arable land at the expense of food crop production. Soil fertility is already at extremely low levels making food crop yields constantly low. Households have been forced to rely on food imports from other areas mainly Nyandarua and Kiambu Counties. Tea prices have increasingly become unpredictable. Most of the income goes to food purchases, health, and education exposing farmers to food insecurity when tea crop prices plummet. The community's overreliance and increased pressure on shrinking climate-sensitive natural resources expose their livelihoods to impacts of erratic weather patterns such as altered species distribution, a resurgence of diseases, weeds, and pests harmful to animals and human beings. The steep terrain and fragile soils increase the risk of soil erosion and landslides which reduce soil fertility. Consequently, there is massive catchment area encroachment, exploitation of adjacent Kimakia forest, biodiversity loss, and general nutritional deficiencies/hidden hunger and food insecurity (MCDP, 2013; Ndaki FDA-PRA, 2014).

3.5 Conceptual Framework

The conceptual framework (Fig 3.3) illustrates the study's comprehensive and holistic approach to investigating the flow of temperature and rainfall changes impacts on the Kimandi-Wanyaga community's food insecurity. It also demonstrates the stakeholder involvement in the study's endeavor to determine the PELIS potential as a viable adaptation opportunity for improved food security. It illustrates the presumed intersection of climate variables (rainfall and temperature) and the underlying socio-economic challenges that drive the study community's food insecurity. Many studies argue that erratic rainfall patterns result in prolonged droughts that cause water body recession and crop water stress. Water-stressed crops are susceptible to pests and disease attacks. Excess rainfall on steep terrains and fragile soils predispose landscapes to flash floods resulting in soil erosion, environmental degradation, and low soil productivity. When landslides occur on steep terrains, they cause human and livestock fatalities and crop loss.

Variable temperatures may affect crop water availability leading to heat stress. Variable temperatures sometimes cause mist and fog. These impacts may alter crop diseases and pests' environments and proliferate their outbreaks. Low temperatures during harvest raise crop moisture content and increase fungal attacks and post-harvest losses and hence low crop productivity. Management of soil fertility, crop pests, and diseases increase the use of fertilizers and agrochemicals resulting in higher food crop production costs (Abdel-Motagally *et al.,* 2018; Jones, 2016; Stirling *et al.,* 2012). The intersection of these impacts with the community underlying socio-economic challenges of diminishing land resources, rising population and inadequate livelihood options, are presumed to raise the community's vulnerability to food insecurity.

The transdisciplinary approach employed in the study integrated different researchers' and non-researchers' knowledge, problem perceptions, and interests in searching for solutions to climate-induced food insecurity. The aim was to create win-win partnerships that would embrace the existing situation, melt between the different stakeholders and cross-fertilize the knowledge structure. The study identified cultivation of selected traditional vegetables including *managu (Black nightshade) terere (Amaranths spp.)* Cow peas *(Vigna unguiculata*) *saget (Cleome gynandra) and murenda (Corchorus olitorius)* under the existing pilot PELIS program as a promising climate adaptation strategy to diversify crops and livelihoods for food security. The research supervision was by the University of Nairobi, Institute for Climate Change and Adaptation (ICCA).

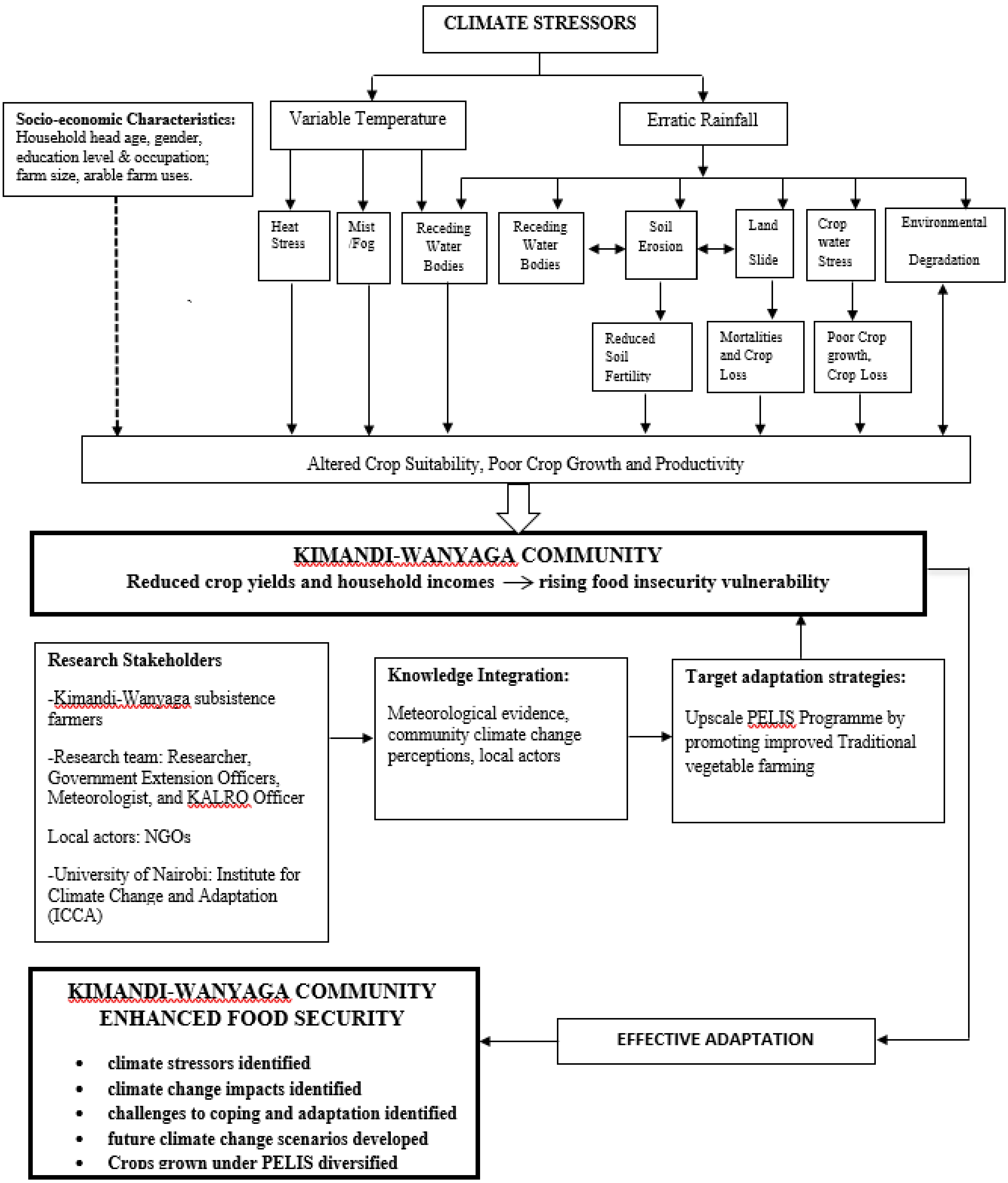


Figure 3.3: Conceptual Framework

3.6 Data Collection and Project Planning Process

3.6.1 Reconnaissance survey

A reconnaissance preceded the start of fieldwork to consult with local leaders, introduce the research project, gain community trust and plan for further engagements. Repeated visits and meetings were held with key community leaders and Sub-County Officers to enhance mutual trust and manage impractical stakeholder expectations. The need to learn and understand together by combining researcher and non-researcher knowledge was emphasized. A general account of natural, socioeconomic, sociocultural conditions, and agricultural traditions helped to conceptualize the research problem.

3.6.2 Interdisciplinary Team Formation, Stakeholder Selection and Problem Framing

The selection of significant stakeholders was based on the required expertise to meet study objectives, desired change, and willingness to participate in the study. The interdisciplinary team included a sociologist, agronomist, nutritionist, agricultural economist, meteorologist, and Kenya Agricultural and Livestock Research Organization (KALRO) officer. The non-researchers were local farmers, government administrators, and NGO representatives. Supervision was by the University of Nairobi (UoN) Institute for Climate Change and Adaptation (ICCA).

3.6.3 Enumerators Recruitment and Training

Four local field data collection enumerators consisting of, one supervisor and three interviewers were drawn based on data collection competence, local language knowledge, and trust from local people. To mitigate data collection bias and errors, the enumerators underwent one-day hands-on training on survey piloting, qualitative interviewing, and data entry. The enumerators' roles were to conduct interviews, identify and organize contacts with KIIs.

The questionnaires were pilot tested for consistency and study reliability with local non-research area members and revised accordingly based on pilot survey results. The pilot sample size should be between 1% to 10% of the sample size. Analysis of collected data is not necessary if the sample is small (Mugenda & Mugenda, 2003). The pilot sample of 15 respondents (5% of the sample size) was considered small and therefore, the data collected were not analysed. They were administered in face-to-face interviews during the household survey, FDGs and KIIs.

3.6.4 Research Approach

This study applied a transdisciplinary research approach to examine holistically the temperature and rainfall changes and how they affect food security among Kimandi-Wanyaga smallholder farmers. Transdisciplinary research applies research and change as two parallel approaches. The research process is an approach founded on internal reflexivity that embraces mutual learning and knowledge integration between disciplines and with society. The change process involves collaboration among the scientific community and between science and society. Disciplinary boundaries are transgressed to embrace complexity, diversity, uncertainty, values and societal knowledge for perceived common good. In this study, the Transdisciplinary approach aimed to enhance the study community's food security situation through stakeholder collaboration and knowledge integration throughout the research process. The level of stakeholder involvement in the research process is explained in Table 3.4.

Table 3.4: Description of the Stakeholders' Engagement in the Study

Stakeholders	Stakeholder involvement
Academic research team: The research student, supervisors from the University of Nairobi, Institute for Climate Change and Adaptation (ICCA).	Project conceptualization, proposal development, stakeholder and fieldwork coordination, and development of the Ph.D. thesis, and research papers.
Interdisciplinary team: Research student, Gatanga sub-County Extension Officers, Meteorologist, KARLO Officer.	The team members have research experience in a similar ecosystem. They contributed to proposal development, pilot testing of the research tools, moderation of FGDs, facilitation of on-farm demonstrations, and data analysis.
Local actors: Local NGOs involved in climate change-related activities, Key Informants.	Provided in-depth special knowledge lacking in other members of the society, problem identification, project design, and transect walks.
Research society: Kimandi-Wanyaga smallholder farmers	Involved in most stages of the research such as problem identification, FGDs, on-farm demonstrations, and cultivation of the traditional vegetables.

3.7 Field Work

The eighteen-month duration (August 2015-January 2017) was devoted to intensive stakeholder involvement, consultation, and data collection. The introduction of the cultivation of selected traditional vegetables under the PELIS program demonstrated the existence of available climate adaptation interventions which, if appropriately adopted, could contribute to solving climate-induced food insecurity. Constant self-assessment (reflexivity) to examine the research progress took place among the interdisciplinary team throughout fieldwork. Meetings were planned through phone calls, one-on-one, and group interactions. Local community interactions were organized by community leaders and data collection enumerators.

3.7.1 Objective 1. To determine whether there are rainfall and temperature changes in Kimandi-Wanyaga sub-Location in Murang'a County, Kenya.

To achieve objective 1, data collection included both observed and the community perceptions of rainfall and temperature changes. According to the World Meteorological Organization (WMO) the level of missing data for a station should be below 10%. The rainfall and temperature data for local volunteer weather stations were examined for completeness. The estimation of the missing data was done through the regression equation:

$y = a + bx$ ………………………………………………………………………………… **(1)**

Where y = dependent variable (predicted temperature in the affected station)

x = independent variable (available temperature data for the station)

a = intercept

b = regression coefficient

The data contained more than 10% of missing data and so was regarded inadequate for sound conclusions. The study, therefore, used monthly data available at Thika Meteorological Station whose rainfall data (1961-2016) and monthly minimum temperature data (1988-2016) were complete. The station's monthly maximum temperature data (1980 to 2016) had 2 years' missing data (1997,1998) which were estimated as 6.9% through linear regression (Equation 1). The rainfall data were analysed for annual and seasonal trends, and the temperature data were analysed for trends using the MAKESENS procedure (Salmi *et al.,* 2002).

The MAKESENS procedure is based on the non-parametric Mann-Kendall test for detecting trends, and the non-parametric Sen's slope estimator, for estimating the magnitude of the trends. Mann-Kendall test detects the presence of decreasing or increasing monotonic trends of annual time series with no seasonal or other cycles, while Sen's method estimates a linear slope for the trends. MAKESENS was mainly developed to detect and estimate trends, in a time series of annual values of atmospheric and precipitation concentrations.

The study, therefore, found MAKESENS approach appropriate for trend analysis because data does not require conformity to a particular distribution, the approach allows for missing data and the Sen's method is not highly sensitive to outliers or single data errors. The two-tailed test in MAKESENS analysis is specifically employed at four significance levels: at 0.1, at 0.05, at 0.01, and 0.001 symbolized as:

*** If trend at $\alpha = 0.001$ level of significance

** If trend at $\alpha = 0.01$ level of significance

* If trend at $\alpha = 0.05$ level of significance

+ If trend at $\alpha = 0.1$ level of significance

If blank cell, $\alpha > 0.1$ level of significance

Therefore,

A trend at $\alpha = 0.001$ significance level indicates a high probability of the existence of a monotonic trend.

A trend at $\alpha = 0.1$ significance level indicates the data values are from a random distribution with a 10% probability risk of rejecting the hypothesis of no trend.

The **Z** statistic is presumed to have a normal distribution and is used to evaluate the presence of a statistically significant trend. A positive value stipulates an upward trend and a negative value stipulates a downward trend.

3.7.7.1 Mann-Kendall test

For data values greater than 10, the normal approximation test is used. *S* variance is calculated using the following equation accounting for any ties present:

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5)\right] \quad \textbf{(2)}$$

Where: q = number of tied groups

t_p = number of data values in the p^{th} group

The test statistic *Z* is computed using the values of *S* and *VAR(S) as* follows:

$$Z = \frac{S-1}{\sqrt{VAR(S)}} \quad if\ S > 0 \quad \textbf{(3)}$$

$$Z = 0 \quad if\ S = 0 \quad \textbf{(4)}$$

$$Z = \frac{S+1}{\sqrt{VAR(S)}} \quad if\ S < 0 \quad \textbf{(5)}$$

3.7.1.2 Sen's method

Sen's method estimates the true slope of an existing trend (annual change) assumed to be linear and fitting the equation:

$f(t)=Qt+B$………………………………………………………….. **(6)**

Where:

Q is the slope

B is a constant

To get the slope estimate Q:

first calculate the slopes of all data value pairs as follows:

$Q_i = \frac{X_j - X_k}{j-k}$ Where j>k ……………………………………………………………. **(7)**

If we have *n* values *xj* in the time series, we get as many as $N = n(n-1)/2$ slope estimates *Qi*. The Sen's estimator of slope is the median of these *N* values of *Qi*. The *N* values of *Qi* are rated from the smallest to the largest and the Sen's estimator is:

$Q = Q_{[\frac{N+1}{2}]}\ if\ N\ is\ odd$……………………………………………………………… **(8)**

or

$Q = \frac{1}{2}\left(Q_{[\frac{N}{2}]} + Q_{[\frac{N+2}{2}]}\right) if\ N\ is\ even$……………………………………………………… **(9)**

Data on the community perceptions were gathered using semi-structured questionnaires (Appendix II and III) through a household survey, FGDs, KIIs, and two transect walks (Sub-sections 3.8.1-3.8.5). Using the MS Excel and SPSS statistical packages the data were analysed through descriptive (frequencies and percentages) and inferential statistics (Chi-Square tests) and presented in figures, tables and direct quote formats.

3.7.2 Objective 2. To Determine Whether the Perceived Rainfall and Temperature Changes Have Affected Food Security in Kimandi-Wanyaga sub-Location in Murang'a County, Kenya.

To achieve objective 2, data collection focused on the community perceptions of rainfall and temperature change impacts on their food security. The data were elicited using semi-structured questionnaires through a household survey, FGDs, KIIs, transect walks, and resource mapping (Sub-sections 3.8.1-3.8.5). Through the participatory resource mapping (Plate 3) the community members articulated knowledge of their key livelihood resources. Using the MS Excel and SPSS statistical packages the data were analyzed through descriptive (frequencies and percentages) and inferential statistics (Chi-Square tests) and presented in tables, figures, and direct quote formats.

3.7.3 Objective 3. To Examine the Challenges that Kimandi-Wanyaga Community in Murang'a County Faces while Responding to Rainfall and Temperature Changes.

To achieve objective 3, primary data collection focused on the community's climate coping strategies and the challenges they faced while addressing the perceived climate risks on their food crop production. The data were collected using semi-structured questionnaires (Appendix II and III) through a household survey, FGDs, KIIs, and two transect walks (Sub-sections 3.8.1, 3.8.3-3.8.5). Using the MS Excel and SPSS statistical packages the data were analyzed through descriptive (frequencies and percentages) and presented in tables, figures, and direct quote formats.

3.7.4 Objective 4. To Explore the Potential of the Cultivation of Traditional Vegetables under the PELIS Programme in Enhancing Crop and Livelihood Diversification among the Kimandi-Wanyaga Community in Murang'a County

To achieve objective 4, data collection focused on the community's level of involvement in the existing PELIS pilot program and adoption of traditional vegetables. To to enhance domestication of the traditional vegetables for improved diet income sources diversity, the study conducted two on-farm demonstrations (Sub-section 3.8.6) on five selected traditional vegetables including, Cowpeas *(Vigna unguiculata) Managu (Black nightshade) Terere (Amaranth spp.)* and *Murenda* (*Corchorus olitorius*).

3.8 Data collection Tools

3.8.1 Focus Group Discussions (FDGs)

The FGDs are important for the collection of inductive and naturalistic qualitative data which captures rich elaborative participants' real perceptions, feelings, ideas, and attitudes (Krueger 1988). They were an important technique to triangulate and validate the secondary data collected. Two-phase sampling was done to segment the study population into two homogeneous subgroups. In the first phase, Kimandi-Wanyaga Sub-Location was sub-divided into two homogeneous clusters of Wanyaga and Kimandi based on the sampling frame. In the second phase, two FGDs comprising fourteen participants (Kimandi) and ten participants (Wanyaga) were purposively selected from each cluster based on gender, long-time residence (>30 years) and the main source of livelihood being smallholder farming. The discussion sessions that lasted approximately 2 hours (Plates 1-4) were guided by semi-structured topical questionnaires and moderated by interdisciplinary team members.

Plate 1: Consultations Preceding the FGDs at Ndakaini Dam Site

Plate 2: A Female Focus Group Discussion at Ndakaini Dam Site

Plate 3: Resource Mapping during Focus Group Discussions at Ndakaini Dam Site

Plate 4: Various Stages of FGDs at Wanyaga.

3.8.2 Participatory Resource Mapping

Each focus group drew their locality maps indicating their livelihood resources which were then openly discussed (Plates 3 & 4). These opened up community interactions and enabled data collection on livelihood resources such as rivers, forests, crops, road infrastructure, and other land uses. Gaihre *et al*. (2019) argue that co-learning with communities opens up innovations and enables them to take charge of their resources to enhance production for improved food and nutritional security. The technique was also necessary for triangulating and validating secondary and FGDs data. The maps also guided the selection of suitable farm demonstration sites and transect walk routes.

3.8.3 Transect Walks

The interdisciplinary team and key informants conducted a transect walk in each cluster of Kimandi and Wanyaga to visit different parts of the study area, view existing conditions and talk to people. The aim was to clarify and ground-truth secondary data and information from FGDs and KIIs (Plate 5). Spatial baseline data collected focused on land uses, infrastructure, water resources, and type of environmental degradation. Key informants explained various features of interest including crops and areas affected by landslides and deforestation. Note-taking and photographing occurred.

Plate 5: A Transect Walk at Wanyaga

Deforestation to expand farming land	An area affected by landslide in Kimandi

Plate 6: Various Climate Change Related Impacts Sighted during Transect Walks

3.8.4 Household Survey

This tool was important for triangulation and validation of secondary data and information collected from the FGDs, KIIs, resource maps and transect walks. The study sample was selected from a population of all the Kimandi-Wanyaga Sub-Location small-scale subsistence households, based on KNBS 2009 census. A comprehensive household list (sampling frame) was obtained from the Gatanga Sub-County Administration Office. A systematic random sampling technique was used to select cases directly from the sampling frame (Bryman, 2004). Taro Yamane formula (Yamane, 1973) at 95% confidence level was used to derive the household survey sample from a total of 943 households (2009 census) as follows:

Taro Yamane formula:

$$n = \frac{N}{1+N(e)^2} \quad \text{(10)}$$

Where:

n = sample size

N= number of households in the population

e = allowable error (%)

Substituting numbers to the formula:

$$n = \frac{943}{1 + 943(0.05)^2}$$

n = 280.8637

Rounded off to **281** households

Numbers were assigned to all the households in the population without any inherent order. To locate 281 households from 943 households, a systematic sampling procedure (Prewitt, 1975) was used whereby a probability inclusion range (sampling fraction) expressed as:

$$= \frac{n}{N} \quad \text{(11)}$$

where n is the sample size and N is the population size, was determined as:

$$= \frac{281}{943} \qquad = 1/3$$

Thus, one out of three households were interviewed. The first household was selected through a random start. Subsequently, every third household in the list was interviewed (See Plate 7) to a total of 281 households. Unavailable respondents were recalled until a response was obtained. Each enumerator covered four households daily. The supervisor recorded each interviewed household on a GPS kit. The respondents were the household heads, male or female (for female-headed households). The respondent to the question on dietary diversity was the person in charge of household meal preparation during the preceding 24 hrs. To gain insights into the community's dietary diversity, the study conducted a qualitative measure of the households' access to a variety of foods, using the Household Dietary Diversity Score (HDDS).

The HDDS draws insights on twelve food groups consumed within a reference period of the previous 24 h acts as a proxy for diet quality and gives a snapshot reflection of the households' economic ability to access different foods (Hoddinott & Johannes, 2002). The study counted the total number of the twelve food groups consumed by a household within the preceding 24 hours. To adapt the food group list to Kimandi-Wanyaga context, a nutritionist and some local women categorized, translated the food group lists into locally available foods, and recognized names for a meal, snack, and household. They also identified ingredients used in preparing local foods. A household is, "a group of people living in the same compound consisting of an enclosed set of buildings, eating from the same pot and recognizing one head of household usually, a husband and father or guardian" (KNBS 2009 Census Report). The respondent was the person who prepared the household food the previous day and was asked to list all the foods the household members had eaten during the previous day and night. The total number of the twelve food groups a household had consumed within the preceding 24 hours were counted.

Plate 7: One of the Enumerators Interviewing a Farmer

3.8.5 Key Informant Interviews

A key informant (KK) is an expert source of information. Because of their position within society or personal skills they provide deeper insights to what happens in their surroundings (Tremblay, 1982). In this study, KIIs were purposefully sampled to provide information, ideas, and insights required to meet the study objectives. They were selected based on available time and resources, information available from other sources (e.g. FGDs and household survey) ensure sufficient representation, and avoid significant omissions. Their in-depth knowledge enabled triangulation of data from other sources. They included, 1) a government official, 2) a socio development officer, 3) a community forest officer, 4) Ndakaini dam weather station officer, 5) Kenya tea development extension officer, and 6) an elderly farmer. The KIIs were contacted by the data enumerators and invited to participate in the interviews. A convenient time and place for the meeting was arranged. The interview duration was conducted by the researcher through semi-structured interview guides and lasted between 30-40 minutes. The interviews were audio-taped and transcribed.

3.8.6 On-farm Demonstrations

3.8.6.1 Experimental design and treatments layout

The experimental (demonstration) sites were located at Kimandi and Wanyaga and conducted on volunteer farmers' farms. The treatments were a factorial design ordered in a Randomized Complete Block Design (RCBD) with four factors (no manure or fertilizer, nitrogen fertilizer, manure, nitrogen fertilizer and manure) at two levels for nitrogen fertilizer (0, 10g /m) and two levels for manure (0, 20kg/8m) (see Tables 3.5 & 3.6).

The planting and field management of the vegetables were guided by the Kariara Ward Agricultural Extension Officer. The skills were transferred on quality seed selection, land preparation, proper spacing, fertilizer application, field management, harvesting, cooking, nutritional value and value addition by drying to lengthen the shelf life (See Plate 8).

Table 3.5: The Randomized Complete Block Design (RCBD)

Block **No.**	**Size**	Vegetable Name	3M	1M Path	3M	1M Path	3M	1M Path	3M	1M Path
1	3M	Amaranth	A		B		C		D	
1M Path										
2	3M	Black nightshade	D		C		B		A	
1M Path										
3	3M	Jews marrow	C		D		A		B	
1M Path										
4	3M	Cow peas	B		A		D		C	
1M Path										
	3M	Spider plant	D		B		C		A	

Table 3.6 The Experimental Treatments

Units/Blocks	Treatment
A	Traditional vegetables planted with no manure or fertilizer
B	Traditional vegetables planted with inorganic fertilizer, N: P: K (23:23:0) at a rate of 10g /meter
C	Traditional vegetables planted with well decomposed manure at a rate of: 20 kgs per 8metres
D	Traditional vegetables planted with inorganic fertilizer N: P: K (23:23:0) at 10 g /meter and well decomposed manure (1/2 debe/8 meters).

3.8.6.2 Planting and fertilization

The traditional vegetables used as test crops were, cow peas (*Vigna unguiculata) saget (Cleome gynandra) managu (Black nightshade) terere* (*Amaranths spp.)* and *murenda (Corchorus* *olitorius.* The planting dates were, on 1st December 2015 at Kimandi and on 8th December 2015 at Wanyaga site. Land preparation was done by double digging using hoes to remove all crop residues, break soil clods to ensure a very fine texture and level the soil surface. The soil between rows was raised to ensure adequate drainage in case of heavy rainfall. Shallow furrows were made with a hand hoe at a spacing of 45-50cm between rows. The seeds were planted by broadcasting at the onset of rains to ensure adequate moisture during the growing season. The seeds were mixed with ash for even distribution. The mixture was spread evenly by drilling along the rows. One can use a rake or broom to spread the seeds lightly. The seeds are very small (2500-3000/gram) and therefore the force of rain or watering is adequate to cover them with sufficient soil. Well decomposed manure was used at a rate of 20 kgs/8m. The nitrogen fertilizer, (N: P: K; 23:23:0) was applied at a rate of 10g/m. The manure/fertilizers were mixed well with the soil before planting the seeds. Using well-decomposed manure and compound fertilizers (N: P: K, 23:23:0) during planting and additional manure application (C: A: N, 26:0:0) after every 3 wks shortens duration between harvests. Well-decomposed manure improves soil structure, fertility, and water holding capacity. The plots were kept weed-free throughout the study period.

3.8.6.3 Harvesting

The first harvest also called thinning was done after 4-5 weeks after germination at a height of 15 cm to uproot taller plants. After achieving adequate spacing between plants, the top shoots were picked to allow new shoots to sprout. This process is called ratoon cropping and was repeated 4 times. The length of harvested shoots varied between 15-50cm depending on the vegetable type.

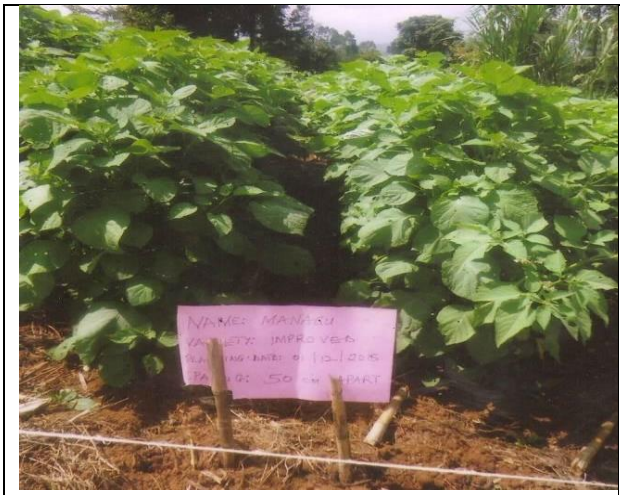
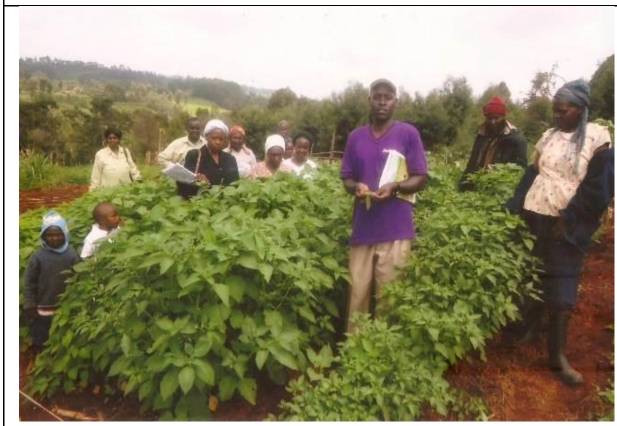
NB: The frequency and total duration of harvesting depend on management practices. For instance, with additional manure or fertilizer, farmers can harvest up to 10 times. Irrigation and additional application of well-decomposed manure and CAN (26%N) also shorten the duration between harvesting.

3.8.7 Pairwise Preference Ranking

The vegetables were ranked using pairwise preference ranking exercises (See Plate 9) conducted during the on-farm demonstrations to understand the farmers' interest in growing the selected traditional vegetables as follows:

1. Five types of traditional vegetables were presented to the on-farm demonstration's participants.
2. Any two of the vegetable types were picked and the farmers were asked to choose which of them they would prefer to grow.
3. Probing questions were used to find out why they made the choices.
4. The results were recorded on a matrix.
5. The winner of each comparison was entered in the appropriate box.
6. The exercise was repeated with a different pair of the vegetables until all the combinations were done.
7. The final ranking was achieved by adding up the number of times each vegetable type appeared as a winner and therefore showing the most and least popular vegetable type.


Plate 8: Guiding a Farmer on Field Management of the Vegetables at a Demonstration Plot

 Improved traditional vegetable plot during Wanyaga demonstration	 Improved traditional vegetable plot during Wanyaga demonstration
 Kariara Ward Nutritionist/Agronomist training on field management and nutritional value of the vegetables.	 An agro-economist training on marketing of vegetables.
 A sociologist/adult educator training on health benefits of vegetables .	 Mr. Wasike demonstrating on right cooking of the vegetables.

Giving planting seeds to participating farmers

Demonstration on drying of the vegetables on a sack

The Vegetables pairwise preference ranking table

Plate 9: Various stages of the demonstration on improved traditional vegetable farming at Wanyaga.

3.8.8 Farmer follow-up visits

The farmer follow-up visits were made monthly for four seasons to monitor and record the types of vegetables, field management, challenges encountered and use of the vegetables adopted by the farmers.

CHAPTER FOUR: ANALYSIS OF RAINFALL AND TEMPERATURE CHANGES IN KIMANDI-WANYAGA SUB-LOCATION IN MURANG'A COUNTY, KENYA.

4.1 Introduction

The chapter focused on the objective one that analysed both the observed and the perceived rainfall and temperature trends in Kimandi-Wanyaga community in Murang'a County, Kenya. The World Meteorological Organization (WMO) standards stipulate that the maximum level of missing data for a station be under 10%. For better representation of the study area, data from local volunteer weather stations were examined for completeness. The data had more than 10% missing data and therefore found inadequate for sound results. The study obtained rainfall data (1961-2016) and monthly minimum temperature data (1988-2016) data from Thika Meteorological Station. The station's monthly maximum temperature data (1980 to 2016) had 2 years' missing data (1997,1998) estimates at 6.9%. The data were analysed through Mann-Kendall test and Sen's slope estimator referred to as MAKESEN procedure. The community perceptions data (1984 to 2014) were collected through household survey, FGDs, and KIIs.

4.2 Characteristics of the Sample Population

Results from this study (Table 4.1) indicate that most of the household heads were middle-aged (57.3%) males (76.2%). They had also achieved secondary education (52.7%). The farm sizes of most households (93.3%) were under 4.5 acres with most of it being under tea crop (67.34%). Their main source of livelihood for most of the households (83.3%) was farming.

Table 4.1: Sample Population Characteristics

Characteristic	Category	Percentage
Age in years	<25	0.4
	25-35	12.1
	36-45	27.8
	46-55	29.5
	56-65	16.4
	65>	14.2
Gender	Male	76.2
	Female	23.8
Formal Education Level	None	8.9
	Primary	28.8
	Secondary	52.7
	College/University	9.5
Household Farm Acreage	0-0.5	6.0
	0.51-1.0	19.6
	1.01-1.5	17.8
	1.51-2.0	16.0
	2.01-2.5	16.0
	2.51-3.0	10.3
	3.01-3.5	2.5
	3.51-4.0	5.0
	4.01>	6.7
Household arable farm uses	Tea Crop	67.34
	Food Crops	20.59
Household head occupation	Farming only	83.3
	Farming plus informal jobs	8.9
	Farming plus formal jobs	7.8

4.3 Rainfall and Temperature Trends within Kimandi-Wanyaga.

4.3.1 Rainfall Trend Analysis

The results of the MAKESENS procedure analysis for the monthly rainfall are stipulated in Table 4.2 and Figs. 4.1-4.3.

Table 4.2: The Seasonal and Annual Rainfall Trends.

ANNUAL RAINFALL					MAM RAINFALL				OND RAINFALL			
N	Test Z	Sig.	Q	% change	Test Z	Sig.	Q	% Change	Test Z	Sig.	Q	% Change
56	0.01		0.063	0.373345	-0.37		-0.747	-9.41882	1.1		1.195	18.88649

Where: **N:** Number of annual values without missing values. **Test Z:** The Z statistic **Significance:** The significance level. **Q:** Sen's slope **% change:** The percentage change.

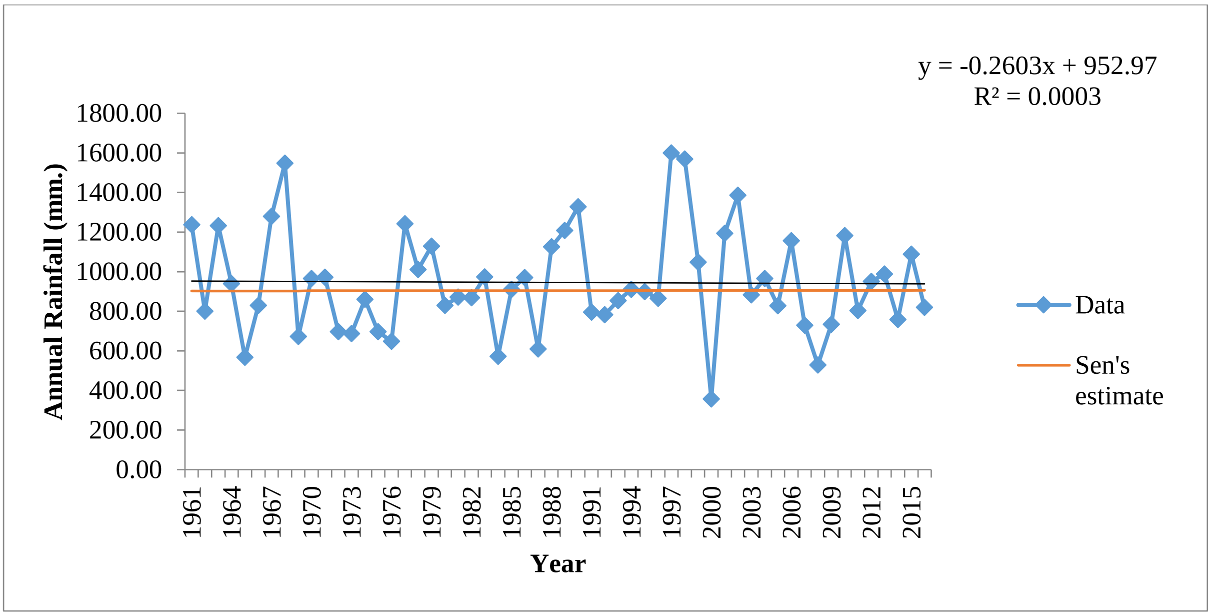


Figure 4.1: Annual Rainfall Trend for Thika Meteorological Station (1961 – 2016).

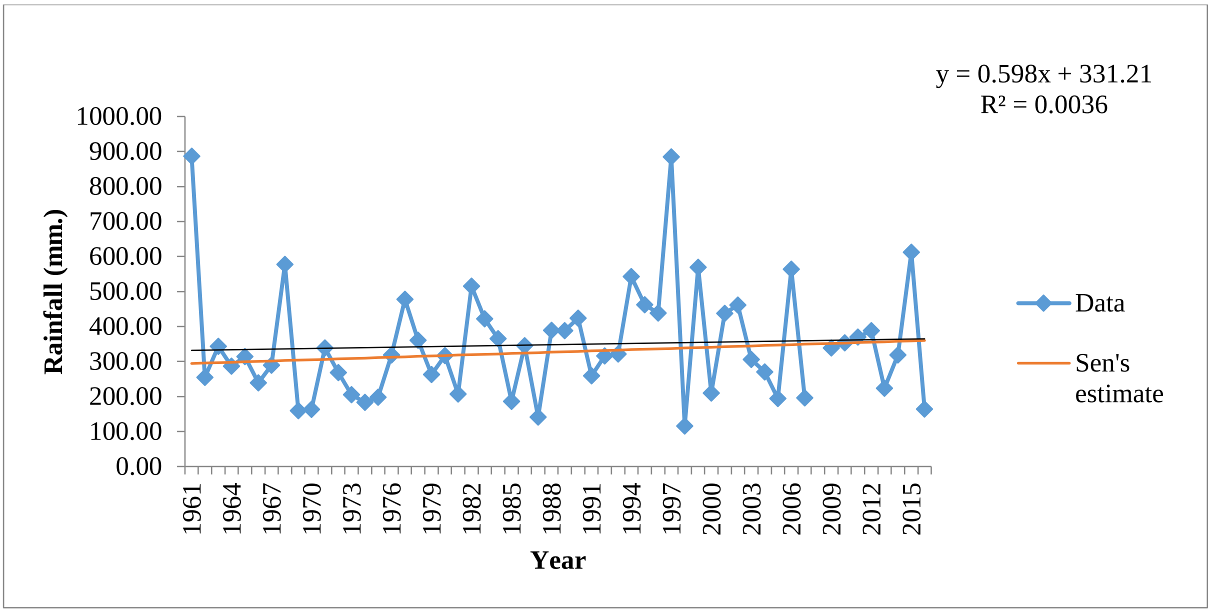


Figure 4.2: Long Rains (March, April, May) Rainfall Trend for Thika Meteorological Station (1961-2016).

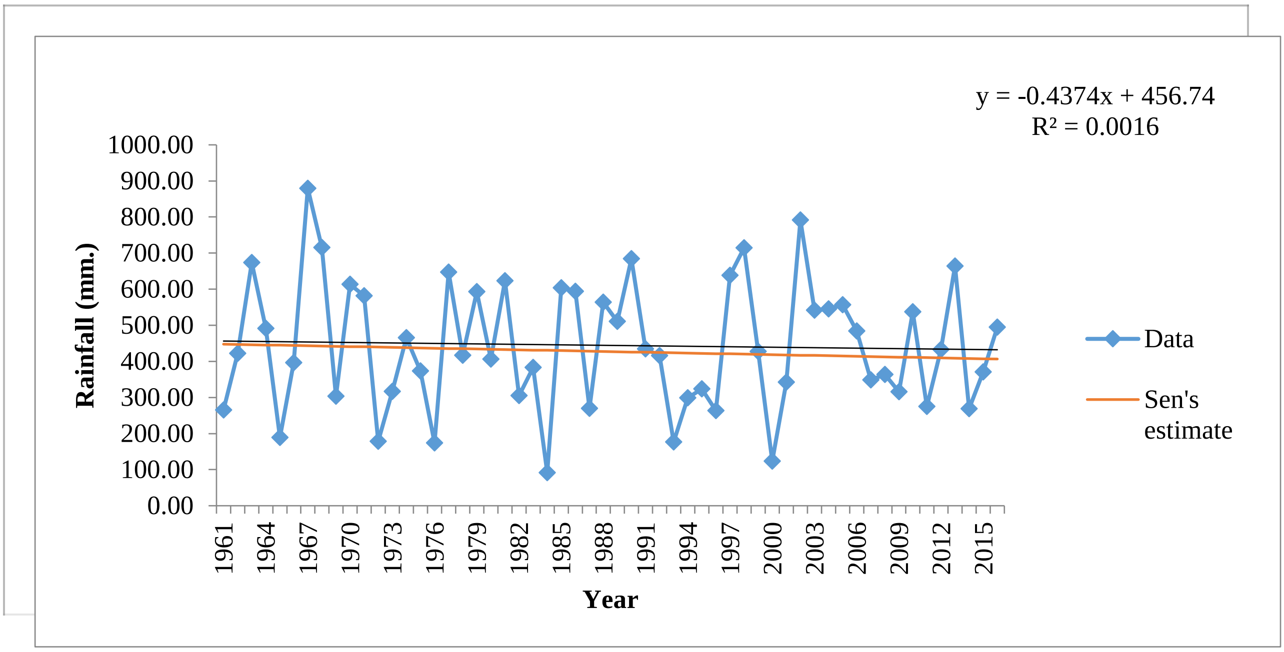


Figure 4.3: Short Rains (October, November, December) Rainfall Trend for Thika Meteorological Station (1961-2016).

The seasonal level test results shown in Table 4.2 and Figures 4.1 to 4.3, indicate a reduction in the long rainfall season (March to May) of -9.42% and a magnitude of -0.747. The results also show a rise in the short season rainfall (October to December) of 18.89% and a magnitude of 1.195. The annual rainfall had increased by 0.37335% and a magnitude of 0.063. However, both the annual and seasonal rainfall trends indicated statistically insignificant variability (α > 0.1).

4.3.2 Temperature Trend Analysis.

The trend analysis results for the monthly maximum temperature from 1980 to 2016 and minimum temperature from 1988 to 2016 are shown in Table 4.3 and Figs 4.4, 4.5. The results of the minimum temperature indicate a positive trend of 4.011% at a magnitude of 0.016 (α > 0.1). These indicate that the minimum temperature variation was statistically insignificant, an indication of no trend in the time series data. The maximum temperature results showed a positive trend of 9.745% rise at a magnitude of 0.04 (α = 0.001) indicating a statistically significant rising maximum temperature trend.

Table 4.3: The Trend Analysis Results for the Maximum and Minimum Temperatures

TMIN					TMAX				
N	**Test Z**	**Significance**	**Q**	**% change**	**n**	**Test Z**	**Significance**	**Q**	**% change**
29	1.44		0.016	4.011	35	3.82	***	0.040	9.745

Where: **N:** Annual values without missing values. **Test Z:** The Z statistic. **Significance:** The significance level. **Q:** Sen's true slope **% change:** The percentage change.

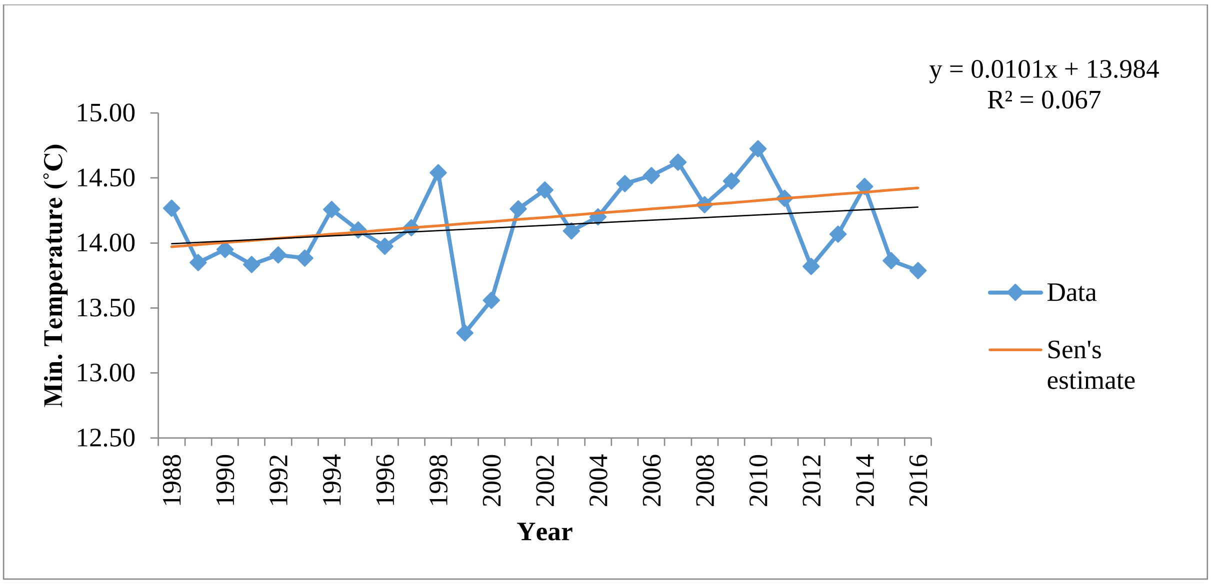


Figure 4.4: Monthly Minimum Temperature Trend

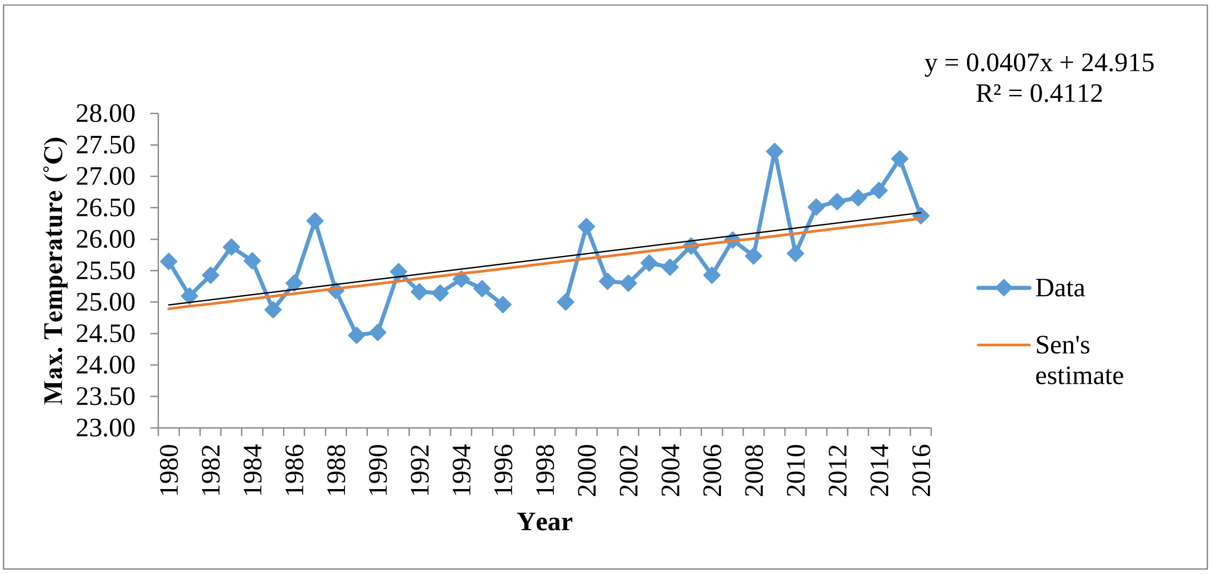


Figure 4.5: Monthly Maximum Temperature Trend.

4.4 The Community Climate Change Perceptions

4.4.1 Climate Change Awareness

From the study findings, most of the households (91.1%) were aware of climate change. Moreover, 95.4% of respondents had noted local climate changes from 1984 to 2014 as demonstrated in the following section.

4.4.2 Mist and Fog Occurrences

The study results in Figure 4.6 indicate that a majority of the respondents (64.1%) perceived increased frequency of mist occurrence while 22.8% perceived decreasing frequency of mist. One FGDs participant asserted that:

> "In the past, there used to be fog (*thatu*) in every April which does not happen anymore. July was also foggy and the coldest month of the year. July was locally referred to as "*muoria nyoni*" meaning that 'the cold froze birds to death'. Currently, July has become warmer while the cold season, fog and mist have shifted to August up to October."

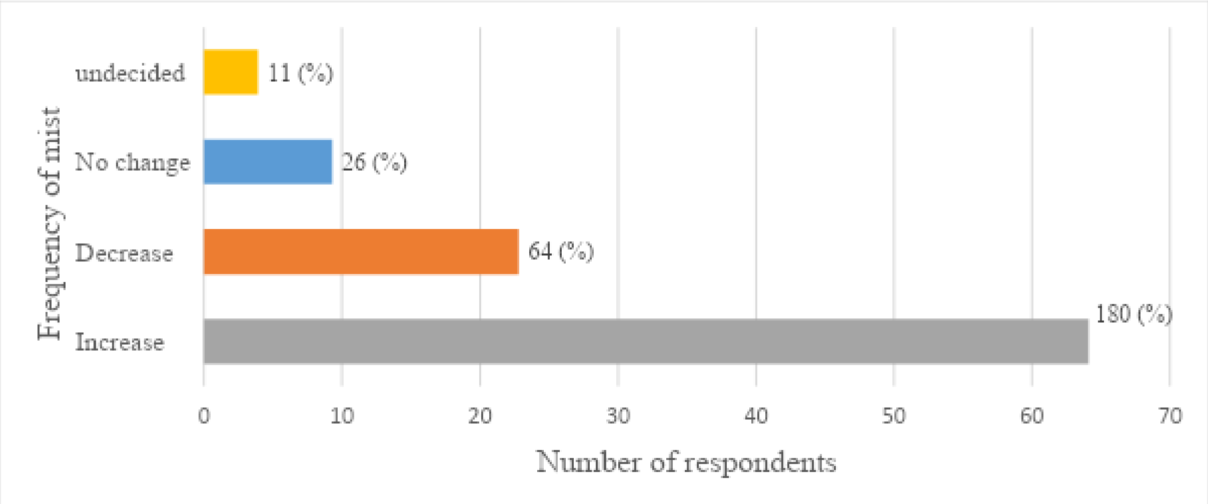


Figure 4.6: Frequency of Mist

4.4.3 Rainfall Changes

Regarding changes in drought frequency, nearly 72.2% of respondents perceived a rise, 22.1% reported a decrease while 5.7% reported no change. These finding concurred with the views of the area Assistant Chief who asserted that:

> "There are increased incidences of dry spells which have often taken longer than in the past. This leads to livestock feed shortage, reduction in tea production and food crop yields. To escape drought effects residents are growing short season crops such as cabbages (*Brassica oleracea*) courgettes *(Cucurbita pepo)* Irish potatoes *(Solanum tuberosum)* Sukuma wiki *(Brassica oleracea var. viridis)*."

Study findings on flood frequency indicated that 57.3% of respondents had observed a decrease, 33.5% had observed no change, 5.3% had observed an increase while 3.9% were unsure of any changes in flood frequency. One FGD participant noted that:

> "Floods are not very common here due to the steep terrain. However, during heavy rainfall, there is flooding on farms along river valleys which submerges crops such as vegetables and root crops. Soil erosion happens in open areas with no tea bushes."

Additionally, participants of one focus group discussion unanimously agreed with the views of one of the participants that:

> "Rainfall has become unreliable and is interrupting our normal cropping seasons. Planting times have become highly uncertain Traditionally, there were two predictable cropping seasons determined by the two rainfall seasons with long rains falling from March to May and short rains falling between October and December. This has become unpredictable hence crop planting is delayed due to dryness. Sometimes we lose seeds if we dry plant in anticipation of the rains. When we plant at the beginning of rains, we lose the crops if the rains stop earlier, fall for a short time or stop at the height of crop growth. We also spend more time and money due to more weeding times. Rainfall uncertainty makes crops to get stunted making yields to fall."

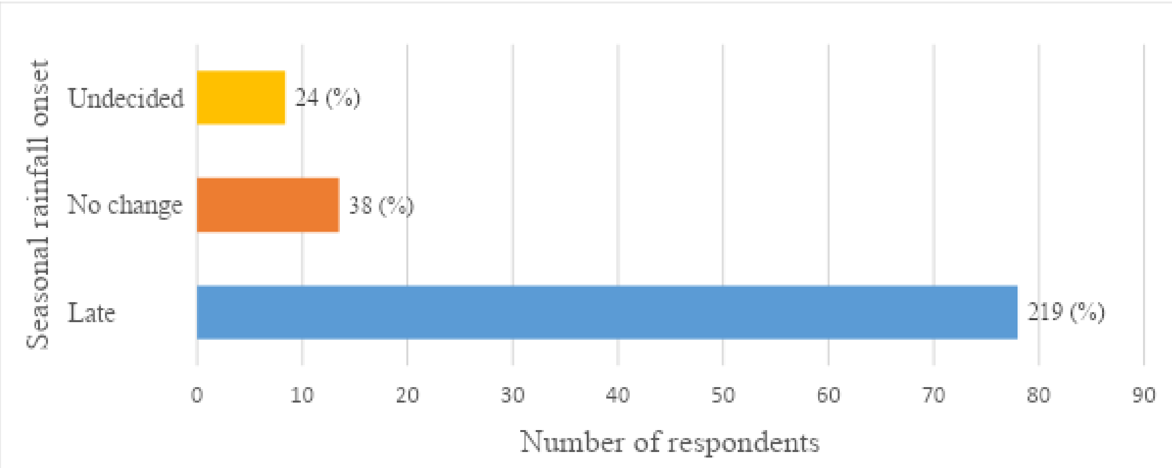


Figure 4.7: Perceived Changes in Onset of the Rainfall Seasons

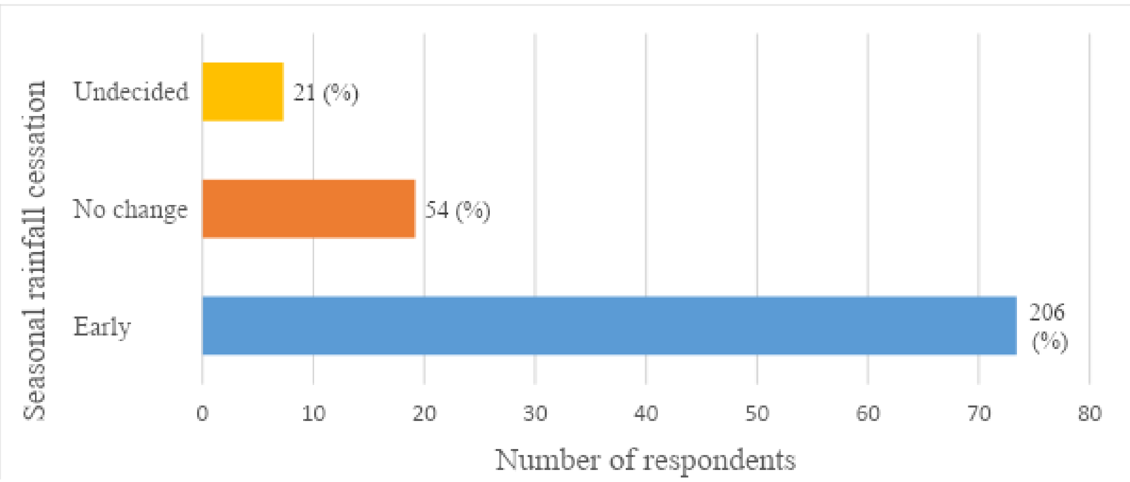


Figure 4.8: Perceived Changes in Cessation of the Rainfall Seasons

The study results indicate that a majority of the respondents (78%) perceived delayed seasonal rainfall onset (Figure 4.7) and about 73.4% of the respondents perceived early cessation of seasonal rainfall (Figure 4.8).

Regarding the community perceptions on changes in rainfall intensity, 77.2% of the respondents perceived a decrease, 9.6% perceived an increase, and 5.7% perceived no change. About 7.5 % were unsure of the changes. The FGDs participants agreed that rainfall intensity had become erratic. According to them, the rainfall amounts fluctuated from being too heavy to very light and were, therefore, insufficient for crop growth. These resulted in low food crop productivity.

The study findings on the community perceptions adequacy of rainfall for food crop growth, (Figure 4.9) indicate that most respondents (79.4%) perceived decreased rainfall adequacy during the crops growing seasons. One FGDs participant noted that:

> "Our main problem is that most of the rains fall at once thus fewer rainy days. Sometimes the rains stop mid-way the season resulting in poor crop yields or total crop loss."

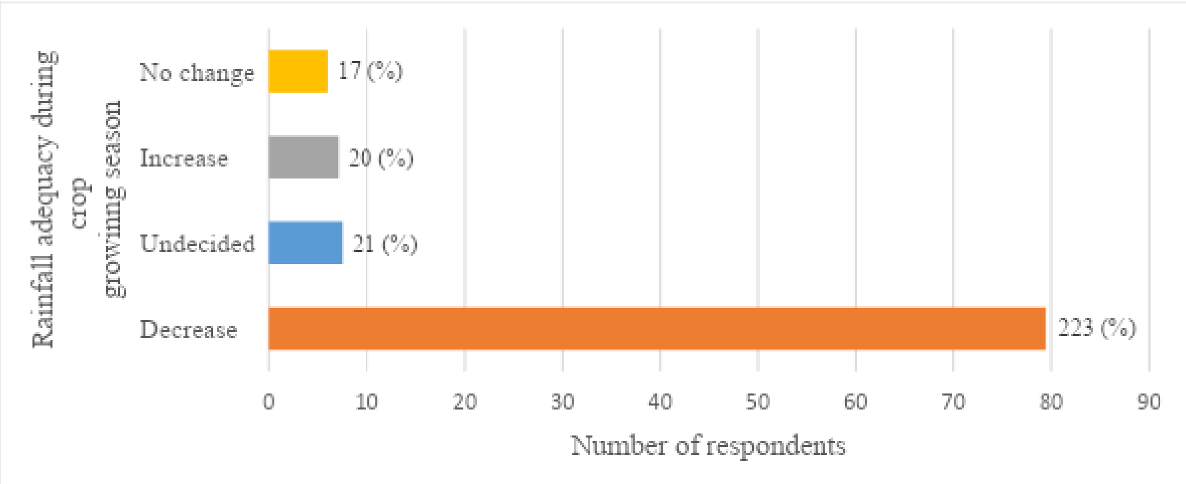


Figure 4.9: Adequacy of Rainfall During the Food Crops Growing Season

4.4.4 Temperature Changes

The study results on the study community perceptions on local temperature changes during the period 1984 to 2014 are summarized in the figure 4.10. One elderly key informant also opined that:

> "Seasons have really changed in this area. In the past, we knew the start and end of hot and cold seasons. Nowadays, temperatures have become very unpredictable. You cannot tell when it will be warm or cold. You cannot tell when the cold season will start or end. Sometimes it is warmer than expected while other times it's too cold. A day can start warmer and end up very cold. Sometimes it's so cold that our crops are damaged by frost. Other times, it's so hot that our crops dry up".

Reiterating this were FGD participants who unanimously concurred that:

> "Lately as compared to the past, we cannot predict how the temperatures will turn out. For example, July used to be the coldest month of the year here but nowadays it's quite warm. August used to be warm but has turned out to be the coldest month. July cold has moved to August and beyond."

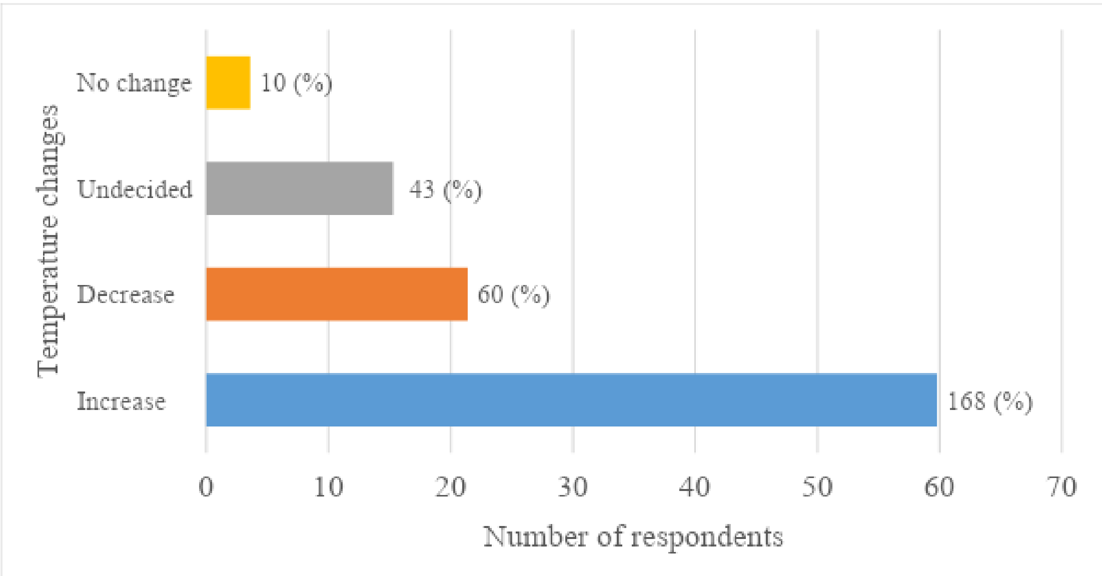


Figure 4.10: Temperature Changes

From the study results (Figure 4.10) a majority of the respondents (59.8%) perceived increasing local temperatures while about 21.4% perceived decreasing temperatures.

Table 4.4: Specific Weather Events Occurrences

Drought Year	% of respondent	Excessive Rain	% of respondents	Temperature	% of respondents	Mist Fog	% of respondents
1984	32.46	1997	19.47	1984	8.33	2006	4.76
1985	1.75	1998	28.32	2000	15.74	2013	11.90
1986	5.26	2010	0.88	2003	2.78	2016	14.29
1996	0.88	2015	27.43	2004	0.93	2002-2006	4.76
1998	0.88	2016	1.77	2010	1.85	2006-2007	2.38
2000	18.42	19982015	3.54	2014	1.85	2013 beginning	2.38
2004	4.39	1997-1998	15.04	2015	0.93	2013 February	2.38
2007	0.88	1998-2015	1.77	2016	4.63	2013 January February	4.76
2009	3.51	2010, 0ctober	0.88	2010 September	0.93	2013 January/ February	2.38
2010	7.02	2014, September	0.88	2015-2016	9.26	2016 June	2.38
2013	0.88			2016 but unpredictable	0.93	2016 May and June	2.38
2014	7.89			2016 January	0.93	2016, May and June	19.05
2015	1.75			2016 May and June	0.93	Annually (June – August)	2.38
2016	1.75			2016, May and June	0.93	between June & August	2.38
19842015	1.75			2016, May to June	0.93	every June to August	2.38
2000-2004	0.88			Changes Unpredictable	32.41	Happens in January	2.38
September	0.88			Continuous & unpredictable	7.41	July to August	2.38
1984	2.63			Continuous & unpredictable	4.63	June - July 2016	2.38
1999-2001	0.88			Mostly unpredictable	0.93	Normally in August	4.76
2005-May	0.88			Throughout	0.93	2015- January	2.38
2009-September	0.88			Unpredictable	1.85	2015- January	4.76
2016-January	0.88						
Every year	1.75						
Often	0.88						
Total	**100**		**100**		**100**		**100**

4.5 Discussion

From the study results, the majority of the household heads are middle-aged (57.3 %) and male (76.2 %). Ndambiri *et al.* (2012) argue that male household heads are presumed to perceive climate change more than females since male household heads have higher accessibility to current knowledge. Elderly farmers are assumed to notice changes in climate better than youthful farmers since farming experience enhances agronomic superiority. Most of the household heads were literate because nearly 52.7 % of them had achieved secondary-level education. Higher learning enlightens farmers on current climate change information. Hence, more learned farmers can notice climate change better than less-educated ones (Ndambiri *et al.,* 2012). The acreage of most households (95.3 %) was below 4.5 acres classifying them as smallholder farmers defined as those owning under 2.0 hectares (4.94 acres) (IFAD, 2013). The majority of the farmers (67.34 %) had dedicated most of their arable land to tea farming. The result agrees with the Murang'a County report (MCIDP, 2018).

The study results also revealed that the farmers had noticed irregular timing, intensity, amount, and timing of rainfall from 1984 to 2014. Perceived declining rainfall has also occurred in Ethiopia (Kassie *et al.,* 2013). However, the community perceptions on rainfall decline differed from the observed rainfall trends. The MAKESEN test showed that the rainfall trends were not statistically significant ($\alpha > 0.1$). A range of studies concurs that differences can happen between observed data and community perceptions (Rao *et al.,* 2011; Osbahr *et al.,* 2011; Kassie *et al.,* 2013; Zuma-Netshiukhwi *et al.,* 2013). Other studies have noted a difference between the way scientists and farmers quantify, assess, and describe rainfall and the impacts on the environment (Dahlberg and Blaikie 1996; Kinlund's, 1998; Ovuka and Lindqvist, 2000). It explains that farmers' perceptions depend on their recent encounters with drought occurrences. The complexity of a changing climate makes communication and collaboration necessary. The dependability of a prediction process determines its accuracy and approval by consumers for them to make their adaptation decisions based on it (Zuma-Netshiukhwi *et al.*, 2013; Ayal and Leal Filho, 2017). Therefore, adaptation intervention should rely on many information sources (Stigter, 2010; Coe and Stern, 2011).

Concerning temperature, the study results indicate that most respondents perceived rising temperatures from 1984 to 2014. Their perceptions concurred with the observed monthly maximum temperature data for Thika Meteorological Station and confirmed other similar studies. For example, temperatures in Siaya Sub-County, in Kenya showed rising trends (Wetende *et al.* 2018). Most farmers (87.5%) in Ondo State, Nigeria majority of farmers (87.5 %) have also experienced rising temperatures (Olayemi 2012). Africa's temperatures have risen above a decade ago. Thi warming could worsen in the coming thirty years (IPCC, 2014; Christensen *et al.*, 2007; Hulme *et al.* 2001). Warmer temperatures could reduce Africa's crop yields due to heightened crop-water stress that could cause crop drying, wilting, and sunburn (Faye *et al.* 2018; Dass *et al.* 2018; Nwokwu and Aniekwe, 2014).

4.6 Conclusions

Results from this study indicate a nearly 9.42 % reduction in the long rains (March to May) an 18.89 increase in the short rains (October to December) and a 0.37335 % increase in the annual rainfall. The trends were not statistically significant ($\alpha > 0.1$) indicating no significant rainfall variation in the study area. The results revealed a disparity between the scientific and community perspectives on the rainfall variations. Many respondents and a key informant perceived increasing drought frequency and prolonged dry spells. A majority of the households and a Key Informant had noticed persistent droughts. The majority of the respondents reported a decrease in rainfall intensity. Most of the respondents and a key informant perceived that irregular seasonal rainfall onset and cessation had reduced the number of rain days and made rainfall inadequate for crop production. The results showed a disparity in how farmers understand rainfall changes. Scientists measure rainfall amounts in mm over a period with a specific motive of minimizing uncertainty and raising predictability. However, farmers measure rainfall amounts based on how beneficial the available moisture is to them. Farmers, therefore, experience their environment and strive to make the best of their lives. The FGDs participants and a KII acknowledged that local temperatures were increasingly becoming unpredictable. Most of the respondents reported warming temperatures which agreed with observed temperature data. These implied that similar to other areas globally, the study area was warming.

CHAPTER FIVE: PERCEIVED PRESENT AND FUTURE RAINFALL AND TEMPERATURE CHANGE IMPACTS ON FOOD SECURITY AMONG KIMANDI-WANYAGA COMMUNITY

5.1 Introduction

This chapter focused on the research study's second objective by examining the perceived present and possible future rainfall and temperature change effects on food security in Kimandi-Wanyaga sub-Location in Murang'a County, Kenya. Studies have argued that local perceptions reflect a local concern that focuses on the real effects of climate variation on people's way of life, reliant on local context, and which may not be wholly captured using models (van Aalst *et al.,* 2008). The perceptions of people in a particular locality are rooted in their socio-cultural interactions and have a significant role in determination of changes that occur in their environment. Thus, farmers experience their surroundings and strive to make the best of their lives (Dahlberg and Blaikie, 1996; Kinlund's, 1998; Bhatta *et al.,* 2019). Local perceptions refer to "the way people identify and interpret observations and concepts" (Vignola *et al.,* 2010). This necessitates enhanced communication of the perceptions of local communities' undertaking autonomous adaptation to policymakers. An understanding of the way farmers observe, respond, and adapt to climatic changes and events at the microlevel can be a robust guide to policy and programming decisions (Castellanos *et al.,* 2013; Wheeler *et al.,* 2013). The data was collected by using household survey, FGDs and KIIs. Analyzed data were presented in tables, figures, and quotation formats.

5.2 Food Shortage Changes for the Period 1984 to 2014

The study results showed that approximately 71.9% of the responses perceived a change in food unavailability from 1984 to 2014. The study results (Table 5.1) found that most respondents at 45% attributed food shortage to reduced and unpredictable rain, persistent droughts, warming temperatures, and uncertain rainfall seasons. About 11.4% of the respondents associated food shortage with unproductive and acidic soils.

Table 5.1: Reasons for Changes in Food Shortage

Food shortage reasons	Frequency	Percent
Reduced and unpredictable rain, persistent droughts, warming temperatures, and uncertain rainfall seasons	91	45.0
Unproductive and acidic soils	23	11.4
Increased outbreaks of food crop pests and diseases	17	8.4
Unreliable income to make full use of farm potential	12	5.9
Small farm acreage for crops growth resulting in continued cropping	11	5.4
Poor food crop varieties	6	3.0
Low food crop yields	13	6.4
Irregular seasonal yields	16	7.9
Poor uncertified seeds	8	4.0
Decreased irrigation from river waters	5	2.5
Total	**202**	**100.0**

From the FGDs, participants agreed with the views of one of the participants that:

> "Rainfall has become unreliable and is interrupting our normal cropping seasons. Planting times have become highly uncertain Traditionally, there were two predictable cropping seasons determined by the two rainfall seasons with long rains falling from March to May and short rains falling between October and December. This has become unpredictable hence crop planting is delayed due to dryness. Sometimes we lose seeds if we dry plant in anticipation of the rains. When we plant at the beginning of rains, we lose the crops if the rains stop earlier, fall for a short time or stop at the height of crop growth. We also spend more time and money due to more weeding times. Rainfall uncertainty makes crops to get stunted making yields to fall."

5.3 Households' Food Insecurity.

The various replies from the household survey showed that during the year 2014, 62% of households had experienced hunger, 68% had experienced financial inadequacy to buy food, while 71% had rationed their meal sizes. Nearly 74% of the households had skipped a meal, and 76% decreased the variety of foods they consumed. The FGD participants agreed with one participant that:

> "Rainfall in this area has changed and it has reduced our crop yields, especially maize. This has brought food shortages. In the past, we used to harvest enough maize to store for the whole year. Every home had a granary for storing maize. We dried the maize in the sun and stored it for making *Githeri* (boiled maize and beans) and porridge. We

used to cook a lot of food and store it in the granaries. The granaries were not locked so that all family members and visitors would be able to serve themselves food freely. We shared our food freely because we had a lot of food. We also had many celebrations in a year especially after harvesting our crops. Now we don't have granaries because we have little food to store. We don't have enough food to keep until the next harvest and we buy most of our foods from the local markets, Thika town or from Nyandarua County. Most of the money we get from tea is used to buy food and pay school fees. Families with small farms don't have enough money to buy food and spend on other things and sometimes they go hungry. They have to work on other people's farms to earn money."

Regarding the duration of the households self-provisioning, 40.2% of the households reported 2 months, 38.8% reported 1 month, 20.6% indicated 3 months, and 0.4% said 6 months. A KI said that:

"Most of us here do not harvest enough food to use until the next harvest. Families with enough money usually buy food such as Irish potatoes, green peas, cabbages, tomatoes and carrots from our neighboring Counties."

The results of the number of the households' daily meals indicated that 71.5% had two meals, 27.1% had three meals, 9.2% had one meal, and 1.4% would consume four meals.

5.3.1 The Community's Dietary Diversity

The study results on the community's dietary diversity analysed through the Household Dietary Diversity Score (HDDS) method (Table 5.2) show within that last 24 hours being referenced, majority of the respondent households had taken cereals (82.6 %), followed by sugar and honey (67.3 %) oils and fats (65.5 %) vegetables (60.5 %) roots and tubers (58.7 %) and, legumes and nuts (55.5 %). The least consumed food groups were fruits (31 %) meat and poultry (30.6 %) and eggs (23.5 %).

Table 5.2: Food Categories Consumed within the Reference 24-Hour Period. (n=281).

Food Categories	Count	Percent
Cereals	232	82.6
Sugar/honey	189	67.3
Oil/fats	184	65.5
Vegetables	170	60.5
Root and tubers	165	58.7
Legumes/nuts	156	55.5
Milk and milk products	123	43.8
Fruits	87	31.0
Meat/poultry	86	30.6
Eggs	66	23.5
Fish	17	6.0
Miscellaneous food items	148	52.7

NB: Multiple Responses Frequency Table

One key informant also asserted that:

> "The common diets here are *Githeri* (boiled maize (*Zea mays*) and beans *(Phaseolus vulgaris*) fried with cabbages (*Brassica oleracea*) Irish potatoes *(Solanum tuberosum)* or mashed with pumpkin *(Cucurbita moschata)* leaves, *Ugali* (maize flour cooked with boiled water to a dough-like consistency) eaten with *Sukuma wiki (Brassica oleracea var. viridis)* or cabbages (*Brassica oleracea*). Also common are rice *(Oryza sativa)* beans *(Phaseolus vulgaris)* arrowroots *(Xanthosoma sagittifolium)* sweet potatoes *(Ipomea batata)* and eggs but meat and chicken are not commonly eaten by many households".

Table 5.3: Household Dietary Diversity Score (HDDS)

	N	Minimum	Maximum	Mean	Std. Deviation
HDSS	281	2	7	4.0036	1.11323

The study results of the calculated HDDS (Table 5.3) indicated that the study community's average household dietary diversity score was approximately 4.0036.

5.3.2 The Distribution of HDSS across the Households

Table 5.4: Distribution of HDSS Across the Households

HDSS	Frequency	Percent
2	19	6.8
3	74	26.3
4	109	38.8
5	53	18.9
6	18	6.4
7	8	2.8
Total	**281**	**100.0**

The study results of the distribution of the HDSS among the survey sample (Table 5.4) indicated that most of the households (38.8%) had an HDDS score of 4.

5.4 Household Characteristics and Food Security

The study examined the association between the household heads' socio-demographic characteristics and the food security within the study community. The demographic characteristics considered consisted of gender, age, education level, occupation, and the farm acreage under food crop production. The indicators of food security were the number of daily meals, meal size, and dietary variety of meals.

5.4.1 Gender of Household Heads and Food Security of Households

The Table 5.5 provides the cross-tabulation analysis results between the gender of household heads and the food security indicators. The results indicate a significant association between the gender of the household heads and the household number of daily meals as depicted by χ^2=11.625 and p=0.003 that was less than 0.05. The study also found that the gender of household heads was significantly associated with the meal sizes (χ^2=4.620, p= 0.032) and the household meal quality (χ^2=5.560, p= 0.018). The findings reveal that more female-headed households consumed fewer daily meals, smaller meal sizes, and lower quality daily meals than male-headed households. The findings concur with Aidoo *et al.* (2013) that the food security status of male-led households is expected to be higher than the female-led ones.

Table 5.5: Cross-Tabulation Analysis Between Gender of Household Heads and the Food Security Indicators.

Gender of household head	Household daily meals					
	Two	Three	Four	Total		
	n; (%)	n; (%)	n; (%)	n; (%)	χ^2	p-value
Male	143; 66.8	67; 31.3	4; 1.9	214; 76.2	11.625	0.003
Female	59; 88.1	8; 11.9	0; 0.0	6; 23.8		
Total	202; 71.9	75; 26.7	4;1.4	281; 100.0		
	Reduction in food sizes in 2014 due to food unavailability					
	Yes	**No**	**Total**			
	n; (%)	**n; (%)**	**n; (%)**		**χ^2**	**p-value**
Male	143; 66.8	71; 33.2	214; 76.2		4.620	0.032
Female	54; 80.6	13; 19.4	6; 23.8			
Total	197; 70.1	84; 29.9	281; 100.0			
	Decreased meals variety due to food unavailability					
	Yes	**No**	**Total**			
	n; (%)	**n; (%)**	**n; (%)**		**χ^2**	**p-value**
Male	155; 72.4	59; 27.6	214; 76.2		5.560	0.018
Female	58; 86.6	9; 13.4	6; 23.8			
Total	213; 75.8	68; 24.2	281; 100.0			

5.4.2 Age of Household Heads and Food Security of Households

The results of the linkage analysis comparing the household's age and food security situation (Table 5.6) show a significant association (χ^2=24.264, *p*= 0.007) between the age of the household head and the how many daily meals are consumed in the particular household. There were also significant associations between the age of the household heads and the household meal sizes (χ^2=13.039, *p*= 0.023) and meal variety (χ^2=13.543, *p*= 0.019). The findings showed that households led by relatively younger persons had a higher expectation of better food security compared to those by older ones. Several studies argue that youthful household heads will be stronger and active than older household heads and can cultivate larger farm sizes and obtain high yields (Abafita and Kim, 2014; Babatunde, 2007). Therefore, younger household heads can make their households more food secure than the elderly ones.

Table 5.6: Cross-Tabulation Analysis on Household Heads' Age and the Households Food Security

Age of household heads	Household daily meals				χ^2	p-value
	Two	Three	Four	Total		
	n; (%)	n; (%)	n; (%)	n; (%)		
=<25years	0; 0.0	1; 100.0	0; 0.0	1; 0.4	24.264	0.007
26-35years	16; 47.1	16; 47.1	2; 5.9	34; 12.1		
36-45years	53; 67.9	24; 30.8	1; 1.3	78; 27.8		
46-55years	60; 73.2	21; 25.6	1; 1.2	82; 29.2		
56-65years	38; 82.6	8; 17.4	0; 0.0	46; 16.4		
Above 65 years	35; 87.5	5; 12.5	0; 0.0	40; 14.2		
Total	202; 71.9	75; 26.7	4; 1.4	281; 100.0		
	Reduction in food sizes in 2014 due to food unavailability				**χ^2**	**p-value**
	Yes	**No**	**Total**			
	n; (%)	**n; (%)**	**n; (%)**			
=<25years	0; 0.0	1; 100.0	1; 0.4		13.039	0.023
26-35years	17; 50.0	17; 50.0	34; 12.1			
36-45years	52; 66.7	26; 33.3	78; 27.8			
46-55years	60; 73.2	22; 26.8	82; 29.2			
56-65years	36; 78.3	10; 21.7	46; 16.4			
Above 65 years	32; 80.0	8; 20.0	40; 14.2			
Total	197; 70.1	84; 29.9	281; 100.0			
	Decreased meals variety due to food unavailability				**χ^2**	**p-value**
	Yes	**No**	**Total**			
	n; (%)	**n; (%)**	**n; (%)**			
=<25years	0; 0.0	1; 100.0	1; 0.4		13.543	0.019
26-35years	22; 64.7	12; 35.3	34; 12.1			
36-45years	54; 69.2	24; 30.8	78; 27.8			
46-55years	65; 79.3	17; 20.7	82; 29.2			
56-65years	38; 82.6	8; 17.4	46; 16.4			
Above 65 years	36; 90.0	4; 10.0	40; 14.2			
Total	215; 76.5	66; 23.5	281; 100.0			

5.4.3 Occupation of Household Heads and Food Security of Households

Table 5.7 outlines the Cross-tabulated analysis findings comparing the household heads occupation and their households' food security.

Table 5.7: Cross-Tabulation Analysis Between Occupation of Household Heads and the Households' Food Security

Occupation of household heads	Household daily meals				χ^2	p-value
	Two	Three	Four	Total		
	n; (%)	n; (%)	n; (%)	n; (%)		
Farmer only	175; 75.1	58; 24.9	0; 0.0	233; 82.9	23.037	0.000
Farmer and other income source	27; 56.2	17; 35.4	4; 8.3	48; 17.1		
Total	202; 71.9	75; 26.7	4; 1.4	281; 100.0		
	Reduction in food sizes in 2014 due to food unavailability				**χ^2**	**p-value**
	Yes	**No**	**Total**			
	n; (%)	**n; (%)**	**n; (%)**			
Farmer only	179; 76.8	54; 23.2	233; 82.9		29.368	0.000
Farmer and other income source	18; 37.5	30; 62.5	48; 17.1			
Total	197; 70.1	84; 29.9	281; 100.0			
	Decreased meals variety due to food unavailability				**χ^2**	**p-value**
	Yes	**No**	**Total**			
	n; (%)	**n; (%)**	**n; (%)**			
Farmer only	187; 80.3	46; 19.7	233; 82.9		14.770	0.000
Farmer and other income source	26; 54.2	22; 45.8	48; 17.1			
Total	213; 75.8	68; 24.2	281; 100.0			

The study results (Table 5.7) show that the occupation of the household heads and the number of meals consumed by household heads daily were significantly associated (χ^2=23.037, p= 0.000). From the study findings, the household heads who were farmers and earned an extra off-farm income had their households consume a higher number of daily meals than the household heads' who were only involved in farming. Similarly, the occupation of the household heads and the size of meals consumed were significantly associated given (χ^2=29.368, p= 0.000). A significant association also existed between the occupation of the household heads and the households' meal variety (χ^2=14.770, p= 0.000).4.4 Education of Household Heads and Food Security of Households

5.4.4. Education of Household Heads and Food Security of Households

The study results (Table 5.8) on the cross-tabulated analysis comparing the education of household heads with the households' food security show no substantial linkage between education level of household heads and the number of households' daily meals as shown by χ^2=4.357 and p=0.628) that is higher than 0.05. There was also no substantial linkage between the household heads' education level and the households' meal sizes (χ^2=5.572, p= 0.134). Furthermore, the association between the household heads' education level and the households' meal variety was not statistically important (χ^2=5.667, p= 0.129).

Table 5.8: Cross-Tabulated Analysis Between Education of Household Heads and Households' Food Security

Education of household heads	Household daily meals					
	Two	**Three**	**Four**	**Total**	**χ²**	**p-value**
	n; (%)	**n; (%)**	**n; (%)**	**n; (%)**		
No formal education	21; 84.0	4; 16.0	0; 0.0	25; 8.9	4.357	0.628
Primary	58; 71.6	21; 25.9	2; 2.50	81; 28.8		
Secondary	106;71.6	40; 27.0	2; 1.40	148; 52.7		
College / University	17; 63.0	10; 37.0	0; 0.0	27; 9.6		
Total	202; 71.9	75; 26.7	4; 1.40	281; 100.0		
	Reduction in food sizes in 2014 due to food unavailability					
	Yes	**No**	**Total**		**χ²**	**p-value**
	n; (%)	**n; (%)**	**n; (%)**			
No formal education	20; 80.0	5; 20.0	25; 8.9		5.572	0.134
Primary	63; 77.8	18; 22.2	81; 28.8			
Secondary	97; 65.50	51; 34.5	148; 52.7			
College / University	17; 63.0	10; 37.0	27; 9.6			
Total	197; 70.10	84; 29.9	281; 100.0			
	Decreased meals variety due to food unavailability					
	Yes	**No**	**Total**		**χ²**	**p-value**
	n; (%)	**n; (%)**	**n; (%)**			
No formal education	21; 84.0	4; 16.0	25; 8.9		5.667	0.129
Primary	67; 82.7	14; 17.3	81; 28.8			
Secondary	110; 74.3	38; 25.7	148; 52.7			
College / University	17; 63.0	10; 37.0	27; 9.6			
Total	215; 76.5	66; 23.5	281; 100.0			

5.4.5 Farm Acreage under Food Crops Cultivation and Household's Food Security

The study examined whether the household farm acreage under food crops was associated with how food secure the households were in the study locality. The findings of the study (Table

5.9) indicate a significant association between the households' farm size under food crops and the sum daily meals in the households' (χ^2=60.898, p= 0.000). The farm acreage under food crops was also significantly associated with the households' meal sizes (χ^2=17.410, p= 0.001) and meal variety (χ^2=29.960, p= 0.000). These findings implied a significant association between the households' farm acreage under food crops and how food secure the households were in the study locality. These findings reflect that the bigger household's farm acreage under food crops, the higher the number, ration, and variety of households' daily meals. The findings agree with Mitiku *et al.* (2012) that a bigger size of productive land implies more yields, increased access to food sources and assurance of a food secured household.

Table 5.9: Cross-Tabulation Analysis Between Farm Acreage Under Food Crop Cultivation and the Households' Food Security

Farm acreage under food crop production	Number of meals eaten daily				χ^2	p-value
	Two	Three	Four	Total		
	n; (%)	n; (%)	n; (%)	n; (%)		
0.00-0.50	173; 74.9	58; 25.1	0; 0.0	231; 82.2	60.898	0.000
0.51-1.00	22; 71.0	9; 29.0	0; 0.0	31; 11.0		
1.01-1.50	4; 40.0	4; 40.0	2; 20.0	10; 3.6		
Above 1.50	3; 33.3	4; 44.4	2; 22.2	9; 3.2		
Total	202; 71.9	75; 26.7	4; 1.4	281; 100.0		
	Reduction in food sizes in 2014 due to food unavailability					
	Yes	No	Total		χ^2	p-value
	n; (%)	n; (%)	n; (%)			
0.00-0.50	172; 74.5	59; 25.5	231; 82.2		17.410	0.001
0.51-1.00	19; 61.3	12; 38.7	31; 11.0			
1.01-1.50	4; 40.0	6; 60.0	10; 3.6			
Above 1.50	2; 22.2	7; 77.8	9; 3.2			
Total	197; 70.1	8; 29.9	281; 100.0			
	Ate lower quality foods than usual because food was inadequate					
	Yes	No	Total		χ^2	p-value
	n; (%)	n; (%)	n; (%)			
0.00-0.50	187; 81.0	44; 19.0	231; 82.2		29.960	0.000
0.51-1.00	21; 67.7	10; 32.3	31; 11.0			
1.01-1.50	3; 30.0	7; 70.0	10; 3.6			
Above 1.50	2; 22.2	7; 77.8	9; 3.2			
Total	213; 75.8	68; 24.2	281; 100.0			

5.5 The Linkage on Perceived Rainfall Variations and Household Food Security (1984 - 2014).

Chi-Square tests conducted to determine the linkage of perceived rainfall change impacts how food secure the households were. The perceptions of rainfall changes were determined based on drought frequency, rainfall adequacy during crops growth, rainfall intensity, rainfall onset season, and rainfall season cessation. The indicators of household food security were the number of household daily meals, duration of time households ate own-produced food, diet variety, and meal sizes.

The study results of the association between the perceived changes in drought frequency and the household's food security (Table 5.10) show a p-value of 0.000 of less than 0.05. This implied a significant association between drought frequency and the households' number of daily meals (χ^2=73.807[a], p= 0.000) the duration of time households ate own-produced foods (χ^2=53.951[a], p= 0.000) the households' meal quality (χ^2=31.411[a], p= 0.000) and the households' meal sizes consumed in the year 2014 (χ^2=53.333[a], p= 0.000).

Table 5.10: Analyzed Linkage on Perceived Drought Occurrences and Households' Food Security

Frequency of drought	Household daily meals					
	Two n; (%)	Three n; (%)	Four n; (%)	Total n; (%)	χ²	p-value
No change	42; 67.70	20; 32.30	0; 0.00	62; 22.06	73.807[a]	0.000
Decreased	5; 31.20	7; 43.80	4; 25.00	16; 5.69		
Increased	155; 76.40	48; 23.60	0; 0.00	203; 72.24		
Total	202; 71.90	75; 26.70	4; 1.40	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.23.

	Number of months in a year household ate own-produced foods						
	1 Month n; (%)	2 Months n; (%)	3 Months n; (%)	6 months n; (%)	Total n; (%)	χ²	p-value
No change	12; 19.40	30; 48.40	20; 32.30	0; 0.00	62; 22.06	53.951[a]	0.000
Decreased	2; 12.50	3; 18.80	10; 62.50	1; 6.20	16; 5.69		
Increased	95; 46.80	80; 39.40	28; 13.80	0; 0.00	203; 72.24		
Total	109; 38.80	113; 40.20	58; 20.60	1; 0.40	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.06.

	Decreased meals variety due to food unavailability				
	Yes n; (%)	No n; (%)	Total n; (%)	χ²	p-value
No change	38; 61.30	24; 38.70	62; 22.06	31.411[a]	0.000
Decreased	5; 31.20	11; 68.80	16; 5.69		
Increased	170; 83.70	33; 16.30	203; 72.24		
Total	213; 75.80	68; 24.20	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 4.87.

	Reduction in food sizes in 2014 due to food unavailability				
	Yes n; (%)	No n; (%)	Total n; (%)	χ²	p-value
No change	26; 41.90	36; 58.10	62; 22.06	53.333[a]	0.000
Decreased	4; 25.00	12; 75.00	16; 5.69		
Increased	167; 82.30	36; 17.70	203; 72.24		
Total	197; 70.10	84; 29.90	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.78.

Table 5.11: Analysis of the Perceived Changes Rainfall Adequacy During the Crops Growing Season and the Household's Food Security

Rainfall adequacy during crop growing season	Number of meals households took daily					
	Two n; (%)	Three n; (%)	Four n; (%)	Total n; (%)	χ^2	p-value
Decreased	172; 77.10	51; 22.90	0; 0.00	223;79.36	43.265[a]	0.000
No change	10; 58.80	7; 41.20	0; 0.00	17; 6.05		
Increased	7; 35.00	10; 50.00	3; 15.00	20; 7.12		
Undecided	13; 61.90	7; 33.30	1; 4.80	21;7.47		
Total	202; 71.90	75; 26.70	4; 1.40	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.30.

	Number of months in a year that households ate homegrown foods						
	1 Month n; (%)	2 Months n; (%)	3 Months n; (%)	6months n; (%)	Total n; (%)	χ^2	p-value
Decreased	96; 43.00	88; 39.50	39; 17.50	0; 0.00	223;79.36	29.430[a]	0.001
No change	6; 35.30	8; 47.10	3; 17.60	0; 0.00	17; 6.05		
Increased	1; 5.00	10; 50.00	8; 40.00	1; 5.00	20; 7.12		
Undecided	6; 28.60	7; 33.30	8; 38.10	0; 0.00	21;7.47		
Total	109; 38.80	113; 40.20	58; 20.60	1; 0.40	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.47.

	Consumed lower quality variety of foods than usual because food was not enough				
	Yes n; (%)	No n; (%)	Total n; (%)	χ^2	p-value
Decreased	184; 82.50	39; 17.50	223;79.36	31.045[a]	0.000
No change	11; 64.70	6; 35.30	17; 6.05		
Increased	7; 35.00	13; 65.00	20; 7.12		
Undecided	11; 52.40	10; 47.60	21;7.47		
Total	213; 75.80	68; 24.20	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.11.

	Reduction in food sizes in 2014 due to food unavailability				
	Yes n; (%)	No n; (%)	Total n; (%)	χ^2	p-value
Decreased	181; 81.20	42; 18.80	223;79.36	75.860[a]	0.000
No change	9; 52.90	8; 47.10	17; 6.05		
Increased	0; 0.00	20; 100.0	20; 7.12		
Undecided	7; 33.30	14; 66.70	21;7.47		
Total	197; 70.10	84; 29.90	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.08.

The findings of the analyzed linkage on rainfall availability during cropping season and how food secure the households are given by Table 5.11. Rain availability in the duration of the crops' growth had significant relation with how many meals would eventually be taken by the households daily (χ^2=43.265[a], p= 0.000), how many months the households took homegrown foods (χ^2=29.430[a], p= 0.000), how varied the food eaten in the households were (χ^2=31.045[a], p= 0.000) and the households' meal rations taken in that year 2014 (χ^2=75.860[a], p= 0.000).

Table 5.12: Analyzed linkage on the Perceived Rainfall Intensity and the Households' Food Security

Rainfall intensity	Household daily meals				χ^2	p-value
	Two n; (%)	Three n; (%)	Four n; (%)	Total n; (%)		
Decreased	172; 79.30	45; 20.70	0; 0.00	217; 77.23	69.170[a]	0.000
No change	8; 50.00	8; 50.00	0; 0.00	16; 5.69		
Increased	6; 22.20	17; 63.00	4; 14.80	27; 9.61		
Undecided	16; 76.20	5; 23.80	0; 0.00	21; 7.47		
Total	202; 71.90	75; 26.70	4; 1.40	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 4.23.

	Duration in year that households ate the foods they produced					χ^2	p-value
	1 Month n; (%)	2 Months n; (%)	3 Months n; (%)	6 months n; (%)	Total n; (%)		
Decreased	99; 45.60	85; 39.20	33; 15.20	0; 0.00	217; 77.23	44.119[a]	0.000
No change	5; 31.20	7; 43.80	4; 25.00	0; 0.00	16; 5.69		
Increased	2; 7.40	9; 33.30	15; 55.60	1; 3.70	27; 9.61		
Undecided	3; 14.30	12; 57.10	6; 28.60	0; 0.00	21; 7.47		
Total	109; 38.80	113; 40.20	58; 20.60	1; 0.40	281; 100.0		

[a] 0.0cells (0.0%) have expected count less than 5. The minimum expected count is 5.06.

	Decreased meals variety due to food unavailability			χ^2	p-value
	Yes n; (%)	No n; (%)	Total n; (%)		
Decreased	178; 82.00	39; 18.00	217; 77.23	22.555[a]	0.000
No change	11; 68.80	5; 31.20	16; 5.69		
Increased	14; 51.90	13; 48.10	27; 9.61		
Undecided	10; 47.60	11; 52.40	21; 7.47		
Total	213; 75.80	68; 24.20	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 4.87.

	Reduction in food sizes in 2014 due to food unavailability			χ^2	p-value
	Yes n; (%)	No n; (%)	Total n; (%)		
Decreased	165;76.00	52; 24.00	217; 77.23	20.136[a]	0.000
No change	11; 68.80	5; 31.20	16; 5.69		
Increased	13; 48.10	14; 51.90	27; 9.61		
Undecided	8; 38.10	13; 61.90	21; 7.47		
Total	197; 70.10	84; 29.90	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.78.

The findings of the association between changes in rainfall intensity and the household food security (Table 5.12) reflected an important association between start of the rainy season onset and the household daily meals (χ^2=69.170[a], p= 0.000) the duration of time the households consumed homegrown foods (χ^2=44.119[a], p= 0.000) the food variety taken in the households (χ^2=22.555[a], p= 0.000) and the size of households meals consumed in the year 2014 (χ^2=20.136[a], p= 0.000).

Table 5.13: Analyzed linkage of Perceived Changes in the Onset of the Rainfall Season and the Households' Food Security

Seasonal rainfall onset	Number of meals the households consumed daily					
	Two	Three	Four	Total	χ^2	p-value
	n; (%)	n; (%)	n; (%)	n; (%)		
Changed	161; 73.50	58; 26.50	0; 0.00	219; 77.94	31.715[a]	0.000
No change	20; 52.60	14; 36.80	4; 10.50	38; 13.52		
Undecided	21; 87.50	3; 12.50	0; 0.00	24; 8.54		
Total	202; 71.90	75; 26.70	4; 1.40	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.06.

	Number of months in a year that households consumed own-produced foods						
	1 Month	2 Months	3 Months	6months	Total	χ^2	p-value
	n; (%)	n; (%)	n; (%)	n; (%)	n; (%)		
Changed	100; 45.70	85; 38.80	34; 15.50	0; 0.00	219; 77.94	33.905[a]	0.000
No change	4; 10.50	16; 42.10	17; 44.70	1; 2.60	38; 13.52		
Undecided	5; 20.80	12; 50.00	7; 29.20	0; 0.00	24; 8.54		
Total	109; 38.80	113; 40.20	58; 20.60	1; 0.40	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 9.14.

	Decreased meals variety due to food unavailability				
	Yes	No	Total	χ^2	p-value
	n; (%)	n; (%)	n; (%)		
Changed	171; 78.10	48; 21.90	219; 77.94	3.403[a]	0.182
No change	27; 71.10	11; 28.90	38; 13.52		
Undecided	15; 62.50	9; 37.50	24; 8.54		
Total	213; 75.80	68; 24.20	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.81.

	Reduction in food sizes in 2014 due to food unavailability				
	Yes	No	Total	χ^2	p-value
	n; (%)	n; (%)	n; (%)		
Changed	161; 73.50	58; 26.50	219; 77.94	6.887[a]	0.032
No change	20; 52.60	18; 47.40	38; 13.52		
Undecided	16; 66.70	8; 33.30	24; 8.54		
Total	197; 70.10	84; 29.90	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 7.17.

The findings of the linkage of rainfall onset how food secure the household was (Table 5.13) indicate a significant association between the seasonal rainfall onset and the number of households' daily meals (χ^2=31.715[a], p= 0.000), the duration when the households consumed own-produced foods (χ^2=33.905[a], p= 0.000) and the size of meals the households consumed in the year 2014 (χ^2=6.887[a], p= 0.000). The study found no statistically significant association between the seasonal rainfall-onset and the households' meal variety (χ^2=3.403[a] a; p=0.182).

Table 5.14. Analyzed Linkage on the Perceived Changes in the Rainy Season Cessation and the Households' Food Security (source: survey data from 2015)

Rainfall cessation	Household daily meals					χ^2	p-value
	Two n; (%)	Three n; (%)	Four n; (%)	Total n; (%)			
Changed	153; 74.30	53; 25.70	0; 0.00	206; 73.31		17.851[a]	0.001
No change	34; 63.00	16; 29.60	4; 7.40	54; 19.22			
Undecided	15; 71.40	6; 28.60	0; 0.00	21; 7.47			
Total	202; 71.90	75; 26.70	4; 1.40	281; 100.0			
[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.31.							
	Number of months in a year that family consumed own-produced foods						
	1 Month n; (%)	**2 Months n; (%)**	**3 Months n; (%)**	**6 months n; (%)**	**Total n; (%)**	**χ^2**	**p-value**
Changed	90; 43.70	80; 38.80	36; 17.50	0; 0.00	206; 73.31	13.186[a]	0.040
No change	13; 24.10	24; 44.40	16; 29.60	1; 1.90	54; 19.22		
Undecided	6; 28.60	9; 42.90	6; 28.60	0; 0.00	21; 7.47		
Total	109; 38.80	113; 40.20	58; 20.60	1; 0.40	281; 100.0		
[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.28.							
	Decreased meals variety due to food unavailability						
	Yes n; (%)	**No n; (%)**	**Total n; (%)**			**χ^2**	**p-value**
Changed	164; 79.60	42; 20.40	206; 73.31			11.100[a]	0.004
No change	39; 72.20	15; 27.80	54; 19.22				
Undecided	10; 47.60	11; 52.40	21; 7.47				
Total	213; 75.80	68; 24.20	281; 100.0				
[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.08.							
	Reduction in food sizes in 2014 due to food unavailability						
	Yes n; (%)	**No n; (%)**	**Total n; (%)**			**χ^2**	**p-value**
Changed	154; 74.80	52; 25.20	206; 73.31			13.116[a]	0.001
No change	35; 64.80	19; 35.20	54; 19.22				
Undecided	8; 38.10	13; 61.9	21; 7.47				
Total	197; 70.10	84; 29.90	281; 100.0				
[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.28.							

Table 5.14 shows the association of perceived changes on when the season's rainfall ceased and how many meals the household took daily (χ^2=17.851[a], p= 0.001), how many months within a year they took their own homegrown foods (χ^2=13.186[a], p= 0.040), the varied the meals were (χ^2=11.100[a], p= 0.004) and the households' meal sizes during the year 2014 (χ^2=13.116[a], p= 0.001). Based on these findings, the study community's perceived rainfall changes and the level of their household food security were significantly related. The study however found no statistically significant association between the seasonal rainfall-onset and the quality of household meals.

5.6 The Association between Perceived Temperature Changes and the Households' Food Security (1984-2014).

To determine the association of changes perceived in temperature and how food secure the household was, a Chi-Square assessment and analysis was conducted. The findings are given in Table 5.15.

Table 5.15. Cross-Tabulation Analysis of the Perceived Temperature Changes and the Households' Food Security (source: survey data from 2015

Temperature changes	Number of meals households consumed daily					
	Two n; (%)	**Three** n; (%)	**Four** n; (%)	**Total** n; (%)	**χ^2**	**p-value**
Decreased	42; 70.00	18; 30.00	0; 0.00	60; 21.35	27.498[a]	0.000
No change	6; 60.00	2; 20.00	2; 20.00	10; 3.56		
Increased	121; 72.00	46; 27.40	1; 0.60	168;59.79		
No response	33; 76.70	9; 20.90	1; 2.30	43; 15.30		
Total	202; 71.90	75;26.70	4; 1.40	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.14.

	Number of months in a year that households consumed own-produced foods						
	1 Month n; (%)	**2 Months** n; (%)	**3 Months** n; (%)	**6months** n; (%)	**Total** n; (%)	**χ^2**	**p-value**
Decreased	27; 45.00	19; 31.70	14; 23.30	0;0.00	60; 21.35	34.549[a]	0.000
No change	1;10.00	4;40.00	4;40.00	1;10.00	10; 3.56		
Increased	67;39.90	71;42.30	30;17.90	0;0.00	168;59.79		
No response	14;32.60	19;44.20	10; 23.30	0;0.00	43; 15.30		
Total	109; 38.80	113; 40.20	58; 20.60	1; 0.40	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.04.

	Decreased meals variety due to food unavailability				
	Yes n; (%)	**No** n; (%)	**Total** n; (%)	**χ^2**	**p-value**
Decreased	42;70.00	18;30.00	60; 21.35	22.555[a]	0.000
No change	3;30.00	7;70.00	10; 3.56		
Increased	141; 83.90	27; 16.10	168;59.79		
No response	27;62.80	16; 37.20	43; 15.30		
Total	213; 75.80	68; 24.20	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 4.42.

	Reduction in food sizes in 2014 due to food unavailability				
	Yes n; (%)	**No** n; (%)	**Total** n; (%)	**χ^2**	**p-value**
Decreased	42; 70.00	18; 30.00	60; 21.35	21.922[a]	0.000
No change	3;30.00	7;70.00	10; 3.56		
Increased	131; 78.00	37;22.00	168;59.79		
No response	21; 48.80	22; 51.20	43; 15.30		
Total	197; 70.10	84; 29.90	281; 100.0		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 4.99.

The findings in Table 5.15 show a significant relation between the changes in temperature and how many meals the household took daily (χ^2=27.498a, p= 0.000), how many months the household ate their homegrown foods (χ^2=34.549a, p= 0.000), how varied the meals were (χ^2=22.555a, p= 0.000) and meal sizes that households consumed in the year (2014) (χ^2=21.922a, p= 0.000). Based on the Chi-Square test results and analysed linkages, there was a significant association between the study locality's perceived temperature variations and the food security in households.

Similar views obtained from the FDGs indicate that participants agreed with the views of one elderly participant that:

> "Weather changes have reduced food crop yields especially maize (*Zea mays*) and brought food shortage. In the olden days, we used to harvest enough maize to last for the whole year. Every home had a granary for storing excess maize which was dried in the sun and stored for making *Githeri* (boiled maize and beans) and porridge. A lot of foods were cooked and stored in outside granaries which were not locked to allow family members and visitors free access. This generosity was due to plentiful food those days. Nowadays, the granaries are no more. We also used to have annual community celebrations after bumper harvests which are no more. Nowadays, food sharing is limited due to food shortage. Most of the food consumed here is bought from local markets, Thika town or from neighbouring Nyandarua County. When rains fail, there is total crop failure. Most of the money from tea is used to buy food and pay school fees. Families with small farm holdings and few tea bushes have little money to buy food and for other uses. Sometimes they go hungry and work on other people's farms for survival."

5.7 Rainfall and Temperature Change Impacts on Natural Resources (1984-2014)

According to 92.9% of the respondents, temperature and rainfall changes had affected natural resources relevant to their food crop production namely land, rivers, crops, livestock and trees.

5.7.1 Perceived Impacts on Land.

The study results are indicated in Table 5.16. Plate 10 shows a picture of an area affected by a landslide in the study area. One Key informant reported that:

> "Landslides occurred here in the 1970s and 1990s leading to loss of crops such as tea, maize (*Zea mays*) arrow roots *(Xanthosoma sagittifolium)* and cabbages (*Brassica oleracea*) grown along river valleys. Landslides also caused human and livestock fatalities and injuries, loss of productive farmlands and settlements. They occurred due to high rainfall, steepness of the terrain and weak soil texture. Affected sites have been rehabilitated by planting trees and diversion of road runoff through use of pipes."

Table 5.16: Effects of Rainfall Changes on Land

Impacts on Land	Frequency	Percentage
Heavy rains: increased soil erosion and soil nutrients leaching, reduced soil fertility	106	37.7
Adequate rainfall: improved tree cover, tea bushes and Napier grass, prevented soil erosion and landslides	57	20.3
Heavy rains: increased land degradation, low soil fertility	68	24.2
Heavy rainfall: increased landslides, destroyed vegetable crops decreased farming area, felled trees	37	13.2
Undecided	13	4.6

NB: Multiple Responses Frequency Table.

From the study results (table 5.16) most of the respondents (37.7%) reported that heavy rainfall increases soil erosion and nutrient leaching resulting in low soil fertility. About 24.2% noted that heavy rainfall degrades their land leading to poor soil productivity. According to 20.3% of the respondents, adequate rainfall improves tree cover, tea bushes and Napier grass thus reducing soil erosion. About 13.2% of the respondents alluded that heavy rainfall increased landslide occurrence in the area. Plate 10 shows an area affected by a landslide.

Plate 10: Section of Land affected by Landslide

5.7.2 Perceived Impacts on Rivers

The study findings stipulated in Table 5.17 show that most of the respondents (66.2%) noted that unpredictable and low rainfall intensity had reduced the number of permanent rivers, river water volumes and farming along river valleys.

Table 5.17: Perceived Rainfall Change Impacts on Rivers

Effects of rainfall changes on rivers	Frequency	Percent
Unpredictable & low rainfall intensity: reduced number of permanent rivers, river water volumes, farming along river valleys.	186	66.2
Heavy rainfall: increased river water volumes, burst river banks, destroyed crops along river valleys	24	8.5
Reduced rainfall/drought: drying up of some rivers, reduced farming along river valleys	33	11.7
High rainfall: increased floods, deposited fertile silt along river valleys	28	10.0
Undecided	10	3.6

NB: Multiple Responses Frequency Table.

5.7.3 Perceived Impacts on Crops Grown

From the study results, approximately 56.9% of the respondents reported that low rainfall or drought had caused the disappearance of some indigenous crops and reduced farming activities along river valleys. About 19.9% of the respondents associated heavy rainfall with the upsurge of crop pests such as bean fly and crop diseases such as blight, maize lethal necrosis, and anthracnose. About 12.1% of the respondents associated heavy rainfall with the rotting of crops such as cabbages (Brassica oleracea) and maize (Zea mays) (See plate 11) and stunting of beans (Phaseolus vulgaris). About 5.7% of respondents associated heavy rainfall with deteriorating soil fertility due to soil erosion and nutrient leaching. The consequences were increased use of farm chemicals and fertilizers which raised food crop production costs rendering crop farming unprofitable. Nevertheless, 3.6% of the respondents reported that silt deposited by floods on farms near river valleys was rich in nutrients which favored the growth of particular crops like maize (Zea mays), beans (Phaseolus vulgaris), bananas (Musa spp.), courgettes (Cucurbita pepo), cabbages (Brassica oleracea) and Irish potatoes (Solanum tuberosum). One elderly KI noted that:

> "Some crops commonly growing here in the past have disappeared. Food crop yields have reduced due to rainfall reduction and frost effects. Farming of sugarcane *(Saccharum officinarum)* pumpkins (*Cucurbita moschata)* arrowroots *(Xanthosoma sagittifolium)* and sweet potatoes *(Ipomea batata)* has reduced with original local landraces fast disappearing. In the past, sugarcanes were grown in plenty for use in brewing *muratina, a traditional* beer required in dowry settlements. Deforestation to

expand farming land has drastically reduced other useful fruits commonly growing in the wild such as *ndunda* (*Passiflora edulis*) *ndare* (*Rubus pinnatus*) *ngambura* (*Dovyalis abyssinica*) *mbiru* (*Vangueria madagascariensis*) *matuya* (*Myrianthus holstii*) and *ngoe* (*Syzygium guineense*). The wild arrowroot variety locally known as *kigoi* (*Xanthosoma spp*.) eaten during food shortages is still present though it is diminishing. High incidences of mist and frost often burn plant leaves resulting in low yields and massive crop loss especially on tea. High incidences of crop pests and diseases have led to indiscriminate and overuse of inorganic fertilizers acquired for tea production to grow food crops. Nowadays, maize cannot be grown without use of chemicals and fertilizers or manure due to deteriorating soil fertility and proliferation of diseases and pests that did not exist in the past. For example, cutworms that cut down germinating seedlings, particularly cabbages (*Brassica oleracea*) have increased. Other diseases are making most vegetable crops to turn yellow."

The various observed rainfall and temperature change impacts on crops are shown on Plate 11 shows.

Rotting of maize due to heavy rainfall

Effect of frost bite on tea bushes

Stunted arrowroots *(Xanthosoma sagittifolium)* **due to flooding**

Effect of heavy rainfall on cabbages (*Brassica oleracea*)

Plate 11: Various Rainfall and Temperature Impacts on Crops

5.7.4 Perceived Impacts on Trees

Study results showed that about 94.7% of the respondents had observed diminishing tree cover. They cited that deforestation to expand cropping land had reduced the previously dominant indigenous trees like *Mutuya (Myrianthus holstii) muiri (Prunus Africana/red stinkwood)* and *Mukoe (Syzygium guineense).* The lengthy growth of trees discouraged farmers from growing trees, preferring to grow food crops. Disease outbreaks such as cypress canker *(Seiridium spp.)* had diminished the cypress tree population. However, 3.9% of the respondents noted that despite low rainfall, deep-rooted trees like blue gum and grevillea robusta continued to thrive. A key informant noted that:

> "Many trees very common in the past including *muthaiti* (*Cinnamomum camphora) podo (Podocarpus falcatus*) *muiri (Prunus Africana/red stinkwood) mugumo (Ficus craterostoma)* and *Muthanduku (Acacia mearnsii)* are quickly disappearing. *Ithanji* (*Typha minima*) commonly growing on marshlands and used for thatching/roofing houses has drastically reduced. Most of the wetlands have dried up and are been used for crop production."

5.8 Rainfall and Temperature Change Impacts on Physical and Socioeconomic Resources (1984-2014).

5.8.1 Perceived Impacts on Roads

The study results indicate that 63% of the respondents noted that erratic rainfall had led to poor road conditions. They cited that floods eroded roads causing potholes, gullies, and landslides on roadsides (See plate 12) and sometimes destroyed bridges curtailing transportation. Roads became muddy during rains and dusty during dry seasons. About 35.2% of the respondents noted that, despite efforts by the Kenya Tea Development Agency (KTDA) to improve the roads for easier tea collection, poor road conditions persisted during heavy rainfall.

Plate 12: Eroded Roadside due to Heavy Rainfall

5.8.2 Perceived Impacts on Market Accessibility

The study results indicate that most of the respondents (50.5%) perceived increased food crop products during heavy rains flooded local markets and fetched low prices. This forced the farmers to sell their produce through middlemen who exploited them by paying very low prices. About 47.7% of the respondents noted that the poor state of roads during heavy rains raises the cost of transport and interrupts market accessibility. One KII added that high perishability of farm produce and poor storage means leads to high postharvest losses also noting that during the dry season, farm products supply was scarce resulting in high food prices.

5.8.3 Perceived Impacts on Income Sources.

The study results shown in Table 5.18 show that about 42.4% of respondents reported that cultivation of food crops has decreased due to the increased usage of farm inputs like fertilizers raising the cost of food crop production. The unpredictability of the farm earnings also discourages farmers from growing food crops. Approximately 29.5% of the respondents are practicing other kinds of farming such as intercropping, growing of fruit trees like avocado (*Persea americana*) other trees planting such as blue gum *(Eucalyptus globulus)* and grevillea *(Grevillea robusta)* to earn quick income.

Table 5.18: Effects of Climate Changes on Income Sources

Effect of climate changes on incomes sources	Frequency	Percent
Decreased food crop farming due to high cost of crop management (high input use), unpredictable farm earnings.	119	42.4
Practicing intercropping, growing fruit trees e.g. avocado (*Persea americana*) trees planting e.g. blue gum *(Eucalyptus globulus)* and grevillea *(Grevillea robusta)* for quick income.	83	29.5
Intercropping tea with tree tomatoes to supplement income.	41	14.6
Abandoning food crops for cash crops mainly tea.	34	12.1
Undecided	4	1.4

NB: Multiple Responses Frequency Table.

Results of the FGDs indicated that tea was their main source of income, noting that favorable weather increased tea yields and the reverse was true. Hence, erratic weather patterns led to unstable tea prices. Some farmers preferred planting purple tea or other crops like avocados (*Persea americana*) and tree tomatoes which fetched quick income. Most youths had migrated to towns in search of employment while others were operating *boda boda* (motorcycles) for income.

5.8.4 Perceived Impacts on Labor.

From the study results, approximately 78.3% of respondents reported a high cost of labor compared to crop production earnings. They noted that poor health due to outbreaks of climate-related diseases e.g. respiratory diseases, arthritis, cholera, and diarrhea reduced labor supply and productivity. Some family members spent time caring for the sick hence interrupting farming activities. According to 15.6% of the respondents, opportunities to sell labor were highest during tea peak seasons but local laborers faced strong competition from migrants from other areas. About 2.49% of the respondents indicated a rising preference for official jobs due because farming had become unprofitable. One KII added that:

> "Tea peak periods normally occurring during heavy rains are affected by labor shortage since children are usually in school. Labor shortage mainly affects the elderly, sick and disabled who are forced to source labor from outside. Also, ageing families whose children have grown up and left for greener pastures and cannot afford hired labor are overworked. Labor to pick tea is usually outsourced from other Counties. People from the lower coffee-growing zone have migrated into this area to provide labor."

5.8.5 Perceived Impacts on Household Expenditure.

According to 70.8% of the respondents, the cost of living had risen. Constant low food crop yields had forced most households to spend more on food purchases than before. The high demand for fertilizer and farm chemicals to improve soil fertility and control crop pests and diseases had raised the cost of food crop production and increased the food prices. About 27.1% of the respondents reported that erratic weather patterns had proliferated human diseases and pests and raised health expenses. Consequently, households' purchasing power had reduced. Food shortage had also curtailed communal social activities and encouraged individualism. One key informant asserted that:

> "High input costs discourage farmers from using certified seeds for planting. They therefore preserve and carry forward seeds from one season to the next. They believe that traditional varieties yield more and are resistant to pest and disease attack and therefore cheaper to manage. However, this often leads to poor yielding crops varieties and proliferation of pests and diseases. There is no crop improvement."

5.8.6 Perceived Impacts on Health.

The study results indicated that 90.4% of the respondents noted that heavy rainfall had increased water-borne diseases like cholera, typhoid, and diarrhea, favored mosquito breeding, and increased malaria cases. Low temperatures were associated with increased respiratory diseases such as pneumonia and influenza. The health burden disrupted economic activities due to more spending on medication while some household members spent time caring for the sick.

5.9 The Community's Anticipated Future Rainfall and Temperature Change Impacts on Food Crop Production (2015 - 2045).

The study findings (Table 5.19) show that about 29.5% of the respondents perceived that the anticipated future increase in rainfall would reduce food crop yields. Another 23.1% of the respondents perceived that the anticipated increase in future rainfall could favor tea production as experienced during the 1997 El Niño episode. Approximately 22.1% of the respondents felt that the likely increase in future rainfall could increase rotting and damage crops.

Table 5.19: Anticipated Impacts of Future Increased Rainfall on Food Crop Production

Effect of increased rainfall on crop production	Frequency	Percentage
Favour tea production as experienced during 1997 El Niño episode	65	23.1
Reduce food crop yields	83	29.5
Increase rotting and damage to crops	62	22.1
Increase outbreak of pests and diseases	27	9.6
Heighten leaching of soil nutrients	11	3.9
Increase rates of soil erosion	9	3.2
Increase yields of food crops	22	7.8
Undecided	2	0.7

NB: Multiple Responses Frequency Table.

The study results (Table 5.20) indicate that the majority of the respondents (73.7%) perceived that the anticipated future reduced rainfall below crop needs could reduce food and cash crop productivity. About 11% of the respondents perceived that the anticipated future reduced rainfall below crop needs could increase stunting and delay maturity of food crops.

Table 5.20: Anticipated Impacts of Future Reduced Rainfall (Below Crop Needs) on Crop Production

Effect of reduced rainfall (below crop needs) on crop production	Frequency	Percentage
Reduce food and cash crop productivity	207	73.7
Increased stunting and delayed maturity of food crops	31	11.0
Increased food crop germination failure	17	6.1
Increased drying and withering of food crops	12	4.3
Increased outbreak of food crops pest and diseases	14	5.0

NB: Multiple Responses Frequency Table.

The results in Table 5.21 show that most respondents (48%) perceived that the anticipated future prolonged high temperatures could reduce food and cash crops production. About 11.7% of the respondents perceived that the anticipated future prolonged high temperatures could cause drying of crops due to moisture stress.

Table 5.21: Anticipated Impacts of Future Prolonged High Temperatures on Food Crop Production

Effects of prolonged high temperatures on food crops	Frequency	Percentage
Reduced food and cash crops production	135	48.0
Stunted / slow growth of crops	16	5.7
Failure of some crops to germinate	31	11.0
Drying of crops due to moisture stress	33	11.7
Wilting of crops	30	10.7
Sun scorch in fruits	15	5.3
Outbreak of pests (e.g. aphids) and diseases	21	7.5

NB: Multiple Responses Frequency Table.

5.10 Discussion

Findings of the study indicate the respondents perceived difficulties accessing food. Food availability shortages across seasons were also apparent because crops grown in the majority of the households (80%) could hardly last until the following season. The farmers were experiencing food inaccessibility shown by the monetary strains that resulted in rationed and reduced variety and quantity with some households even going hungry as a result of food unavailability. Results from the FGDs confirmed that the weather changes had reduced food crop yields and resulted in food shortages compared to the past. They noted that plentiful food in the had led to high food generosity and many communal celebrations. They reported that food generosity had reduced because most of the households purchased their food. The livelihoods of the most rural population in non-rich nations are depend mostly on farming, especially in crop and livestock products that are consumed in the farming household and what they are able to sell (Taylor and Adelman, 2003). The incomes of households that rely heavily from farming are the most vulnerable to climate variations. Climate change is likely to eventually have an effect on prices, food access, and farm-generated income at both national and farming households' levels (Hachigonta *et al.,* 2013).

The HDDS findings indicate most household diets contained food rich in energy like, cereals, fats, honey, oils and sugar which were short of micronutrient-rich food categories like fruits, meat, poultry and eggs. From a scoring range of 0–12, the household average HDDS score of 4.0036 shows a diet that is not adequately diversified. A Key informant noted that the households did not commonly consume poultry and meat, as they were expensive. Studies have shown that oils and fats have negligible contribution to important micronutrients in meals, although they increase the energy levels and the intake of plant carotenoids and fat-soluble vitamins. Inadequate intake of micronutrients within a day reflects to quite unbalanced meals leading to micronutrient deficiency-related morbidity. Low diet varieties show a probability of decreased food intake per capita reflecting lower calories and hence decreased food availability (Kennedy *et al.,* 2011; Hoddinott and Yohannes, 2002). Recently, studies have established that climatic impacts could affect the micronutrient access in developing nations (Nelson *et al.,* 2018). Inadequate levels of micronutrient availability have been reported in Kenya (GoK, 2012-2017). Food insecurity due to the changing climate, has also been noted in farming households in Tanzania and Ghana (Warner and Afifi, 2014).

The study results shown in chapter 4 on section 4.5.3 showed that residents perceived irregular variations in precipitation quantity, intensity, frequency, and occurrences during the 1984 – 2014 period with adverse effects on their farm yields. They observed that irregular rainfall had interfered with their normal cultivation calendar which was ordinarily set by the two rainfall durations of long rains (MAM) and short rains (OND). This apparent seasonal volatility and rainfall insufficiency resulted in delay of planting crops with seeds getting lost when they planted in dry soils with expectation of looming rainfall. Even the farmers who timed their planting well with the onset of rainfall would suffer crop failure due to earlier cessation of the rains or even stopping before the crops fully matured. The community observed that the uncertainty on when to plant led to stunting of crops, increase in time and cash spent in weeding and decrease in farm yields. These perceptions showed that the community heavily relied on rainfall to secure their food. These perceptions confirmed the Chi-Square tests and associated analyzed results. Except for association between when the rainfall started and meals variety consumed in the household which was found to be statistically insignificant, the findings showed a significant linkage between rainfall variations and their food security. Other studies on farmers' perceptions of decreased rainfall and adverse effects on food availability have been reported (Kangalawe *et al.,* 2017; Chepkoech *et al.,* 2020; Kassie *et al.,* 2013).

Results of this study show most respondents perceived rising temperatures from 1984 to 2014 resulting to negative effects on their crop yields. The community perceptions findings were affirmed by meteorological data showing an increasing trend in monthly temperature highs, a clear indication that the study locality was indeed warming. The findings confirm other similar findings on temperature changes (Olayemi, 2012; Wetende *et al.,* 2018; Kaoga *et al.,* 2021). The temperatures in Africa are higher in a decadal trend which will likely hasten in the coming decades (Christensen *et al.,* 2007; IPCC, 2014; Hulme *et al.,* 2001).

These residents also perceived that the types of food crops grown in the area had changed. They cited the drastic reduction in the cultivation of indigenous crops such as yams (*Dioscorea alata),* sweet potatoes *(Ipomea batata),* cassava *(Manihot esculenta*) and arrowroots *(Xanthosoma sagittifolium)* due to the rising crop pests and diseases especially noting the commercial production of passion fruits was curtailed by the emergence of woodiness disease. They noted that crops that grew well in the past under high rainfall and cold temperatures such as pears and plums were slowly disappearing with reduced rainfall and warming temperatures. Hence, they were gradually being replaced by tree crops such as avocados (*Persea americana*) and macadamia (*Macadamia integrifolia*) and fast-maturing, short-season crop varieties such as tomatoes *(Solanum lycopersicum)* spinach (*Spinacia oleracea*) courgettes *(Cucurbita pepo)* and cucumbers *(Cucumis sativus)*. In agreement with these findings are Zandalinas *et al.* (2018) and Varshney (2018) who recently noted that with climate change, drought-tolerant crops will become more inevitable. The community also observed that the rate of deforestation in the area was rising due to pressure to expand cropping land. They added that there had been a massive decline in the number and distribution of indigenous and exotic trees such as *muthaiti (Cinnamomum camphora) podo (Podocarpus falcatus) muiri (Prunus Africana/red stinkwood) mugumo (Ficus craterostoma) muthanduku (Acacia mearnsii) and Ithanji (Typha minima).* Wade *et al.* (2003) concur that above 50% of tropical and subtropical forests have significantly been altered.

Many studies have reflected on the effects of rainfall and temperatures variations on crops. They note that crop growth is highly vulnerable to excessive or decreased precipitation and high temperatures at initial developing stage which results in the seeds getting diseases or even dying. During the reproduction, increased temperatures, low water content or waterlogging lead to lower grains being formed in cereals and decrease potato sizes. Waterlogging as maturation advances results in fungi, crops rotting and increased disease occurrence. Excessive rainfall also reduces output of corn drying matter (Rosenzweig *et al.,* 2001; Sita *et al.,* 2017; Malik *et al.,* 2015; Kim *et al.,* 2019). Water shortages promote aflatoxin concentration in maize (Pandit and Sharma, 2020). Tomato crops with soil having moisture content below 60% results in decreased stem structure, crop height and length of the internode (Alordzinu *et al.,* 2021). The IPCC also indicates a continuously increasing global temperature trend, a situation likely to remain the same or worse in the next 30 years. Rising temperatures affect crop-water availability causing wilting and crop drying. Plants' optimum growth and development occur at crop-specific day and night temperature thresholds. Proper plant growth requires the rate of photosynthesis to be higher than respiration. High temperatures elevate the rate of respiration above the photosynthetic rate, and temperatures below optimum cause poor plant growth (IPCC, 2014). Continuous intense exposure to higher or lower temperatures harm plant leaves (Samakovli *et al.,* 2020). A 3°C rise in temperature globally could alter crops constitution (Thomas *et al.,* 2004). High rainfall causes flooding or mudslides that damage houses, farms, trees while causing loss of human lives and livestock. Excessive raining seasons reduce farm outputs because of waterlogged crops and increased pests (Rothacker *et al.,* 2018;

Bjorkman and Niemela, 2015; Hertel *et al.,* 2010). In Kenya, cowpea yields were affected by pests, diseases, and drought (Zhao *et al.,* 2017).

Regarding human health, the study community perceived that variable rainfall and temperatures had increased climate-related ailments. The findings confirm reports that climate change had presented significant health shocks such as diseases, injuries, and death in Murang'a County (MCIDP, 2015). A growing body of studies also indicates that variable and warming climate is favoring global resurgence, emergence, and redistribution of infectious diseases due to their sensitivity to climatic impacts (McMichael *et al.,* 1996; Kuhn *et al.,* 2012; Wu *et al.,* 2016). Githeko and Ndegwa (2001) have linked inter-annual temperature variability with malaria spread after observing an increase in malaria hospital admissions in Kenya highlands after 3-4 months of increased maximum temperatures and rainfall. Moreover, Wandiga *et al.* (2010) also observed that despite several non-climatic risk factors of clinical immunity, erratic disease, and vector surveillance schedules, agricultural practices, population movements, and immunity patterns, malaria transmission in Kenya highlands was closely linked to inconsistent maximum temperatures. Additional studies link excess rainfall and high temperatures with increased risk or outbreak of water-borne diseases such as cholera and other diarrheal diseases. An example is medium sunshine hours and high temperatures which have been found to favor the multiplication of *Vibrio cholerae*. Such ailments lower people's effective food utilization, compound hunger resulting in lower labor productivity (Olago *et al.,* 2007; Moors *et al.,* 2013; Kostyla *et al.,* 2015; IPCC, 2007; Delpla *et al.,* 2009; Checkley *et al.,* 2008; Lama *et al.,* 2004). Pathogens have optimum survival temperatures and temperature changes may impact life cycles of disease-causing pathogens. Mosquitoes for example have a maximum temperature of 22^{o}C-23 ^{o}C (Mellor and Leake, 2000; Tian *et al.,* 2015a) an extrinsic incubation period (EIP) of 26 days at 20oc to 13 days at 25 ^{o}C.

Climate variations may likely alter the spatial-temporal spreading of infectious ailments likes malaria by influencing vector habitats (Harvell *et al.,* 2002; Tjaden *et al.,* 2018). Climate impacts on health have taken a significant toll on the study community's income due to increased family expenditure on households' medical needs. In support of this are Barret *et al.* (2015) findings that climate change raises the health burden of affected human populations. Tol (2018) further argues that climate change will decrease the income potential of vulnerable communities. On labor supply, climate-related ailments lower labor productivity (Zander *et al.,* 2015; Hallegatte & Rozenberg, 2017) as more time and money are spent on health care putting pressure on food-related activities. Reduction in farming production could lead to increased poverty levels for small-scale farmers (Popoola *et al.,* 2018; Zhao *et al.,* 2016; Lohmann & Lechtenfeld, 2015; Fox *et al.,* 2004).

On income sources, the study community perceived that climate change had reduced their income levels because of over reliance on rainfall for farming. Constant food crop yields reduction increased their spending on food purchases. The food prices were also rising with increased production costs occasioned by increased demand and farm input costs. The proliferation of human and livestock pests and diseases associated with rainfall and temperature changes raised the households' health burden and ate into their incomes. This reduced their purchasing power and raised their susceptibility to food insecurity. Food shortage also reduced social connection. Many studies agree that crop production costs will rise with climate change following adjustments in crop varieties, farming schedules, water usage, modern technologies and infrastructure, flooding damages, and agricultural chemical development. Climate-induced shortfalls also raise commodity prices due to the higher cost of inputs and labor. Increased competing demands greatly strain scarce fragile resources thwarting efforts to improve food security (Rosenzweig *et al.,* 2001; Sarkar & Padaria, 2016; Tadese *et al.,* 2018). According to Campbell *et al.* (2016) and Rufino *et al.* (2013) people's ability to access food through buying will be affected by climate change with projections of a rise in food prices across a wider spectrum of scenarios. Food affordability also depends on households' purchasing power which is climate-sensitive, particularly among agricultural households. Kurukulasuriya *et al.* (2006) point to diminishing farm incomes under prevailing climate scenarios. Hasegawa (2018) and Kaur and Kaur (2018) foresee future economic deprivations and higher hunger possibilities resulting from climate variations. These observations confirm the findings of this study that the impacts of rainfall and temperature changes were eroding the community's purchasing power by raising the crop production costs, health burden, and food prices thus raising the community's vulnerability to food insecurity.

The study community's market accessibility was challenged by fragile road infrastructure and high transportation costs. They cited that heavy rainfall damaged their roads and sometimes caused landslides which cut off communication and the food supply chain. An example is the torrential rainfall events in Kenya associated with late 1997 to early 1998 El Niño phenomenon that caused floods and damage to infrastructure. Its weather-related effects had significant effects on agriculture (Rosenzweig *et al.,* 2001). Oversupply of food crop products during favorable weather coupled with market inaccessibility also exposed the farmers to middlemen exploitation. According to IPCC (2001) future global and regional weather variations particularly the occurrence and concentration of dangerous climate events such as floodings, droughts, hailstorms, and cyclones will likely intensify. These will greatly fluctuate crop outputs, local food availability and increase risks of mudslides and soil degradation with significant impacts on food security.

The community anticipated that the future fluctuation in rainfall intensity, timing, and distribution could result in rainfall inadequacy and disrupt crop production cycles. These confirm Fischer *et al*. (2019). Jongman (2015) notes that climate-related rainfall increases magnify the intensity and occurrence of floods. Based on the current rising temperature trend supported by observed temperature data, the farmers anticipated worsening temperature rise. The community perceived that the likely future prolonged high temperatures could reduce food and cash crop production and cause crop drying due to moisture stress. Higher temperatures are likely to decrease crop yields in Africa because of decreased soil water content resulting in crops that are sun burnt, wilted or dried up (Kangalawe *et al.,* 2017; Faye *et al.,* 2018; Sultan *et al.,* 2019; Nwokwu and Aniekwe, 2014). Climatic variations will impact how reliable the calendar of growing crops will be and the farmers' income (M'mboroki *et al.,* 2018).

Without adequate adaptation, improved crop genes and fertilizers, a 1°C rise in earth's temperature would result in a decreased global outputs of corn (by 7.4%), soybean (3.1%), rice (3.2%) and wheat (6.0%) (Owade *et al.,* 2020). Substantial decreases of 40% in tea outputs could happen in Sub Saharan African because of warmer climatic conditions. In Kenya, a bleak outlook portends in future for the small-scale tea farmers. The indication of frost injury on tea indicates that tea is quite vulnerable to extreme threats and sensitive to frosting. This situation might worsen with changes brought by climatic variations with negative impacts on people employed and output (Ochieng *et al.,* 2016; Adhikari *et al.*, 2015).

The study also examined whether the community's socio-economic characteristics were associated with their food insecurity. From the Chi-Square tests results, a substantial linkage existed on household's head gender and the food situation in the household. A higher number of male-led households were found to be food secure than the female-led ones. According to Baten and Khan (2010) male household heads are more likely to access valuable resources to improve their crop production, boost their income and their households' food security than female household heads. A significant association was also established between the age of household heads and the households' food security. From the study findings, more female-headed households consumed fewer numbers, smaller sizes, and lower quality of daily meals than the male-headed households. Aidoo *et al.* (2013) concur that the food security of male-led households is likely to be higher compared with that of the female-led households. A significant link was also realized between household heads' age and the food availability in the household. The findings showed households led by relatively younger persons were expected secure their food availability compared to households led by older persons. Abafita and Kim (2014) and Babatunde (2007) have observed that younger heads in households exhibit more strength and energy than older household heads. They can therefore cultivate larger farm sizes and obtain high yields to guarantee their households more food security when compared to those headed by older persons. The study also found a significant linkage on the occupation of the household heads and how diversified the foods eaten were in the household. The household heads whose only source of income was only farming had their households consume fewer numbers and a lower quality of daily meals than those household heads who combined farming with other income sources. According to Dev, Sultana, and Hossain (2016), diversified livelihoods increase food availability by availing access to meals through additional income that relaxes their financial constraints. Etone, *et al.* (2019) also reported that multiple sources of income with reliable amounts are essential to ensure households' food security. Babatunde and Qaim (2010) further noted that diversification to off-farm activities contribute to higher food production by easing households' capital constraints.

Insignificant linkage was shown from the results between the household heads' education level food availability in the households within the study locality. These results supported those observed by Fekadu and Mequanent (2010) and Etonea and others (2019). However, the findings contradicted those of Amaza *et al.* (2006) who argued that households led by persons with more education would be food insecure since they were able to produce, consume more, and make right and knowledgeable decisions on producing and their nutrient content. These findings were also inconsistent with those of Dev and others (2016) who demonstrated educated household heads had a substantial effect in their households' food security. A significant association was also found between the households' farm acreage under food crops and the households' food security. The households with smaller farm acreage under food crops consumed a fewer number, lower quality and size of meals compared to those with larger farm acreage under food crops. A greater range of farm acreage as noted by Mitiku *et al.* (2012)

implies more food produced and increased access to cereals enhancing the adequacy of food available to households.

5.11 Conclusion

This study showed a decrease of 9.42% in the normally longer rainy season of MAM while the shorter rain season of OND showed an increase of 18.89%. The annual rainfall had an increase of 0.37335. This showed a statistically insignificant ($\alpha > 0.1$) trend in rainfall variation in the study locality which meant that normal rains were being observed both seasonally and annually during the 1984 – 2014 duration. The observed rain trends and what the community had perceived to be rainfall changes was different. Most of the study respondents and a KI had a perception of frequent droughts and longer dry periods resulting in lower crop outputs and famine which necessitated food assistance. The findings show that scientists have a different way of measuring, observing, and interpreting rainfall data and its effects on crop yields from local farmers. While climate scientists analyzed rainfall inclinations on their statistically derived averages, the local farmers analyzed the rainfall variations relying on the availability to meet their farm crops water needs.

On the temperature variations, the farmers were observed that the climate was becoming become warmer. This confirmed the observed temperature statistics, calculated Chi-Square assessments, the analyzed linkage findings between rainfall variations and the household's food availability. The findings confirmed a warmer climate in the area, concurring with other areas globally, which risks the food availability in the community studied.

The HDDS findings also revealed that households in the areas did not have a diversified variety of foods. Significant associations were also established between the household heads' gender, age, occupation and the size of arable farm under food crops, and the households' food security status. However, insignificant linkage was found between education levels of and food security in the particular household.

Most households (71.9%) had changed their crop varieties and 63.7% had altered their planting dates to coincide with rainfall onset. About 58.7% of the households had changed the types of fertilizers and pesticides used, 56.2% had adopted harvesting and water conservation while 53.7% of the households had practiced bucket irrigation on farms near rivers. Another 50.5% of the households had switched from crops to livestock farming.

CHAPTER SIX: CHALLENGES FACING CLIMATE CHANGE COPING AND ADAPTATION AMONG KIMANDI-WANYAGA COMMUNITY IN MURANG'A

6.1 Introduction

This chapter addresses the study's third objective that analyses challenges limiting the ability of Kimandi-Wanyaga farmers in Murang'a County in Kenya to adjust to climate change-related impacts on their food crop production. The study, therefore, examined the current practices adopted by the community to deal with climate-related risks and the challenges facing their climate coping efforts. Also identified were the available opportunities that could enhance the community's resilience to rainfall and temperature change impacts. The study refers to climate change coping as the short-term reactionary measures undertaken by the farmers to survive rainfall and temperature change effects on their food crop production activities. Climate change adaptation refers to sustainable practices undertaken by the community to live with rainfall and temperature change effects on their food crop production. Data collection was through a household survey, FGDs, and KIIs.

6.2 Results

6.2.1 The Community's Past Climate Coping Strategies

The study results on the community's coping practices during the 30 years preceding 2014 (Table 6.1) indicate that the community had adopted a combination of climate coping techniques. Most households (71.9%) had changed their crop varieties and 63.7% had altered their planting dates to coincide with rainfall onset. About 58.7% of the households had changed the types of fertilizers and pesticides used, 56.2% had adopted harvesting and water conservation while 53.7% of the households had practiced bucket irrigation on farms near rivers. Another 50.5% of the households had switched from crops to livestock farming.

Table 6.1: Past Climate Change Coping Measures

	Count	Percent
Concentration on tea farming only	112	39.9
Change of planting dates to coincide with rainfall onset	179	63.7
Dry planting	89	31.7
Change of crop varieties	202	71.9
Movement to different locations	62	22.1
changing from crops to livestock farming	142	50.5
changing from livestock to crop farming	121	43.1
Water harvesting and conservation	158	56.2
Use of soil conservation techniques	132	47.0
Bucket irrigation on farms near rivers	151	53.7
Use of crop insurance	23	8.2
Employment in other farms for wages	91	32.4
Religious beliefs or prayers	120	42.7
Change of fertilizers and pesticides	165	58.7

NB: Multiple Responses Frequency Table.

Other past climate coping mechanisms identified during FGDs included, gathering of wild foods such as *mbiru (Vangueria madagascariensis) ngambura (Dovyalis abyssinica) ngoe (Syzygium guineense) ndare (Rubus pinnatus) matuya (Myrianthus holstii) terere (Amaranth spp.) kigoi (Xanthosoma spp.) managu (Black nightshade)* and free-range grazing of livestock in the forests. Other strategies included use of indigenous food preservation technologies such as use of pest repellants such as *mubangi (Mexican marigold)* to preserve harvested maize against weevils, hanging of maize cobs on roofs to dry, trapping of moles, spraying of potatoes and leafy vegetables with a mixture of ash and water against early and late blights, and use of local land-races crop varieties which were resistant to crop pests and diseases.

6.2.2 The Community's Current Climate Change Coping Strategies

The study findings (Table 6.2) indicate that most of the households (73%) were currently changing the types of crops grown with more preference on local crop varieties. Other current climate coping strategies adopted included rationing of household meals (57.7%), expansion of food crop farming area (43.8%) and diversification to non-farm income sources (39.5%). Other households were selling their possessions cheaply (26.3%) while some sought employment on other farms (26.0%).

Table 6.2: Current Climate Change Coping Strategies

	Count	Percent
Rationing household number of meals	162	57.7
Changing types of crops grown, using local landraces	205	73.0
Diversifying to non-farm income	111	39.5
Employments in other farms for wages	73	26.0
Selling possessions often at low prices	74	26.3
Selling or pledging land	20	7.1
Selling firewood and charcoal	45	16.0
Borrowing grain from distributors	88	31.3
Expanding food crop farming area	123	43.8
Collecting wild foods	71	25.3
Inter-household transfers and loans	38	13.5
Borrowing from merchants and money lenders	116	41.3
Abandoning farming all together	11	3.9
Seeking help from NGOs	61	21.7
Seeking help from community members	66	23.5
Migrating to other places	7	2.5

NB: Multiple Responses Frequency Table

Additional climate coping practices identified during FGDs included, staggered maize planting achieved by subdividing their arable cropland into small sections to enable maize planting at different times of the year and ensure maize supply all year round for home consumption. Maize was also planted between the lines of mature crop of maize or intercropped maize with potatoes and beans *(Phaseolus vulgaris)* to mitigate against total crop failure. Other strategies included, planting of short season crops like courgettes *(Cucurbita pepo)* capsicum, and spinach (*Spinacia oleracea*) to avoid drought, intercropping of tea with tree tomatoes and collective seedling propagation and marketing of avocado *(Persea americana 'Hass')* to avoid middlemen exploitation (See plate 13). A local NGO was assisting farmers to construct water pans for harvesting water (See plate 14). One farmer reported to be progressively replacing part of his tea crop for Hass avocado *(Persea americana 'Hass')* farming which he reported to be more profitable. Kales were also grown in kitchen gardens.

Plate 13: A Hass Avocado Tree Nursery.

Plate 14: A Water Pan Constructed to Harvest Water.

6.2.3 Other Income Generating Activities Undertaken

The study results (Table 6.3) show that the community members were involved in other income generating activities besides crop farming. These included, rearing of poultry, pig, dairy cows, goat, sheep, rabbits (32%) operating green groceries (17.1%) formal employment (7.5%) sale of second-hand clothes (5.7%) shop keeping (5%) operating motorbikes (5%) and masonry, and carpentry (5%).

Table 6.3: Examples of Extra Income Generating Activities Undertaken

Income generating activities	Frequency	Percentage
Undecided	23	8.2
Green groceries	48	17.1
Selling second-hand clothes	16	5.7
Fish farming	7	2.5
Poultry, pig, dairy cows, goat, sheep, rabbit farming	90	32
Masonry, carpentry	14	5
Motorbike operator	14	5
Taxi business	3	1.1
Shop keeping	14	5
Motor vehicle operator	3	1
Tailoring	4	1.4
Beauty shop	5	1.8
Formal employment	21	7.5
Entertainment	5	1.8
Table banking	5	1.8
Selling tree seedlings	5	1.8
Selling bamboo *(Bambusoideae)* trees	4	1.4

NB: Multiple Responses Frequency Table.

6.2.4 Institutions Involved in Assisting the Community during Extreme Climate Events

Results of the various identified institutions involved in assisting the community to during extreme climate occurrences are shown in Table 6.4.

Table 6.4: Institutions Assisting the Community during Extreme Climate Events

INSTITUTIONS	TYPE OF ASSISTANCE
Government (GoK) Food aid	During drought periods, the government provided food aid in the form of maize, beans *(Phaseolus vulgaris)* maize flour and cooking oil. E.g. during 1984 drought, the government provided yellow maize flour to most affected households.
UNICEF Food aid	During the 1995 famine, UNICEF provided food aid e.g. maize, beans *(Phaseolus vulgaris)* and rice to most vulnerable households (elderly, orphans, disabled, female-headed households).
Self-help/merry-go-round groups	Assist hunger-stricken households e.g. elderly, orphans, widows and sick with food such as maize/wheat flour, cooking oil, rice and sugar.
Friends and relatives	Remittances and food aid from working relatives and friends.
Local churches	Sometimes contribute food during food crisis
Others	Participation in PELIS in adjacent Kimakia forest.

6.2.5 The Challenges facing Climate Change Coping and Adaptation in Kimandi-Wanyaga

The household survey results (Table 6.5) show that the community coping efforts are facing a myriad challenge. These include, inadequate finances to adopt new crops and farming systems (86.5%) poor health/physical challenges (81.9%) rising incidences and emergence of new weeds, crop pests and diseases (80.8%) and declining workforce due to schooling, out-migration, drug/substance abuse, youth idleness and ageing workforce (75.4%). Other challenges are reduced social connection / social ties (72.2%) limited information and lack of awareness of new coping mechanisms and interventions (71.7%) reduced or absence of government extension services (69.8%) and growing the same types of crops (68.7%).

Table 6.5: Challenges Facing the Community's Climate Coping Responses

	Frequency	Percentage
Declining workforce due to schooling, out-migration, drug/substance abuse, youth idleness and ageing workforce	210	75.4
Reduced social connection / social ties	203	72.2
Inadequate finances to adopt new technologies	243	86.5
Poor health/physical challenges	230	81.9
Limited information and lack of awareness of new coping mechanisms and interventions	202	71.9
Reduced or absence of government extension services	196	69.8
Rising incidences and emergence of new weeds, crop pests and diseases	227	80.8
Growing the same types of crops	193	68.7
Continuous cropping due to small farm sizes	188	66.9
Inaccessible early climate warning information	187	66.5
Poor roads	133	47.4
High transport costs	200	71.2
Market inaccessibility	69	24.6
Poor storage facilities	138	49.1
Low market prices	208	74.0

NB: Multiple Responses Frequency Table.

One key informant said that:

> "Government extension services are lacking. I am not aware of any agricultural extension services being offered in this area currently. In the past, extension officers used to frequent farms offering advice to farmers on good food crop production

> practices but nowadays they are not there. I wish that the government could enhance agricultural extension services as used to happen in the past. This would guide farmers on the most suitable crops to grow, best farming practices including control of pests and diseases and also give early warning information regarding weather changes."

Another key informant noted that:

> "Labor shortage normally happens during tea peak periods. The most affected are ageing families whose children have grown up and left for greener pastures. Those sick, disabled also suffer from labour shortages. Those who can afford usually hire labour from other Counties especially Kisii, Embu, and Western regions. People from the lower coffee growing zone have also migrated into this area to work on the farms specially to pluck tea. High input costs also discourage farmers from using certified seeds for planting. Farmers therefore store and carry forward seeds from one season to plant in the next season. This often leads to poor yielding crop varieties and proliferation of pests and diseases since crop improvement is impeded. Food crop pests such as weevils, moles, porcupines, aphids are also a challenge to farmers. Weevils particularly damage maize crops in the fields and postharvest. Pest control raises the cost of production thus discouraging farmers from producing in large quantities. Most farmers therefore produce enough for own consumption."

6.2.6 Challenges Encountered While Undertaking Extra Income Generating Activities

The study results (Table 6.6) show that the community was facing various challenges while undertaking extra income generating activities. These include, high cost of doing business especially high charges by county government and high rent charges (25%) outbreaks of livestock diseases and high cost of treatment (20.3%) inadequate capital to sustain the businesses (15.7%) and lack of customers (18%).

Table 6.6: Challenges Encountered with other Income Generating Activities

Challenges faced	**Frequency**	**Percent**
Lack of capital to sustain the business	31	15.7
High cost of doing business (high County government rand rent charges)	49	25.0
Poor salaries	14	7.1
Lack of customers	18	9.1
Outbreaks of livestock diseases and high cost of treatment	40	20.3
Low product prices	12	6.1
Theft of animals especially poultry	4	2.0
Poor roads	1	0.5
Extortion by some County officials	3	1.5
Drought causing farm produce shortages	15	7.6
Slow growth of business	5	2.5
Mismanagement of merry-go-round groups	5	2.5

NB: Multiple Responses Frequency Table.

6.2.7 The Community's Suggested Priority Interventions for Improving Food Security.

Study results on the respondents preferred ways of improving food crop production for food security are stipulated in Table 6.7. The results show that a majority of the respondents (83.3%) would prefer enhanced access to more reliable government extension services and support, about 81.5% of the respondents would prefer grow new types of crops, about 76.2% would prefer to increase the number of crops grown, approximately 68.3% suggested provision of rainwater harvesting facilities, and about 67.3% of the respondents preferred improved access to more reliable climate information on early warning systems. A further 59.1% preferred construction of bunds/terraces to prevent soil erosion/rain water run-off while about 48.8% suggested conservation agriculture and use of improved storage facilities.

Table 6.7: Priority Strategies Suggested by the Community to Improve Food Security

	Frequency	**Percentage**
Grow many types of crops	214	76.2
Grow new types of crops	229	81.5
Legalize use of piped water for irrigation	281	100.0
Training on right use of fertilizers	107	38.1
Use of improve storage facilities	137	48.8
Access to reliable government extension services and support	234	83.3
Access to reliable information on early warning systems	189	67.3
Provide rainwater harvesting facilities	192	68.3
Construct bunds/terraces to control soil erosion/ water run-off	166	59.1
Conservation agriculture	137	48.8
Apiculture	43	15.3
Aquaculture	1	0.4

NB: Multiple Responses Frequency Table.

6.2.8 Non-climate Risks Affecting Food Crop Production

From the study results, 76.2% of respondents indicated that food crop production was affected by land shortage. This resulted from continuous land subdivision as family sizes grew while some of the land was used for Thika Dam construction. Another challenge was unstable market prices due to weather variability as reported by 68.3% of the respondents. They explained that increased food crop supply in the markets during favorable weather flooded markets and lowered market prices exposing farmers to middlemen who bought their produce at exploitative prices. About 67.3% of households reported poor access to big markets due to high transportation costs which lowered their profit margins. They also reported lack of information on prevailing market prices adding that the high perishability nature of food crops forced them to sell their produce at throw away prices to minimize post-harvest losses. More 87.5% of households reported low soil fertility associated with rising acidity due to indiscriminate overuse of inorganic fertilizers and poor farming techniques. They decried lack of funds to purchase manure. Some 58.4% of households reported high cost of inputs such as fertilizers, pesticides and fungicides. High cost of seeds forced farmers to preserve their own harvested seeds and carry them forward from season to season. Poor roads and long distance to markets raised transportation costs which escalated production costs and lowered food crop production profits. Additional 72.6%, reported labour shortage citing inadequate finances to hire labour due to low incomes. Many youths had migrated to towns in search of employment leaving behind an overworked and ageing workforce with low productivity. labour shortage was also linked to poor health and the HIV pandemic. Households also noted that school going children could not help in food crop production since they were in school during peak seasons.

6.3 Discussion

From the study findings, it was evident that the study community perceived temperature and rainfall change that adversely affected their food crops and food security. Perceived rising temperatures had interrupted their seasonal calendars and worsened their adaptive capacity confirming findings by Makuvaro *et al*. (2018) that climate change continues to negatively impact food security and smallholder farmers' well-being. The study results also show that the community had historically made efforts to cope with the risks associated with changes in rainfall and temperatures that threatened their food security, confirming other findings by McDowell and Hess, (2012). Consequently, the farmers had adopted various climate coping measures. Their past coping practices mainly included, adjustments on crop planting dates, change of fertilizers and pesticides used, water harvesting and conservation, manual irrigation along river valleys, and switching from crops to livestock farming. However, the farmers reported that their past coping practices had gradually changed with climate change to include, change of crop types to the local land-races which were reported to possess superior characteristics such as disease and pest resistance and higher yield potential. Other current coping strategies included rationing of household meals as food shortage worsened, expansion of farming land, borrowing of grains from sellers and diversifying to non-farm income sources. These findings are supported by Diallo *et al*. (2020) Challinor *et al*. (2018) and IPCC (2014).

However, the community's coping strategies were found to have encountered various challenges including market inaccessibility, volatile market prices, low financial capacity, high input costs, declining and costly workforce and limited awareness and knowledge on new coping techniques. Others included inadequate/absent government extension services, lack of reliable and prompt climate warning information, lack of credit, limited crop varieties, poor roads and poor health and physical challenges. Shackleton *et al*. (2015) concur that adaptation strategies in Sub Saharan Africa encounter myriad challenges including biophysical, skills, and monetary limitations on farming outputs and rural development. Our findings support previous studies which also argued that access to credit is crucial for adoption of appropriate adaptation strategies by farmers in Africa (Di Falco *et al*. 2011; Webber *et al.,* 2014; Below *et al*. 2015; Soglo and Nonvide, 2019).

According to Nyberg *et al*. (2021) climate coping among smallholder rainfed farmers in Kenya is being challenged by among other factors, inadequate finances, knowledge, land and labour. From the study results, the community's climate coping efforts were being marred by a myriad of challenges including poor state of roads during heavy rains which raised cost of transport and curtailed market accessibility. Coincidentally, this was the period of bumper harvests when farm produce flooded local markets therefore fetching minimal prices. The high perishability nature of farm produce forced the farmers to sell through middlemen who exploited them by paying low prices only to sell at high prices in larger markets. In Tanzania, farmers facing market and pricing challenges for their surplus produce were exploited by middlemen who bought the produce at low prices (Mashindano *et al.,* 2011). As a remedy to minimize post-harvest losses and avoid farmers' exploitation. Studies by Bradford *et al*. (2018) Tesfaye & Tiriyayi (2018) and Kumar and Kalita (2017) point to the need for adequate post-harvest storage strategies to reduce post-harvest crop losses. Other challenges included, limited knowledge on new climate coping techniques and climate warning information attributable to inadequate or absent agricultural extension services. Esteve *et al*. (2018) and Agidi *et al*. (2018) contend that unawareness of viable adaptation strategies continues to challenge smallholder farmers as Prokopy *et al*. (2015) emphasize the need for adequate extension services to farmers to enhance climate change coping mechanisms.

Consequently, the farmers applied poor farming techniques such as growing similar types of crops and continuous cropping which led to nutrient mining. Additionally, the farmers reported that they could not change to crops that were responsive to changes in temperature and rainfall due to unawareness on appropriate crops for their locality. They reported the availability of many varieties in the market, most of which were said to be of very poor quality. To cope with the situation, they had resorted to use of local landraces whose seeds they stored and carried forward from season to season. This resulted in poor yielding crop varieties, proliferation of crop pests and diseases and impeded crop improvement (MCIDP, 2013- 2017). Other studies have noted the inadequate use of quality seeds especially in Africa due to unavailability, high cost or unawareness (Demo *et al.,* 2015; Beckford and Norman, 2016; Mwamakamba *et al.,* 2017; Setimela *et al.,* 2018; Pincus *et al.,* 2019 and Das *et al*. ,2019).

Additionally, the farmers decried inadequate financial capacity to adopt new crops and farming techniques noting that credit was inaccessible and farm inputs were costly. This was compounded by emergence and resurgence of new weeds, crop and animal pests and diseases which necessitated increased use of agrochemicals hence higher cost of crop production. Inadequate finances hinder farmers from acquiring necessary resources to facilitate climate change adaptation (Deressa *et al.,* 2009; Jost *et al.,* 2016). Majority of the farmers had resorted to obtaining finances from informal money lending institutions such as shylocks and merry-go-round groups (Table 6.8). According to FarmDrive (2019) commercial banks in Africa consider agriculture a high-risk endeavor due to, high dominance of small-scale poorly skilled farmers, high rainfall dependence and low technology use resulting in below 1% lending to the sector. Inadequate finances hinder farmers from acquiring necessary resources to facilitate climate change adaptation (Jost *et al*., 2016; Nyberg *et al.*, 2021). Climate change adaptation is expensive (Mendelsohn & Neumann, 2004). Other studies reiterate that some adaptation strategies are unaffordable by small-scale farmers because they require expensive input packages. Hence, agricultural technology adoption requires adequate financial capacity (Adger *et al*., 2007; Knowler and Bradshaw, 2007). Lack of capital to start businesses, high cost of doing business, poor salaries, reduced consumption of goods was also noted. Kurukulasuriya *et al*. (2006) noted diminishing farm incomes under prevailing climate scenarios. Butt *et al*. (2005) also foresee future economic deprivations and higher hunger possibilities resulting from climate variations.

Another reported challenge was a decline in farm workforce supply resulting from youth migration to urban areas in search for employment and leaving behind an overworked, ageing and low productive workforce. Poor health due to climate-related ailments, disabilities and HIV AIDS pandemic also lowered farm labour supply and productivity. School going children could not participate in food crop production activities since they were in school during peak seasons. Drug abuse and consequential laziness of the youthful population also affected labour supply supporting Khan *et al*. (2015). These factors substantially reduced the population involved in farming to sustain the community's staple food demands. The respondents also cited inadequate finances to hire labour due to low farm returns. It has been argued that farmers without who lack adequate family labour or finances to pay for labour cannot adapt to climate change. Credit access increases the likelihood of adoption of climate change technologies. Hence, institutional support is important for promoting climate change adaptation (Nyberg *et al*. (2021).

Reduced farm acreage due to rising population pressure led to continuous cropping, nutrient mining and low soil fertility. This also made some adaptation measures such as crop diversification untenable. For instance, changing to more resilient crop varieties can positively affect farming communities' adaptation responses (Ali & Erenstein, 2017). Indeed, the Kenya Plant Health Inspectorate Service (KEPHIS) has rolled out an SMS service to inform farmers on appropriate crop varieties for their localities although it is mainly targeted on maize. However, this implies that farmers had to sub-divide their already small parcels of land in order to accommodate all the crop varieties needed to cushion them from hunger (MCIDP, 2015). Land fragmentation also happens in order to allow cultivation of both food and cash crops to sustain crop diversification, a strategy seen as very responsive to climate change impacts. Small farm sizes due to growing population pressure may curtail adoption of some viable adaptation techniques (Kassie *et al.,* 2013; Amwata, 2020). In Ethiopia small farm sizes were seen to impede adoption of some viable adaptation options (Teshome *et al.,* 2016). Kassie *et al*. (2013) and Orea *et a*l. (2015) argue that land subdivision negatively affects agricultural productivity due to diminished use of some viable coping mechanisms. An additional challenge included reduced social connectedness due to diminishing resources agreeing with Cornwell *et al.* (2008). The current food shortage attributed to climate change impacts on crop production had declined the community's 'customary collective coping' (Atwood, 1990).

Most household heads were middle-aged males (Table 4. I). Male heads of household heads are low-risk averse. These raise their likelihood to adopt current adaptation strategies than females (Asfaw and Admassie, 2004). High resource access favors climate adaptation. Therefore, women's inability to access finance, land, and education weakens their capacity to adapt to climate change. Gender and climate adaptation can, therefore, be considered context-specific. High education levels (62.2 %) existed among the household heads, who were males (76.2 %). High literacy levels raise the likelihood of adapting to climate change and increase the probability of more literate household heads adapting to climate change than the less literate ones (Madisson, 2006). Higher education levels raise access to information on current technologies (Mignouna *et al.,* 2011). Most household heads were middle-aged (69.4 %). Older farmers are more reluctant to adopt current climate change technologies (Shongwe *et al.,* 2014). However, it established that agronomic superiority, perceptions, and attitudes influence adoption of technology. Many studies associate experience in farming to higher adoption of emerging agricultural technologies. The farm sizes of most households (59.4 %) were below 2 hectares. Small farm sizes communities seem to constrain the adoption of suitable climate-coping techniques (Mignouna *et al.,* 2011; Kebede *et al.,* 2016).

The study community also identified several existing opportunities that if implemented would help in addressing the challenges they were facing while coping with climate change. All the respondents (100%) identified legalization of the piped water highly available in the area for irrigation. They noted that use of available piped water is prohibited by the water service providers. Other opportunities identified included, enhanced access to more reliable government extension services and support, introduction of many new types of crops that are suitable for the area, access to more reliable climate warning systems, provision of rainwater harvesting facilities and use of soil conservation measures. The community also identified various institutions such as the national government, the United Nations Children's Fund (UNICEF) that helped during extreme climate events. The presence of both formal and informal local institutions such as churches, self-help and community-based organizations also presented an opportunity to develop capacity for facilitating adaptation and reducing vulnerability to the impacts of climate.

6.4 Conclusion

From the study findings, various challenges were constraining the community's climate adaptive capacity including, credit inaccessibility, expensive agricultural inputs, low farm income, unstable market prices, climate-related ailments, labour shortage and lack of reliable and prompt climate warning systems. Other challenges included, inadequate or absent government agricultural extension services and unawareness of climate coping technologies appropriate for their locality. Most farmers relied on their traditional crop production techniques such as use of local landraces resulting in low yields, proliferation of pests and diseases and low seed improvement. Volatile farm produce prices made food crop farming unprofitable as peak harvests saturated markets and attracted poor prices. This was exacerbated by high perishability of farm produce, inadequate storage facilities and high cost of transportation and market inaccessibility. Lack of reliable early warning systems also weakened the households' ability to optimize on favorable weather conditions for high crop performance. Small land parcels and limited land ownership, especially for women who were the main food crop producers, constrained credit access and adoption of new technologies.

CHAPTER SEVEN: PROMOTING THE CULTIVATION OF TRADITIONAL VEGETABLES FOR CROP AND LIVELIHOOD DIVERSIFICATION UNDER THE PELIS PROGRAMME FOR FOOD SECURITY AMONG KIMANDI-WANYAGA COMMUNITY

7.1 Introduction

This chapter addresses the fourth objective of the study of exploring the potential of the cultivation of selected traditional vegetables to diversify crops and livelihoods under the pilot PELIS programme with an aim to enhance food security vis-à-vis climate change among Kimandi-Wanyaga community in Murang'a County, Kenya. The PELIS is a pilot Kenyan farming system initiated by the ministries of Forestry, Agriculture, Water and Irrigation under Participatory Forest Management (PFM) guidelines of Forest Act (2005) to boost food security among forest-adjacent communities (GOK, 2007). According to the Kenya Forest Research Institute (KEFRI, 2014) the PELIS pilot project in Kiambu County achieved over 75% tree seedling survival while profitability of potato farming rose four times higher than beans and maize. Hence, the PELIS is a cost-effective strategy for forest conservation and improved food security. The study established that the PELIS programme is also being piloted among the Kimandi-Wanyaga community which is adjacent to Kimakia forest. Based on reported PELIS success in other Counties such as Kiambu (KEFRI, 2014) the study found PELIS a promising avenue to diversify crops and livelihoods through inclusion of traditional vegetables farming for food security. Data were gathered through a household survey, focus group discussions, key informant interviews, and field trials**.**

7.2 Results

7.2.1 Participation in PELIS

From the study findings only 11% of the respondents were involved in the pilot PELIS program.

7.2.2 Reasons for Participation in PELIS

From the study results, about 90.3% of the respondents participating in the PELIS wanted to enlarge their food and income sources, 3.2% had received training and funding to take care of trees, and 6.5% were members of CFA. The activities under PELIS were tree nursery establishment, planting of trees (pine) for sale, cultivation of crops such as green peas *(Pisum sativum)* cabbages (*Brassica oleracea*) carrots (*Daucus carota*) tomatoes and Irish potatoes *(Solanum tuberosum)* for own consumption and sale.

7.2.3 Reasons for Non-Participation in PELIS

The study findings (Table 7.1) show that about 50% of the respondents not participating in PELIS were busy on their farms, jobs and other activities. About 14.4% of them were not aware of the program while 10.8% of the respondents were not interested in the program.

Table 7.1: Reasons for Non-participation in PELIS

Reasons for non-participation in PELIS	Frequency	Percentage
Being busy on own farms, jobs and other activities	125	50.0
Owning large farms to provide enough food	8	3.2
Lack of required registration fees	18	7.2
Poor health, disability and old age	13	5.2
Lack of interest	27	10.8
Unaware of PELIS programme	36	14.4
Living far from the forest	11	4.4
Poor management of the scheme	12	4.8

NB: Multiple Responses Frequency Table.

A key informant narrated her involvement in PELIS programme saying:

> "Initially, we used to walk to Kimakia forest as there were no other means of transport. During rainy seasons, roads became muddy and slippery hence impassable. Forest weather was also very cold. We were often rained on which caused many of us to catch pneumonia. Erecting makeshift shelters in the forest was illegal to control against illegal forest activities such as poaching and logging. The presence of wild animals such as elephants, buffaloes and leopards made walking into the forest risky. One day, we found a leopard carcass on the farm. During peak harvests, farm produce flooded local markets and reduced market prices. Brokers exploited us by buying at very low prices. Nowadays, things are different since we use motorcycles to reach the farms and KFS has put measures in place to protect PELIS sites from game damage. We have also formed marketing groups to bulk produce and hire pick-up vehicles to transport to neighbouring boarding schools, hospitals and other markets such as Gatanga and Thika."

7.2.4 Crops Grown Under PELIS

From the study results, PELIS farmers cultivated a mixture of food crops including maize *(Zea mays)* carrots (*Daucus carota*) Irish potatoes *(Solanum tuberosum)* and pumpkins (*Cucurbita moschata).* A few farmers planted *terere (Amaranth spp.)* and *managu (Black nightshade)* from seeds collected from the wildly growing species. The study also sought to know which types of indigenous vegetables the farmers had been growing on their own farms in the past.

The study results (Table 7.2) indicated that a majority of the respondents (86.8%) were cultivating *Malenge (Cucurbita moschata* and 33.1% were cultivating *Thabai (Urtica urens). Terere (Amaranth spp.)* and *Murenda (Corchorus olitorius)* were not being cultivated at all. Only a paltry 8% and 1% of the respondents were cultivating *Managu (Black nightshade)* and *Saget (Cleome gynandra)* respectively.

Table 7.2: Indigenous Vegetable Crops grown by the Households.

	Frequency	**Percentage**
Malenge (Cucurbita moschata)	244	86.8
Terere (Amaranth spp.)	0	0.0
Managu (Black nightshade)	8	2.8
Thabai (Urtica urens)	93	33.1
Saget (Cleome gynandra)	1	0.4
Murenda (Corchorus olitorius)	0	0.0

NB: Multiple Responses Frequency Table.

7.2.5 Reasons for Low Cultivation of Amaranths (Terere) and Black NightShade (Managu).

Responses from the KIIs and FGDs revealed that *Managu (Black nightshade)* and *Terere (Amaranth spp.)* wildly perpetuated themselves and farmers harvested them for use and sale to greengrocers and at the local markets. The farmers claimed that they didn't know the right way of planting the vegetables. Unavailability of the seeds locally led the farmers to collect the wild seeds and intercrop them with other crops. However, one elderly key informant noted that *Managu (Black nightshade)* and *Terere (Amaranth spp.)* were still considered wild foods only eaten during famine and therefore they should not be cultivated on the farms. Instead, farmers instead cultivated vegetables such cabbages, kale, and spinach.

7.2.6 Motivation of the Community to Grow Traditional Vegetables

The study results (Table 7.3) indicate that the farmers knew the benefits of the traditional vegetables. About 39.9% said that the vegetables were rich in nutrients and hence recommended for strengthening immunity for the sick. Other reasons for growing the vegetables included minimal farm management (19.9%) market responsiveness (highly marketable) (8.2%) faster growth compared to exotic vegetables (7.5%) and long harvesting periods hence high yields (6%).

Table 7.3: Motivation to Grow Traditional Vegetables

Motivation for growing traditional vegetables	**Frequency**	**Percentage**
Market responsiveness (marketable)	23	8.2
Rich nutritional value hence recommended for strengthening immunity for the sick	112	39.9
Require minimal farm management	56	19.9
The vegetables grow naturally	14	5.0
They have long harvesting periods hence high yields	17	6.0
They grow fast growing compared to exotic vegetables	21	7.5
They are drought tolerant	11	3.9
They require less inputs	12	4.3
They are pest and disease resistant	9	3.2
They are adaptable to a range of climatic conditions	6	2.1

NB: Multiple Responses Frequency Table.

7.3 State of Soil Fertility of the Households' Farms

From the study results, 78.6% of respondents reported low soil fertility and 21.4% reported moderate soil fertility. The study findings on how the community managed soil fertility on their farms are outlined in Table 7.4. The results show that most of the respondents (90.7) improve their soil productivity by using farmyard manure, about (63.3%) use inorganic fertilizers, 57.7% use crop rotation while approximately 48.4% of the respondents practice agroforestry.

Table 7.4: Ways of Maintaining Soil Fertility

Ways of maintaining soil fertility	**Frequency**	**Percentage**
Apply inorganic fertilizers	178	63.3
Apply farmyard manure	255	90.7
Crop rotation	162	57.7
Use of agroforestry	136	48.4

NB: Multiple Responses Frequency Table.

7.4 The On-farm demonstrations on Improved Traditional Vegetable Farming

7.4.1 The on-farm demonstration vegetable yields for Kimandi area

The results of the yields obtained from the on-farm demonstration conducted in Kimandi are as shown in Table 7.5.

Table 7.5: The On-Farm Demonstration Vegetable Yields (Kimandi).

Block No.	**Vegetable Name**	**Size**	3M	1M Path	3M	1M Path	3M	1M Path	3M	1M Path
1	Amaranth	3M	A 15 kgs (leaves)		B 34 kgs (leaves)		C 37 kgs (leaves)		D 45 kgs (leaves)	
1M Path										
2	Black nightshade	3M	D 50 kgs (leaves)		C 43 kgs (leaves		B 35 kgs (leaves		A 16 kgs (leaves	
1M Path										
3	Jews marrow	3M	C 19 kgs (leaves)		D 29 kgs (leaves		A 8 kgs (leaves		B 16 kgs (leaves	
1M Path										
4	Cow peas	3M	B22 kgs (Leaves)		A 17 kgs (leaves		D 43 kgs (leaves		C 35 kgs (leaves	
1M Path										
5	Spider plant	3M	D 61 kgs (leaves)		B 37 kgs (leaves)		C 43 kgs (leaves)		A 18 kgs (leaves)	

From the farm demonstration results (Table 7.5) the yields of the treatment A, without manure or fertilizer produced the lowest yields. The yields of treatment B, with only nitrogen fertilizer, (N: P: K, 23:23:0) at a rate of 10 g/meter yielded higher than those of treatment A without manure or fertilizer. The yields of treatment C, with only manure at a rate of 1 20kgs/8meters yielded higher than those on treatment B with only nitrogen fertilizer. The yields of treatment D, with both the inorganic fertilizer, N: P: K (23:23:0) at a rate of 10g/meter and well decomposed manure at a rate of ½ debe/4 meters gave the highest yields compared with all the other treatments.

7.4.2 The On-Farm Demonstration Vegetable Yields for Wanyaga Area

Table 7.6: The On-Farm Demonstration Vegetable Yields (Wanyaga).

Block No.	**Vegetable Name**	**Size**	3M	1M Path	3M	1M Path	3M	1M Path	5M	1M Path
1	Amaranth	3M	A 13 kgs (leaves)		B 32 kgs (leaves)		C 37 kgs (leaves)		D 44 kgs (leaves)	
1M Path										
2	Black nightshade	3M	D 47 kgs (leaves)		C 44 kgs (leaves		B 33 kgs (leaves		A 15 kgs (leaves	
1M Path										
3	Jews marrow	3M	C 19 kgs (leaves)		D 30 kgs (leaves		A 6 kgs (leaves		B 13 kgs (leaves	
1M Path										
4	Cow peas	3M	B19 kgs (Leaves)		A 14 kgs (leaves		D 42 kgs (leaves		C 32 kgs (leaves	
1M Path										
	Spider plant	3M	D 57 kgs (leaves)		B 36 kgs (leaves)		C 40 kgs (leaves)		A 19 kgs (leaves)	

The study results (Table 7.6) indicate that the yields of the traditional vegetables planted with no manure or fertilizer produced very low yields. The vegetables planted with only inorganic fertilizer, N: P: K (23:23:0) at a rate of 10 g/meter yielded higher than those planted with no manure or fertilizer. The vegetables planted with only well decomposed manure at a rate of 1 20kgs/8meters yielded higher than those planted with only inorganic fertilizer, N: P: K (23:23:0) at a rate of 10 g/meter. The vegetables planted with both the inorganic fertilizer, N: P: K (23:23:0) at a rate of 10g/meter and well decomposed manure at a rate of ½ debe/4 meters gave the highest yields compared with all the other treatments.

7.5 Pairwise Preference Ranking for Selected Traditional Vegetables

7.5.1 Pairwise Preference Ranking During First Demonstration at Kimandi.

Twelve farmers participated in the pairwise preference ranking of the vegetables. The results of the exercise shown in Table 7.7 and summarized in Table 7.8 show that Cowpeas *(Vigna unguiculata)* was ranked as the most preferred traditional vegetable by the respondents. *Managu (Black nightshade)* was ranked second while *Murenda (Corchorus olitorius) was* ranked as the least preferred traditional vegetable.

Table 7.7: Vegetables Pairwise Preference Ranking Table at Kimandi.

VEGETABLE NAME	***TERERE (Amaranth spp.)***	***MANAGU (Black nightshade)***	***SAGET (Cleome gynandra)***	***MURENDA (Corchorus olitorius)***	***COW PEAS (Vigna unguiculata)***
TERERE (Amaranth spp.)		*Managu*-5 *Terere*-5 Undecided-2	*Saget*-4 *Terere*-4 Undecided-4	*Murenda*-3 *Terere*-9 (winner) Undecided-0	*Cowpeas*-10 (winner) *Terere*-2 Undecided-0
MANAGU (Black nightshade)	*Terere*-5 *Managu*-5 Undecided-2		*Saget*-4 *Managu*-7 (winner) Undecided-1	*Murenda*-2 *Managu*-9 (winner) Undecided-1	*Cowpeas* -7 (winner) *Managu*-5 Undecided-0
SAGET (Cleome gynandra)	*Terere*-4 *Saget*-4 Undecided-4	*Managu*-7 (winner) *Saget*-4 Undecided-1		*Murenda*-4 *Saget*-6 (winner) Undecided-2	*Cowpeas* -9 (winner) *Saget*-3 Undecided-0
MURENDA (Corchorus olitorius)	*Terere*-9 (winner) *Murenda*-3 Undecided-0	*Managu* -9 (winner) *Murenda*-2 Undecided-1	*Saget*-6 (winner) *Murenda*-4 Undecided-2		*Cowpeas* -10 (winner) *Murenda*-2 Undecided-0
COW PEAS (Vigna unguiculata)	*Terere*-2 *Cowpeas* -10 (winner) Undecided-0	*Managu*-5 *Cowpeas* -7 (winner) Undecided-0	*Saget*-3 *Cowpeas* -9 (winner) Undecided-0	*Murenda*-2 *Cowpeas* -10 (winner) Undecided-0	

Table 7.8: Vegetables Pairwise Preference Ranking Results (Kimandi).

Vegetable name	Winner Score	Rank
Cow peas *(Vigna unguiculata)*	4	1
Managu (Black nightshade)	2	2
Terere (Amaranth spp.)	1	3
Saget (Cleome gynandra)	1	4
Murenda (Corchorus olitorius)	0	5

7.5.2 Pairwise Preference Ranking During Second Demonstration at Wanyaga.

The ten farmers in attendance ranked the vegetables pairwise according to preference. The results are shown on Table 7.9 and summarized in Table 7.10. The study results indicate that Cowpeas *(Vigna unguiculata*) was ranked as the most preferred traditional vegetable. The *Saget (Cleome gynandra)* and *Murenda* **(***Corchorus olitorius)* were the least preferred vegetables.

Table 7.9: Vegetables Pairwise Preference Ranking Results at Wanyaga.

VEGETABLE NAME	***TERERE (Amaranth spp.)***	***MANAGU (Black nightshade)***	***SAGET (Cleome gynandra)***	***MURENDA (Corchorus olitorius)***	***COW PEAS (Vigna unguiculata*)**
TERERE (Amaranth spp.)		*Managu*-9 (winner) *Terere*- 1 Undecided-0	*Saget*-4 *Terere*-5 (winner) Undecided-1	*Murenda*-3 *Terere*-6 (winner) Undecided-1	*Cowpeas* -6 (winner) *Terere*-3 Undecided-1
MANAGU (Black nightshade)	*Terere*-1 *Managu*-9 (winner) Undecided-0		*Saget*-4 *Managu*-5 (winner) Undecided-1	*Murenda*-1 *Managu*-6 (winner) Undecided-3	*Cowpeas* -6 (winner) *Managu*-4 Undecided-0
SAGET (Cleome gynandra)	*Terere*-5 (winner) *Saget*-4 Undecided-1	*Managu*-5 (winner) *Saget*-4 Undecided-1		*Murenda*-2 *Saget*-5 (winner) Undecided-2	*Cowpeas* -6 (winner) *Saget*-3 Undecided-1
MURENDA (Corchorus olitorius)	*Terere*-6 (winner) *Murenda*-3 Undecided-1	*Managu* -6 (winner) *Murenda*-1 Undecided-3	*Saget*-5 (winner) *Murenda*-2 Undecided-2		*Cowpeas* -9 (winner) *Murenda*-0 Undecided-1
***COW PEAS (Vigna unguiculata*)**	*Terere*-3 *Cowpeas-6* (winner) Undecided-1	*Managu*-4 *Cowpeas* -6 (winner) Undecided-0	*Saget*-3 *Cowpeas* -6 (winner) Undecided-1	*Murenda*-0 *Cowpeas* -9 (winner) Undecided-1	

Table 7.10: Pairwise Preference Ranking Results (Wanyaga).

Vegetable	Winner Score	Ranking
Cow peas (Vigna unguiculata)	4	1
Managu (Black nightshade)	2	2
Terere (Amaranth spp.)	1	3
Saget (Cleome gynandra)	0	4
Murenda (Corchorus olitorius)	0	4

7.6 Farmers Follow-up Visits

7.6.1 Farmers Follow-up Visits at Kimandi Area

The farmer follow-up visits were done for four seasons. The results are shown in Table 7.11.

Table 7.11: Farmers Follow-up Visits Results (Kimandi).

Season	No. of farmers	Vegetable type planted	Outcome	Use
1	12	*Terere (Amaranth spp.) Managu (Black nightshade) Cow Peas (Vigna unguiculata)*	*Terere (Amaranth spp.) Cow peas (Vigna unguiculata)* and *Managu (Black nightshade)* grew well under PELIS. *Cow peas (Vigna unguiculata)* performed poorly on farmer's farms hence low yields.	4 PELIS farmers produced enough to sell to Thika market 8 non-PELIS sold surplus to local green grocers.
2	12	*Terere (Amaranth spp.) Managu (Black nightshade) Cow peas (Vigna unguiculata)*	*Terere (Amaranth spp.) Managu (Black nightshade) Cow peas (Vigna unguiculata)* and *Saget (Cleome gynandra)* grew well under PELIS. Non-PELIS farmers only planted *Terere (Amaranth spp.)* and *Managu (Black nightshade)* which grew well	4 PELIS farmers sold to schools and hospitals 8 non- PELIS farmers sold surplus to neighbours
3	12	*Terere (Amaranth spp) Managu* (Black nightshade) *Cow peas (Vigna unguiculata) Saget (Cleome gynandra)*	The variety of *Terere (Amaranth spp.)* provided grew well but developed a lot of seeds and low vegetative growth. It was uprooted early	4 PELIS farmers supplied to schools and hospitals 8 non-PELIS farmers got low *Terere (Amaranth spp.)* yields which they used for family consumption only. Surplus *Managu (Black nightshade)* sold to local green grocers
4	12	*Terere (Amaranth spp) Managu (Black nightshade) Cow peas (Vigna unguiculata) Saget (Cleome gynandra)*	New *Terere (Amaranth spp.)* variety planted which grew well. *Managu (Black nightshade)* grew well.	4 PELIS farmers had bumper harvest and sold to local schools, hospitals and Thika town 8 non-PELIS sold surplus to neighbours

The farmer follow-up visits results (Table 7.11) indicate that the four PELIS participating farmers who planted *Terere (Amaranth spp.) Cowpeas (Vigna unguiculata)* and *Managu (Black nightshade)* produced enough vegetables for household use and sale of surplus to local schools and hospitals and sometimes to Thika market. Eight farmers grew *Terere (Amaranth spp.) Cow peas (Vigna unguiculata)* and *Managu (Black nightshade)* on farmer's farms. Their *Cowpeas (Vigna unguiculata)* produced very low yields. The yields from *Terere (Amaranth spp.)* and *Managu (Black nightshade)* were only enough used for home consumption and little to sell to neighbours and local greengrocers.

7.6.2 Farmers Follow-up Visits at Wanyaga Area

The farmer follow-up visits were done for four seasons. The results (Table 7.12) indicate that the four PELIS participating farmers who planted *Terere (Amaranth spp.) Cowpeas (Vigna unguiculata)* and *Managu (Black nightshade)* produced large quantities for own use and sell surplus to local schools and hospitals and sometimes to Thika market. Eight farmers grew *Terere (Amaranth spp.) Cow peas (Vigna unguiculata)* and *Managu (Black nightshade)* on farmer's farms. Their *Cowpeas (Vigna unguiculata)* produced very low yields. The yields from *Terere (Amaranth spp.)* and *Managu (Black nightshade)* were only consumed at home and little sold to neighbours and greengrocers.

Table 7.12: Farmers Follow-Up Results (Wanyaga).

SEASONS	No of farmers	Vegetables planted	Outcome	Use
1	10	*Terere (Amaranth spp.) Managu (Black nightshade) Cow peas (Vigna unguiculata) Saget (Cleome gynandra)*	*Terere (Amaranth spp.) Cow peas (Vigna unguiculata) and Managu (Black nightshade)* grew well under PELIS. *Cow peas (Vigna unguiculata)* grown on the owners' farm developed poorly hence low yields.	3 PELIS farmers sold to schools and local markets. 7 non-PELIS farmers grew for family use and sold to neighbours only.
2	9	*Terere (Amaranth spp.) Managu (Black nightshade) Cow peas (Vigna unguiculata) Saget (Cleome gynandra)*	*Terere (Amaranth spp.) Cow peas (Vigna unguiculata) and Managu (Black nightshade)* grew well under PELIS. Only *Terere (Amaranth spp.)* and *Managu (Black nightshade)* grew well on non-PELIS farms	3 PELIS farmers sold to schools, hospitals and Thika market. 6 non- PELIS farmers grew for family use and sold to local green grocers.
3	9	*Terere (Amaranth spp.) Managu (Black nightshade) Cow peas (Vigna unguiculata) Saget (Cleome gynandra)*	The variety of *Terere (Amaranth spp.)* provided grew well but developed a lot of seeds and low vegetative growth. It was uprooted early and a new variety was grown. *Managu (Black nightshade)* and *Saget (Cleome gynandra)* grew well but *Cow peas (Vigna unguiculata)* grew poorly.	3 PELIS farmers sold to Thika market. 6 non-PELIS farmers had low *Terere (Amaranth spp.)* yields only for family consumption. *Saget (Cleome gynandra)* and *Managu (Black nightshade)* sold to local green grocers
4	10	*Terere (Amaranth spp.) Managu (Black nightshade) Cow peas (Vigna unguiculata) Saget (Cleome gynandra)*	New variety of *Terere (Amaranth spp.)* planted. *Terere (Amaranth spp.) Managu (Black nightshade) Cow peas (Vigna unguiculata)* and *Saget (Cleome gynandra)* grew well under PELIS. *Managu (Black nightshade)* seeds from previous crop were planted.	3 PELIS farmers harvested enough to sell to nearby schools. 7 Non-PELIS farmers produced enough for family consumption and sell surplus to local markets.

7.7 Discussion

From the study results, the pilot PELIS in Kimakia forest adjacent to the study community. However, just 11 % of the studied households participated in the program because the rest were busy with other activities (50%) unaware of the program (14.4%) lack of interest (10.8%) lack of required registration fees (7.2%) and poor health, disability and old age (5.2%). The PELIS is a Kenyan pilot farming model initiated in 2007 by the ministries of Forestry, Agriculture, Water, and Irrigation under Participatory Forest Management (PFM) guidelines of the Forest Act (2005) to boost food security among forest-adjacent communities (GOK, 2007). The approach has been piloted in tropical forested parts of the Central, Rift valley and Western Kenya and proved to improve livelihoods and food production of communities near forests through the provision of extra arable land (Odwori *et al.*, 2013; Odwori, 2017). In Kiambu County, for example, the PELIS approach increased food crop yields and proved to be cost-effective in forest plantation establishment (KEFRI, 2014). In the case of Malava forest in Western Kenya, PELIS participating farmers managed to fetch between Kshs 5,000 to Kshs 15000 annually from the sale of crops grown (Agevi *et al.*, 2016). The PELIS program can serve as a strategy for climate adaptation through enhanced food security, and mitigation of climate change by afforestation. Despite the low uptake of PELIS in the study community, the farmers who diversified their crops by growing the proposed vegetables were able to harvest enough for own use and sell to local hospitals, schools, and bigger markets.

The respondents understood the importance of the traditional vegetables (Table 7.3) but the stigma associated with the vegetables made the up-take of cultivation of these vegetables to be very low. These findings were in tandem with the preference ranking results (Tables 7.11 and 7.14) that revealed that amaranth (*Amaranth sp.*) and black nightshade (*Solanum nigrum*) were not preferred. Despite the traditional vegetables being highly abundant and nutritious, only 2.85 % of the households cultivated black nightshade. Amaranth was not cultivated at all. The farmers considered the indigenous vegetables as weeds and opted to plant other crops. Those growing in the wild were slowly disappearing due to pressure to expand arable land. A visit to the local seed dealers and markets showed that traditional seeds were not being sold. The farmers harvested the vegetables from the wild where they perpetuated themselves. The study established that the community favored consumption of other vegetables such as kale, spinach (*Spinacia oleracea*), and cabbage (see Section 4.3.6) and regarded traditional vegetables as food for the poor only to be consumed during a food shortage. According to Mwanga *et al*. (2020) indigenous vegetables are an important ingredient for many rural Kenya foods because they contain many micronutrients, have medicinal benefits, including many economic and agronomic benefits. However, in spite of their considerable yield and nutritional potential, they remain lowly regarded, especially among youthful communities. Their adoption is low, and most of them are regarded as weeds, hence their limited domestication (Herforth and Ahmed, 2015; Otieno *et al.*, 2020) note that most communities, particularly the youth prefer consumption of exotic vegetables at the expense of traditional vegetables. There was, therefore, a need to domesticate them.

From the household survey results, the communities mainly rely on smallholder rain-fed farming, with most households (93.3%) owning less than 4.5 acres of land (Table 4.1). These made their livelihoods highly susceptible to climate change. Ragie *et al*. (2020) concur that rural people in many growing economies highly depend on agriculture. They mainly grow crops and keep livestock which they consume and sometimes sell for income (Ragie *et al.,* 2020). Alhassan *et al*. (2019) add that the more a household's income source is dependent on farming, the higher sensitive it is in case farming is most impacted by the change in climate. The majority of them perceived erratic rainfall and temperature changes with adverse effects on their food security. Some of the factors underlying their food insecurity included consumption of two meals daily (71.5%), staying hungry (61.9%) and a shortage of finances to buy food (68%). The food produced by the majority of households (79%) could not reach the following season. The community's dietary diversity was low (Tables 4.3 and 4.4). Hachigonta *et al*. (2013) have observed that agriculture-based livelihoods are highly susceptible to the indirect climate impacts on prices of food, availability of food, and agricultural income at both farm and national scales. According to 78.6% of the respondents, the soil fertility on their farms was also low, concurring with Mango and Hebinck, (2016) that smallholder farming in Kenya is affected by low soil fertility resulting from continuous cropping, and limited application of inorganic fertilizers.

The study observed that the community had adopted various climate coping measures including, adjustments on planting times, types of crops grown, implementation of water and soil conservation techniques, engagement in off-farm employment, and meal size adjustments. Lawson *et al*. (2020) have noted that farmers implement different adaptation and coping strategies to address perceived climate variability and change. In Madagascar, farming households resorted to meal rationing and reliance on wild foods as a coping strategy against climate-related food insecurity (Fitawek, 2020). A wide range of other studies notes that such adaptation interventions can be effective if appropriately implemented (Mersha & van Laerhoven, 2018; Muchuru & Nhamo, 2019; Nkuba *et al.,* 2020). A good example is the use of soil-water conservation measures that have proved to improve rainwater use efficiency for better crop productivity (Wolka *et al.,* 2018). According to the KIIs and FGDs participants, most coping strategies adopted were for temporary endurance due to insufficient knowledge on accessible coping opportunities. Esteve *et al*. (2018) and Agidi *et al*. (2018) contend that unawareness of viable adaptation strategies continues to be a challenge among farmers. Alemayehu & Bewket (2017) agree that lack of resources for proactive risk management and along-lasing undertakings compel the poor to depend on temporary endurance plans. Rai (2019) reiterates that survival-based coping tactics often reduce poor farmers' opportunities to save, invest or recover from the poverty trap.

Similar findings by Dapilah *et al*. (2020) agree that coping strategies based on imperfect foresight and short-duration survival needs diminish future adaptive capacity by threatening environments and minimizing livelihood options. Farmers are entitled to the land, labor, and capital that they own. Their accessibility to food is guaranteed if they are able to utilize these factors to produce sufficient food (Eakin *et al.,* 2014). They can also address rising food costs by enlarging their farming to alternative farms, to make them food marketers, and raise farm wage and labour demand (Meyfroidt, 2018). Therefore, the pilot PELIS presented an avenue for the farmers to expand and diversify their food crop production (Makanji & Oeba, 2019). Traditional vegetables are a rich source of micronutrients necessary for food security, mainly during food shortages (Abukutsa-Onyango, 2003). Therefore, the availability of alternative land under PELIS was identified as a promising adaptation approach to expand their crop diversity, broaden their adaptive capacity and enhance food security under climate change.

The study sought to avoid the stigma related to traditional vegetables by conducting on-farm demonstrations (Figure 2) to encourage the farmers to grow a selected number of vegetable types. Results obtained from the farmer follow-up visits indicated that most farmers planted the vegetables on small plots due to small farm sizes. They consumed the harvested vegetables at home consumption and sold some to nearby greengrocers. The farmers involved in PELIS had larger farms and managed to cultivate the vegetables in high quantities (Table 7). They pooled their produce and hired pick-up vehicles for transporting the vegetables to local schools, hospitals, and larger markets. According to Masombo *et al*. (2020) The optimal yield range of indigenous vegetables is between 20 - 40 metric tons for one hectare. This is achieved if farmers use high-quality seeds, under a suitable environment, the right spacing, and the recommended of rates of organic/inorganic fertilizers. Incorporation of the vegetables in the PELIS program has the double advantage of climate adaptation through crop and income sources diversity and climate change mitigation through afforestation.

7.8 Conclusion

The study results revealed that the community perceived temperature and rainfall changes with adverse risks on their crop farming that lowered their food security. The PELIS presented a viable climate adaptation strategy with considerable benefits of improving the smallholder farmers' food security. Availability of extra land parcels under PELIS emerged as a suitable opportunity to expand crop production by including cultivation of the traditional vegetables such as Cowpeas, Amaranths and Black nightshade, income generation and diet diversity.

The main challenges facing the uptake of the pilot PELIS program were finance inadequacy, inaccessibility of markets for the farm produce, unawareness of the program, unawareness of the program. Domestication of the traditional vegetables among the study community was affected by stigma and inadequate knowledge on cultivating the vegetables.

To deal with these challenges requires collaboration between the County government to promote PELIS awareness among the forest-adjacent communities. Partnership between the relevant stakeholders such as, local farmers, input suppliers, lenders, researchers, transporters, County government, and NGOs, is necessary for enhanced production, consumption, and marketing of the vegetables. These will eliminate the pessimism related to the vegetables and advance knowledge on their potential in diet and income sources diversity, and thus food security among smallholder farmers across Murang'a County and beyond.

CHAPTER EIGHT: GENERAL CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

From the results of this study, the community perceived declining food crop productivity and food insecurity resulting from rainfall and temperature changes. They anticipated that by 2045 the situation could go beyond their coping limits. However, their perceptions of declining rainfall contrasted with observed rainfall data that showed normal rainfall variations. Their perceived temperature changes agreed with observed maximum temperature trends. The study community responded to the impacts by implementing a range of coping measures that face various challenges. The study identified the pilot PELIS program as a promising adaptation opportunity with the potential to expand the community's crop diversity and income sources. The PELIS farmers who adopted traditional vegetable varieties such as Amaranth and black nightshade through the PELIS program produced enough quantities to diversify their household diets and sell the surplus for income. Scaling-up PELIS faced challenges by unawareness of PELIS participation, finance inadequacy, and inaccessibility of markets. The study also found knowledge inadequacy on the domestication of the traditional vegetables a challenge. Several conclusions made from the study include:

1. The study area was warming negatively affecting the smallholder farmers' crop productivity and food security. The discrepancy between farmers' perceptions of declining rainfall and observed normal rainfall trends call for broad-based climate change interventions. Relying on a single information source may lead to maladaptation. The future changes and impacts remain uncertain and require deliberate interventions by relevant stakeholders to enhance the smallholder farmers' preparedness against anticipated future climate risks.
2. The community was practicing a range of climate coping mechanisms for food security. Their adaptive capacity was facing myriad challenges including inadequate knowledge on appropriate crops. Hence, the farmers preferred local races that were slowly facing extinction. Small land parcels also posed a challenge to the adoption of some viable adaptation options.

8.2 Recommendations

Based on this study findings, the following policy and adaptation recommendations are suggested:

- **Improved Climate Information Access among the Local Community**

To strengthen the community's climate change adaptation capacity requires collaboration between farmers, government extension officers, and climate scientists for better knowledge exchange. These call for participatory knowledge-sharing platforms to transfer knowledge on prevailing and imminent climate change risks and available sustainable climate risk management mechanisms.

- **Improved Credit Access**

The main challenge to climate adaptation amongst the study community was credit access to acquire appropriate agricultural inputs. For increased agricultural efficiency under diminishing resources and a changing climate, credit accessibility by farmers should be enhanced for prompt input acquisition.

- **Irrigation Water Availability.**

The water service providers prohibit the use of piped water for irrigation. The water supply in the area was also unreliable. Hence, the community's only form of irrigation was bucket irrigation from nearby rivers. Most of the perennial rivers were drying up due to erratic weather patterns. Therefore, there is a need for concerted collaboration between the County, national governments, and the water service providers to formulate modalities for developing needed infrastructure to ensure reliable water availability for irrigation and household use among the local communities. For sustainable crop-water use in the face of rising temperatures, there is a need to strengthen research on the development of crop varieties adaptable to high temperatures.

- **Improved Soil Conservation and Productivity**

The study noted that high rainfall coupled with the steep terrain of the study area aggravated soil erosion and nutrient leaching resulting in low productive soils. The agriculture ministry can work with the local community to implement soil conservation measures such as agroforestry and terracing for soil conservation. Local farmers should be educated on proper fertilizer application to avoid the indiscriminate application of organic fertilizers.

- **Up-scaling Diversification of Crops and Livelihoods Diversification through the PELIS Pilot Programme for Improved Food Security under Climate Change**

The diminishing household farm acreage resulting from population growth necessitates flexibility to use alternative land. In the face of climate change, the PELIS program presented a promising adaptation opportunity to diversify household diets and incomes for forest-adjacent communities such as Kimandi-Wanyaga. This requires enhanced sensitization and training on PELIS functionality. There is also a need to enhance knowledge transfer on nutritional value and domestication of traditional vegetables for improved diet diversity among smallholder farming communities and complementary institutions such as schools and hospitals. This is achievable by frequently engaging the public through multiple knowledge-sharing and capacity-building platforms such as farmer field days, workshops, and local administration meetings *(barazas).*

- **Agricultural Products Value Addition**

Enhanced value addition of agricultural produce is necessary to mitigate against unstable market prices that precipitate middlemen exploitation. Value addition lengthens shelf-life, minimizes post-harvest losses, and improves market leverage making agricultural production profitable. There is a need for concerted efforts to develop well-coordinated agricultural products value chains. These call for synergy between the local community, county, and national governments and other development agencies to enhance the transfer of requisite knowledge, skills, and technology.

8.3 Recommendations for Further Research

This study was limited to Kimandi-Wanyaga community experiences with rainfall and temperature changes. The study, therefore, examined the impacts of rainfall and temperature changes on the community's food crops and the challenges affecting their climate coping efforts. The study also explored the potential of expanding the community's crops and income generation diversity by incorporation of traditional vegetables in the PELIS pilot program. The study suggests further research on the following areas:

- Climate change vulnerability mapping of Murang’a County
- Improvement of climate change information communication with the vulnerable smallholder farming communities in Murang’a County.
- Further scope also exists on improving seed quality, supply, and agronomic practices for optimum food crop yields.

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APPENDICES

APPENDIX I: SUMMARY DESCRIPTION OF TOOLS USED IN THE FIELDWORK

Tool	Scope	Process
FOCUS GROUP DISCUSSIONS (FGDs) **Semi-Structured Interviews** **Oral Testimonies**	Establish the most important climate hazards that had occurred in the area. Explore chronicle climate variability through participants' reconstruction of observed major climate events in terms of timing, frequency, and magnitude of climate events Establish the most important community's livelihood resources. Establish impact of climate hazards on important livelihood resources. Reveal how the local residents interpret the world of climate change by themselves. To understand the social world of the community, examine how the participants interpret that world by themselves. Establish changes on types of crops grown.	List of questions administered to focus group participants by facilitators Questions discussed freely among FGD participants Facilitation of each group, note taking by members of the interdisciplinary team
Seasonal Calendars	Establish external stressors and their interaction with climate change. To identify the community's coping strategies, challenges and opportunities. Identify times of greatest difficulty and vulnerability Identify climate events adversely affecting the community's livelihoods. Summarize indigenous seasons, weather variations, cropping patterns, crop pests and diseases, labour demands, income generating activities, income and expenditure, types of food consumed and marketing strategies used	Ask participants to draw a 12-month calendar indicating: activities of the year on a monthly basis including driest, middle and wettest periods, cropping patterns, other non-farm activities and challenges faced.
Observations and Photographs.	Capture non-verbal indicators (facial expressions, intonations, eye contact, gestures) that shed light on respondents' concerns, reservations, emphasis, seriousness and which may offer clues for data interpretation.	Keenly observe behaviours, patterns, disagreements etc.
TRANSECT WALKS	Ground-truth information collected during FGDs. Sometimes interesting features and explanations are revealed. View the range of conditions across the study area. Identify local management and use of natural resources, soil types, crop types, water resources problems and opportunities available.	Traverse the study area, observe the situation on the ground and talk to people living there. Ask key informants to participate in the walks. Discuss the research information needs from the walks Observe, take notes, ask questions

Tool	Scope	Process
Photographs	To capture a snapshot situation on the ground	Take photographs on relevant features
HOUSEHOLD SURVEY	Establish the most important climate hazards that have occurred in the area. Explore chronicle climate variability through participants' reconstruction of observed major climate events in terms of timing, frequency, and magnitude of climate events Establish the most important community's livelihood resources. Establish impact of climate hazards on important livelihood resources. Reveal perceptions of local residents to climate change. Establish changes on types of crops grown. Establish external stressors and their interaction with climate change. To identify the community's coping strategies, challenges and opportunities. Identify times of greatest difficulty and vulnerability Identify climate events adversely affecting the community's livelihoods.	List of questions administered to household survey participants by enumerators
KEY INFORMANT INTERVIEWS	Discover information lacking in other community members Capture a multi-perspective of the community's experiences with climate change	List of questions administered to key informant by facilitators
FARM DEMONSTRATIONS **Pairwise Preference Ranking**	Encourage attitude change and transfer knowledge and skills in traditional vegetable farming, value addition and collective marketing. Discover the participants' criteria for choice of the selected traditional vegetables. Avoid introduction of unwanted crops.	Subject matter specialists in agribusiness, agronomy, food and nutrition to conduct training. Participants to rank five traditional vegetable crops through a sequence of comparisons of two vegetables at a time, rating them against each other and giving reasons for the preference. Record the comparisons in a matrix by entering the winner of each comparison. The final ranking is achieved by adding up the number of times each vegetable appears as a winner. Record the results in a matrix.
Farmer follow-up visits	Evaluate rate of vegetable take-up rate	Visit participating farmers' farms Observe the cultivated vegetables Ask questions and record results

APPENDIX II: HOUSEHOLD SURVEY SEMI-STRUCTURED QUESTIONNAIRE

Section 1: Household Characteristics

1. Name of household head ……………………………………………………….
2. Age…………………………………………………………………….
3. Gender M ☐ F ☐
4. Education level ………………………………………………………….
5. Occupation …………………………………………………………….
6. Household composition.

Age	Gender	No formal education	Primary	Post-primary	college	university	Other (married/employed

7. Household farm acreage and use

Land use	Homestead	Cash Crop	Food Crop	Leased IN	Leased OUT	Government Owned (Shamba System)
Size (Acres)						

8. Household food security

Food security indicators	**Yes**	**No**
Did any of your household members go hungry during the last 12 months?		
Did your household run out of money to buy food during the past one year?		
Did your household run out of money to buy food during the past one year?		
Did your household run out of money to buy food during the past one year?		
Did you cut the size of meals during the one past year because there was not enough food to eat?		
Did you skip any meals during the past one year because there was not enough food to eat?		
Did you eat a smaller variety of foods during the past year than you would have liked to because there was not enough food to eat?		

9. How long do you consume food produced in your own farm?

1 month	☐
3 months	☐
6 months	☐
Over 6 months	☐

Section 11:

Objective 1: Rainfall and temperature changes in Kimandi-Wanyaga sub-Location in Murang'a County, Kenya.

The community's climate change perceptions

10. Do you think that the local climate has changed over the period 1984 to 2014?

YES ☐ NO ☐

11. How do you think the following climate aspects have changed over the period 1984 to 2014?

Climate aspect	**Decrease**	**No change**	**Increase**
Frequency of mist/fog			
Frequency of drought			
Frequency of flood			
Rainfall season onset			
Rainfall cessation			
Rainfall intensity			
Adequacy of rainfall during crop growing season			
Temperature			

12. Have these changes affected your livelihood resources?

Yes ☐ No ☐

13. If yes, specify which livelihood resources have been affected and how?

Natural resources

Land………………………………………………………………………………

Rivers……………………………………………………………………………

Crops ……………………………………………………………………………

Livestock………………………………………………………………………

Trees……………………………………………………………………………….

Physical resources (infrastructure)

Roads ……………………………………………………………………………

Buildings…………………………………………………………………………

Human resources

Labor supply …………………………………………………………………….

Health…………………………………………………………………………….

Economic resources

Income………………………………………………………………………………

Expenditure patterns………………………………………………………………......

Market accessibility ……………………………………………………………………….

Financial institutions……………………………………………………………………….

Social Resources

Family size…………………………………………………………………………………

Occupation (source of income) ……….………………………………………………...

Social amenities……..…………………………………………………………………….

Communal activities……………………………………………………………………….

14. Have you experienced any extreme climate events like droughts, floods and fog/mist which have affected your crop production during the period 1984 to 2014?

    YES □ NO □

15. If yes, what were they and what aspects of crop production did they affect?

Extreme climate events	**Tea**	**Food crops**	**Explain**
Excess rainfall			
Drought			
Frost			
Mist/Fog			
Others			

16. What specific weather risks are you experiencing while producing food crops today?

Weather risk	**Yes**	**No**	**Year/Season experienced**
Drought			
Excess rainfall			
Temperature changes			
Fog/mist			
other			

17. What variety of crops have you been growing in your farm for the period 1984 - 2014?

18. Have changes in climate affected the types of food crops you have been growing during the period 1984 to 2014?

    YES □ NO □

19. If yes explain

20. How many months in a year does your family consume food from your own farm? (*Check all that apply).*

1 month	
3 months	
6 months	
Over 6 months	

Objective 2: The perceived rainfall and temperature changes that have affected food security in Kimandi-Wanyaga sub-Location in Murang'a County, Kenya.

How have you been coping with change impacts on your crop production for the period 1984 to 2014? *(Allow participants to come up with answers, but if they are unable to, then read them the options).*

Strategy	
Reduce household food consumption by rationing number or size of meals	
Diversify crops e.g. intercropping, staggered planting, intensive farming	
Diversify to non-farm income e.g. migration to towns in search for employment, taking up other non-farm income generating activities	
Diversify farm with non-farm income activities	
Sell labour by working for wages in other people's farms	
Sell possessions sometimes at deflated prices	
Sell or pledge land	
Sell firewood and charcoal	
Borrow grains	
Expand food crops farming area	
Collect wild foods	
Use inter-household transfers and loans	
Borrow credit from merchants and money lenders	
Distress migration.	
Abandon farming altogether	
Seek assistance from NGO	
Seek assistance from other community members	
Other ways:	

21. What are you currently doing to cope with climate change impacts?

Concentration only on tea farming	
Change of planting dates to wait for onset of rainfall	
Dry planting	
Change crop varieties	
Move to other location	
Switch from crops to livestock	
Switch from livestock to crops	
Increase land under food crop cultivation	
Use water harvesting/conservation techniques	
Implement soil conservation techniques	
Use irrigation	
Migrate to urban areas in search for employment	
Use crop insurance	
Search for off-farm employment	
Work in other farms for wages	
Resort to religious beliefs (prayers)	
Change fertilizers, pesticides and insecticides	
Other adaptations strategies	

Objective 3: The challenges facing Kimandi-Wanyaga community in Murang'a County responses to rainfall and temperature changes.

What challenges do you encounter in your response to climate change impacts?

Declining workforce due to schooling, migration, ageing workforce etc.	
Reduced social connectedness / social ties	
Inadequate finances to adopt new crops/ farming systems	
Poor health	
Limited information or lack of awareness of new coping mechanisms	
Reduced government support for rural communities	
Rising incidences and emergence of new weeds, crop/animal pests & diseases	
Growing the same types of crops	
Continuous cropping due to reducing farm sizes	
Lack of access to early warning information	

22. Among the problems listed below, which ones have you experienced while growing crops on your farm for the past 30 years? (*Check all that apply).* Please give examples.

Pests	
Diseases	
Weather changes e.g. reduced/too much rainfall, floods, mist fog	
Lack of access to inputs	
Poor roads	
Lack of market	
Other (s)	

23. Please explain how you have been managing excess food crops in the period 1984-2014

Harvesting………………………………………………………………………………….

Storage……………………………………………………………………………………

24. Please explain how you manage excess food crop produce after harvesting today (*Check all that apply)*

Sell to neighbours	
Sell through cooperative	
Sell in market/green grocer shops	
Sell through middle men	
Sell to buyers from big towns	
Barter Trade	
Store for future use	
Other(s)	

25. How do you store your food crops after harvesting today? (*Check all that apply).*

Metal silos	
Large pot	
Plastic containers	
Traditional granary	
Baskets	
Drying	
Room in house	
Other(s)	

Income and expenditure

26. How much does your occupation contribute to your household income? (*Check all that apply).*

Occupation	High	Low	None	Number of household members engaged
Farming (Food crops)				
Farming (Cash crops)				
Livestock products				
Salary from employment				
Wages from casual jobs				
Money received from relatives				
Private business ownership				
Pension/social security				
Other (please specify)				

27. Are your sources of income stable?

YES □ NO □

28. Does your household have the following?

Lifelines	**Yes**	**No**
Electricity		
Clean water		
Vehicle/Motorcycle		
Radio/TV		
Mobile phone		

29. How do you normally finance input costs (e.g. fertilizers, seeds, farm chemicals? (*Check all that apply).*

Do not buy inputs	
Own finances	
Loan from banks	
Money lenders	
Other sources	

30. How would you rate your household income level, based on your expenses? (*Check all that apply).*

Usually not enough to cover important household expenses	
Just enough to cover important household expenses	
Usually have some left after important household expenses	

Diet quality

31. How many meals does your family consume daily?

32. What food has your family consumed within the last 24 hours?

Food category	**Yes**	**No**	**Food category**	**Yes**	**No**
Cereals			Fruits		
Fish			Oil/fats		
Root and tubers			Meat/poultry		
Legumes/nuts			Sugar/honey		
Vegetables			Eggs		
Milk and milk products			Miscellaneous		

33. How do you think food production would be affected by continued changes (by 2045) in the following aspects of climate?

Climate aspect	**Effect on food crop growth**
Increased rainfall **(above crop needs)**	
Reduced rainfall **(below crop needs)**	
Increased temperatures **(prolonged hot seasons)**	
Reduced temperatures **(prolonged cold seasons,)**	
Increased incidences of **mist/ fog**	

Objective 4: The potential of the cultivation of traditional vegetables under the pilot PELIS Programme in enhancing crop and livelihood diversification among Kimandi-Wanyaga community in Murang'a County.

Do you participate in the Plantation Establishment Livelihood Improvement Scheme (PELIS)?

YES □ NO □

Explain ____

34. What do you think about the state of soil fertility in your land currently?

Soil Fertility status	Reason
High	
Moderate	
Low	

35. Please explain how you maintain soil fertility for food crop production on your farm.

Use of inorganic fertilizers	
Use of farmyard manure	
Crop rotation	
Agroforestry	
Others	

36. What traditional vegetable crops have you been growing for the period 1984 to 2014?

Malenge (Cucurbita moschata)	
Terere (Amaranth spp.)	
Managu (Black nightshade)	
Thabai (Urtica urens)	
Saget (Cleome gynandra)	
None	

37. Which traditional vegetables crops would you consider growing now and why?

Malenge (Cucurbita moschata)	
Terere (Amaranth Spp.)	
Managu (Black nightshade)	
Tabai (Stinging nettle)	
Saget (Cleome gynandra)	
Murenda (Corchorus olitorius)	
None	
Others	

38. How did you manage your traditional crops after harvesting in the period 1984 to 2014?

Please explain ____

39. Do you have surplus farm produce for sale?

YES ☐ NO ☐

Explain

40. What challenges do you face when marketing your farm produce?

Poor roads	
High transport costs	
Market space availability	
Storage	
Low market prices	
Other(s)	

41. Apart from Kenya Tea Development Authority (KTDA) do you belong to any other crop marketing group?

YES ☐ NO ☐

42. How would you describe the effectiveness of community groups in this sub-Location?

Very helpful	
Somewhat helpful	
Not helpful	
There are no community groups	

43. What do you think should be done to improve the income from your farm produce?

Grow many types of crops	
Grow new types of crops	
Irrigation	
More fertilizer	
Better storage	
More support from government	
Access to reliable information on early warning systems	
Rainwater harvesting	
Construction of bunds/terraces to prevent run-off & soil erosion	
Zero-tillage/minimum cultivation	
Apiculture	
Other(s)	

44. Besides crop production, have you tried out other income generating activities in the period 1984-2014?

YES ☐ NO ☐

Examples ____

45. What challenges did you encounter while undertaking the extra income generating activities?

Explain ____

APPENDIX III: FOCUS GROUP DISCUSSION RESULTS

Date: 03/09/2015 **Venue**: Wanyaga AIC Church Hall

Participants: Females-five; Males- five.

Facilitators: Kariara Ward Agricultural Extension Officer; Ndakaini Adult Education Officer; Kariara Ward Agricultural Economics Officer; Researcher.

A. COMMUNITY PERCEPTIONS ON LOCAL CLIMATE CHANGE AND VARIABILITY DURING THE PERIOD 1984-2014

i. Unpredictable temperatures.

According to the FGD participants it had become difficult to predict how the weather would turn out compared to the past. For example, July used to be the coldest month of the year but it had become warmer. August used to be warm but had turned to be cold implying that July cold had moved to August.

ii. Unreliable rainfall

Rainfall had become unreliable which interrupted cropping seasons. The community's traditional cropping patterns were determined by two rainfall seasons of March to May (long rains) and October to December (short rains).Currently, the farmers were losing seeds if they dry planted in anticipation for the rains. If they planted at the start of rains, the crops grew poorly in case the rains stopped earlier or lasted for a short time stopping at the height of crop growth resulting in poor yields.. Most farmers said that their planting calendars had been highly disrupted.

iii. High occurrence of mist and fog.

The FGD participants reported increased occurrences of frostbite on tea and other food crops which resulted in low tea yields and massive loss of food crops. Crops surviving the frostbite produced low yields. Respondents were concerned that since 1980 the area had become more humid attributing it to weather changes.

B. COMMUNITY PERCEPTIONS ON IMPACTS OF CLIMATE CHANGE AND VARIABILITY ON THEIR LIVELIHOOD RESOURCES

i. Landslides

During the transect walk two areas previously affected by landslides were located. Participants attributed the landslides' occurrence to steepness of the terrain and high rainfall. Deep valleys caused by the landslides were still visible and the land had become unsuitable for farming. The affected areas had been rehabilitated through tree planting and diversion of road runoff water by use of pipes. Harvesting of the planted trees was also dangerous due to the steepness of the terrain.

ii. Soil erosion

Soil erosion was prevalent in areas without tea bushes. Farmers were planting to curb the problem. However, soil erosion continued on bare land where trees had been cut down. Eroded soils were often deposited in nearby rivers such as Githika, Gitabiki, Thika and Kayuyu which drained into Thika dam posing the risk of river and dam siltation and water eutrophication.

iii. Reduced soil fertility

Participants cited that soil erosion and soil nutrient leaching during high rainfall reduced their soil productivity. Also reported was high soil acidity attributed to overuse of Di-ammonium Phosphate (DAP) fertilizer supplied for use in tea production by Kenya Tea development Authority (KTDA). Participants reported that they had for a long time used DAPS for food crop production despite having no knowledge on recommended application rates on food crops. They said that they had since noted the impacts and had started to 'cure the soil acidity' problem by use of alternative fertilizers, especially organic manure. Kariara ward agriculture extension officer who was present said that she had been advising the farmers to apply agricultural lime on their soils.

iv. Crop pests

Participants identified weevils, moles, porcupines and aphids as common crop pests adding that weevils were damaging maize and bean crops pre and postharvest. They said that they commonly used traditional methods against the weevils such as the use of Mexican marigold. They said that Mexican marigold was safe for human beings but acted as a repellent for pests. Moles and porcupines attacked sweet potatoes *(Ipomea batata)* and arrowroots and the farmers controlled them through trapping. However, the farmers claimed that trapping had become expensive which raised the cost of production and the moles and porcupines had become evasive discouraging farmers from cultivating the crops. Regarding preservation of sweet potatoes *(Ipomea batata)* and arrowroots, the farmers did piecemeal harvesting. During surplus, they were heaped together and covered with plant materials for later use. Lack of market for the arrowroots and sweet potatoes *(Ipomea batata)* was reported as a major problem.

v. Livestock pests and diseases

Participants mentioned tsetse flies and ticks as major livestock pests in the locality. They said that tsetse flies were spread by buffaloes found in neighbouring Aberdare forest while East Coast fever (ECF) was spread by ticks. They added that they had observed a rise in animal pests and diseases incidents attributing it to changes in weather patterns. They said that this had increased livestock production costs and reduced livestock farmers' profit margins.

vi. Human pests and diseases

The participants had observed a rise in human diseases especially malaria, arthritis, pneumonia, influenza and common cold attributing it to weather changes. They reported that they had observed increased presence of mosquitoes compared to the past which raised malaria attacks among the community. They blamed the situation on weather changes while some feared it could be caused by close proximity to Thika dam. They added that the area had become more humid, a situation they also associated with rise in human diseases particularly pneumonia. High incidences of sickness had increased the cost of living as more money was spent on treatment and caring for the sick. Ill health also affected household members' labour productivity lowering their economic contribution to the household. They attributed high incidences of non-communicable diseases like cancer, diabetes, high blood pressure to changes in eating habits and other lifestyles noting that most locals had departed from consuming traditional foods preferring to consume processed foods. For example, instead of consuming potatoes, arrowroots, pumpkins (*Cucurbita moschata)* as in the past, many locals opted to eat bread, rice and *chapati* (Tortilla or flatbread). They also said that high use of agrochemicals in crop and livestock production could be a possible cause for the rise of cancer cases.

C. EXTERNAL STRESSORS

i. Inadequate water supply for household use and irrigation

Participants said that despite residing in an important water catchment area that fed water to Thika dam and Nairobi County residents, water scarcity was prevalent in the area. Water supply to the residents was regulated making it quite unreliable. They cited that water vendors in the area were making a lot of money by selling water. They claimed that they had often staged demonstrations against water rationing but nothing had changed. One respondent said that he had plucked off water supply pipes to his home because all he got were water bills but no water. They appealed for a regular water supply and also be allowed to use piped water for irrigation.

ii. Reducing farm sizes

Land fragmentation due to rising family sizes had forced residents to commit most of their farming land to tea farming leaving little land for food crop farming. This had lowered their diet quality resulting in malnutrition among some households. Other households were forced to spend most of their income on food purchase at the expense of other services like healthcare and education.

iii. Poor storage facilities.

Most of the homesteads had no stores for food storage. They said that they had little farm produce to store hence no need to construct storage facilities adding that the little they had was preserved through traditional methods such as drying of maize cobs on the farms, use of Mexican marigold as a repellant and hanging of maize cobs on roof tops.

APPENDIX IV: THE FARMERS' SEASONAL CALENDARS

FGDs participants were asked to compile two seasonal calendars i.e. one for a good year and another for a bad year. The calendars are shown below.

THE FARMERS' SEASONAL CALENDAR IN A GOOD YEAR (1986)

MONTH	ACTIVITY
JANUARY	Warmest month of the year marking beginning of a dry spell.
FEBRUARY	Planting of maize, Irish potatoes (Solanum tuberosum) beans (Phaseolus vulgaris) sweet potatoes (Ipomea batata) tea picking continued
MARCH	Start of the rainy season. Mid-month- spraying of potatoes using the traditional method of mixing ash with water to protect the potatoes against early and late blight. End of the month- weeding, top dressing of crops with fertilizers Tea picking continued
APRIL	-Flush tea (sudden increased tea production) This happens once and disappears - Tea planting for those willing to increase their tea acreage. -Bush clearing for additional tea planting -Labour outsourced from outside the area.
MAY	Middle of the month –tea pruning by men normally done at this time since the yields start to reduce as most of the bushes are unproductive (moribund). End of the month – End of rains. Harvesting of Irish potatoes (Solanum tuberosum) , earthing-up of other crops and weeding. Little tea picking continued
JUNE	-Tea pruning continued
JULY	Coldest month of the year. Tea yields were lowest and hence pruning was at top gear. Under sowing of maize
AUGUST	Harvesting of ready maize that was planted in February. Under-sowing of beans (Phaseolus vulgaris) topdressing of tea, tea picking continued

MONTH	ACTIVITY
SEPTEMBER	Harvesting of sweet potatoes (Ipomea batata). Sun drying of maize and beans (Phaseolus vulgaris). Maize was also preserved using layers of Mexican marigold alternated with maize cobs. Some maize was preserved by hanging on kitchen roofs for drying and smoking. Maize dried in such a manner is commonly known as manja.
OCTOBER	Start of the rainy season. Start of a peak season. Influx of labourers from outside the region (from Embu, Kisii, and western Kenya) mainly to pick tea. Tea bonus is paid. Topdressing of crops was done
NOVEMBER	Tea peak season continued. Harvesting of fresh beans (Phaseolus vulgaris) for home consumption. Beginning of the festive season. Many festivals held at this time e.g. circumcision of boys who have come of age (normally determined by completion of standard 8 exams) weddings, dowry payments, harambees (fundraisers) families get together while others visit distant relatives as the schools were closed for long vacations. Money was available from the tea boom/bonus paid in October. Most of the people working in towns were also visiting their homes.
DECEMBER	Mainly a warm and rainy season. Most festivals took place at this time. Tea peak season continued. A lot of time spent at the tea buying centres due to transport and tea processing challenges. For example, lorries transporting tea leaves from buying centres took too long to offload at the factories since the factories were few and had limited processing capacity. Some lorries had therefore to be diverted to other factories as the factories were overwhelmed by the excess produce during peak season. High December rainfall rendered most rough roads impassable causing some tea transporting lorries to stall leading to spoilage and loss of tea leaves which are highly perishable.

THE FARMERS' SEASONAL CALENDAR IN A BAD YEAR (2000)

MONTH	ACTIVITY
JANUARY	End of rainy season. The month had become colder Little maize to be harvested Tea picking continued
FEBRUARY	Land preparation in anticipation for March rains Tea picking continued
MARCH	Middle of the month, there was a dry spell and therefore there was little activity on farms
APRIL	Middle of the month: weeding the farms where few crops were planted. Vegetables are planted on farms near river valleys There was no flush tea Second land preparation for maize planting
MAY	Planting of maize *(Zea mays)* beans *(Phaseolus vulgaris)* green peas *(Pisum sativum)* using inorganic fertilizers and farmyard manure. No sweet potatoes *(Ipomea batata)* planted Little tea picking and pruning.
JUNE	Planting of maize *(Zea mays)* continued, weeding and top dressing with inorganic fertilizers. Tea pruning and topdressing with fertilizers
JULY	No longer the coldest month of the year. It was becoming warmer Replanting of maize on areas where the crop had failed to germinate. Tea pruning and top dressing carried out.
AUGUST	The little maize available is harvested piecemeal. Topdressing of tea as tea picking continued
SEPTEMBER	Weeding on farms Tipping of tea (initial picking of pruned to restore the tea picking table)
OCTOBER	Tea yields are moderate. Family labour is enough hence no need for hired labour. Tea bonus is paid. Harvesting of green peas (Pisum sativum) and other vegetables
NOVEMBER	Tea picking continued. Tea yields increased but not in large quantities as during good rains. Influx of labourers from outside to pick tea. Harvesting of vegetables continued.
DECEMBER	Tea picking continued. Few labourers were hired. Fewer festivals such as dowry payments, weddings and family get-together took place. Harvesting of green maize and dry beans *(Phaseolus vulgaris)* for home consumption.

APPENDIX V: WANYAGA FARMERS' GENDER DAILY CALENDARS

FGDs participants were asked to draw their daily calendars indicating the activities they undertook on a typical day. Results are shown below

WOMEN DAILY CALENDAR

ACTIVITY	**TIME**
Wake up time	5.00 am
Milking of cows	5.00-6.00 am
Selling of milk to neighbours or dairy farmers cooperative society	6.00-630 am
Preparing children for school Some prepare lunch before going to the farm	6.30 am-7.00
Feeding of livestock	7.00am
Tea picking	8.00 am
Taking tea lea leaves to tea buying centres	9.00 – 1.00 pm
Preparing lunch	1.30 pm
Collecting firewood	3.30 pm
Milking of cows	5.30 pm
Weeding of kitchen gardens	6.00 pm
Bathing of children	7.30 pm
Preparing supper	8.30 pm
Serve supper to family members, take supper and bathe	9.00 pm
Sleep time	10.00pm

MEN DAILY CALENDAR

ACTIVITY	TIME
Wake up time	6.00 am
Milking of cows	6.30 am
Feeding of livestock	7.00 am -7.30 am
Take breakfast	7.30 am - 8.00am
Tea peaking	8.00 am - 1.00 pm
Lunch break	1.00 pm - 1.45 pm
Feeding of livestock	1.45 pm – 2.00 pm
Weighing of tea	2.00 pm – 3.00 pm
Collection of livestock fodder	3.00 pm – 4.30 pm
Milking of cows	4.30.00 – 5.00 pm
Feeding of livestock	5.00 pm – 5.30 pm
Clearing the cow shed	5.30 pm – 6.00 pm
Visit shopping centres to interact with other men	6.00
Newspaper reading	7.00 pm
Take supper	9.00 pm
Sleep time	10.00 pm

Gender Daily Calendar Analysis Summary

Results from the daily calendars were analysed according to gender and presented as follows:

TYPE OF ACTIVITY	HOURS SPENT (WOMEN)	HOURS SPENT (MEN)
Working on the farm	9 Hrs.	6 Hrs.
Tending to livestock	3 Hrs.	4 Hrs. 45 minutes
Family care	4 Hrs.	0 Hrs.
Leisure & sleep	8 Hrs.	13 Hrs. 15 minutes
Total Hours	24 Hrs.	24 Hrs.

APPENDIX VI: FOCUS GROUP DISCUSSION RESULTS KIMANDI COMMUNITY FOCUS GROUP DISCUSSION

Date: 09/03/2015 **Venue**: Ndakaini Dam Site **Participants**: Females-Seven; Males- seven.

Facilitators: Kariara Ward Agricultural Extension Officer; Ndakaini Adult Education Officer; Kariara Ward Agricultural Economics Officer; Researcher.

Objective I: To identify and analyse climate stressors responsible for food insecurity in Kimandi-Wanyaga sub-location, Murang'a County during the period 1984 to 2014.

1. Do you think that the local climate has changed over the period 1984 to 2014?
   YES ■ No ☐

2. If yes, what aspects of the climate have changed since then to now and how have they changed?

	Changed	Not Changed	Explain
Rainfall	■	☐	
Temperature	■	☐	
Mist/Fog	■	☐	
Others			

3. Have these changes affected your livelihood resources?
   Yes ■ No☐

4. If yes, specify which livelihood resources have been affected and how?

i. Natural resources (land, rivers, crops, livestock, trees)

a) Land: Deforestation is on the rise and soil erosion has increased making soils infertile.

b) Rivers: Reduced river water volumes, some perennial rivers have become seasonal, reducing water for irrigation on farms near rivers.

c) Crops grown: Some crops grown in the past have disappeared, others produce low due to water shortage and others are affected by frostbite. Tea production which is the mainstay of our livelihoods has reduced. Food crop yields have also reduced.

d) Livestock: There is reduced fodder when rains are low and too much fodder during heavy rains leading to wastage due to poor means of preservation. Grass used as fodder has also reduced which has increased expenses on buying livestock feed.

e) Trees: Deforestation has risen to expand farming land and indigenous trees are fast disappearing.

ii. **Physical resources such as roads, buildings**

a) Infrastructure: roads have been eroded by heavy rains leading to potholes. Others are impassable during heavy rains. Sometimes landslides blocked roads cutting off communication

b) Buildings: residents are now building houses that keep warm during the cold seasons since sometimes it gets very cold. Most stone houses have moulds growing on them due to high humidity.

iii. **Human resources such as labour supply, health**

a) Labour: Labour supply is highest during heavy rainfall when tea production is at its peak. Food crops growth is highest during rainy seasons and hence extra labour is required. Labour to pick tea is sourced from outside the County especially from Embu, Kisii and Kakamega. Labour shortage is a challenge for the elderly, the sick and the poor.

b) Health: Human health has been adversely affected by the cold spells whereby respiratory diseases such as influenza, common cold and pneumonia have become rampant. Arthritis is also a problem due to the cold weather. Malaria has also become a common problem due to the change in weather patterns. These have increased households' financial burden as they spend a lot of money on seeking treatment and caring for the sick. Sick family members also stay away from work.

iv. **Economic resources such as income, expenditure patterns, market accessibility and financial institutions**

a) Income: Income from crop farming has become very unstable and unprofitable in the area. During favorable weather, food crops are planted and harvested almost at the same time. The supply saturates the market with similar produce leading to low prices. When the weather becomes unfavorable for crop growth, the produce is in short supply, the prices rise. Food crop produce is also highly perishable while the means of preservation are poor. High cost of transport also reduced profit margins. The main source of income for the residents is mainly from tea. When the tea prices are good, the residents are paid well and vice versa. However, the residents noted that tea prices had been falling. Some were looking into planting other crops like Hass avocado *(Persea americana 'Hass')* variety for export or purple tea which fetches better prices. Some were also intercropping tea with tree tomatoes to supplement their incomes. Some young people had gone to towns in search of work. Some were getting into motorbike transport to supplement farm income.

b) Expenditure patterns: mostly the residents use their income to buy food, educate children, pay hospital bills, build houses, do businesses e.g. shops and buy livestock and clothing. Some men spend their income on alcoholism which has led to marriage break-ups.

c) Market accessibility: Most farmers mainly sell at farm gate to neighbours and brokers. Some sell to greengrocers in the local shopping centres. Some have no knowledge about markets in towns and therefore sell to brokers who exploit them by buying at very low prices and then transport the produce to big towns like Thika and Nairobi to sell at very high prices.

d) Financial institutions: These have increased in the area with some banks e.g. Equity, Family bank opening branches in the nearby towns like Kangari mainly to serve tea farmers. Some have started lending some loans to women groups but the loans remain highly inaccessible among most women who lack collateral to access the loans.

v. Social factor such as family composition, occupation, social amenities and communal activities

a) Family composition: Most households were male headed. The female headed households were either through widowhood or were never married. The family sizes were reducing due to challenges of resource scarcity including reducing farm sizes, low income and rising cost of living.

b) Occupation: The main occupation is small-scale subsistence farming where residents grow tea, a few food crops and some livestock. Food crop farming was reduced as most residents would rather increase tea acreage at the expense of food crops. Their occupation has changed greatly since those who relied on charcoal burning in the past when trees were in plenty now don't. Some used to practice free range grazing as an occupation but this doesn't happen as farm sizes are small. In the 1980s, residents used to grow passion fruits for sale to a processing factory in Thika but that had stopped because passion fruit was struck by a disease (passion fruit woodiness virus) which ravaged the crop hindering its cultivation. Some farmers had resorted to growing short season crops such as courgettes *(Cucurbita pepo)* cabbages (*Brassica oleracea*) *sukuma wiki* (kale) and tree tomatoes for sale. Kales are also grown in the kitchen gardens. A few farmers have adopted cultivation of arrow roots for sale, an initiative promoted by a previous NGO. However, the members expressed frustration due to lack of market for their produce. Some are concentrating on livestock farming. Others have opened shops while others started small green grocery trade. Others work at neighbours farms for wages. Some young people have gone into towns to look for work while others have started motorbike businesses.

c) Social amenities: these include schools, hospitals, churches, common playing grounds. Schools have increased due to the high demand for education. The Community Development Fund (CDF) has built a dispensary in the nearby Ndakaini area while a mobile clinic is sometimes available at Kimandi. The county administration has provided space and resources for development of a modern sports ground at Ndakaini mainly to nurture sporting talents among the local youth but the project is yet to take off. Ndakaini half Marathon, an annual sporting event also takes place in the area and has helped to put the area on the map.

d) Communal activities such as dowry payment ceremonies, weddings, which used to be widely celebrated in the area have significantly reduced due to scarcity of resources which had encouraged individualism. Circumcision ceremonies which used to be communally celebrated have reduced as people opt for hospital circumcision with little celebration involved. Plenty of goats, sheep and cattle that were slaughtered during such ceremonies in the past have significantly reduced. Family get-together celebrations have also reduced due to resource scarcity hence change of priorities.

5. Have you experienced any extreme climate events (e.g. droughts, floods, fog/mist, and frost) that have affected your crop production?

   YES ■ NO □

6. If yes, please explain:

The year 2012 was too hot, especially from July to March. Tea production went down. Food crop yields were very low and most crops were lost. Getting livestock feed became a problem and this reduced livestock production. Please specify the aspects of crop production that were affected.

Extreme climate event	Effects on tea	Effects on food crops
Floods	Not affected	Crop loss as crops were washed away especially those grown along river valleys Water-logging which is especially destroyed for beans *(Phaseolus vulgaris)* cabbages (*Brassica oleracea*) and arrowroots. Low food crop yields
Heavy rainfall	High yields	High maize yields Lodging of maize Rotting of maize cobs. Rotting of cabbage heads Stunting of beans *(Phaseolus vulgaris)*
Drought	Drying of tea bushes Low yields	Poor yields Total crop loss Crop theft on farms especially for maize and arrow roots
Mist/Fog	Frostbite Low yields	Frostbite Low yields Crop loss
<u>*Others*</u>		

7. When did these events occur (year and season)? Mainly happened during the 1990s.
8. Have changes in climate affected the types of food you grow/consume today?

   YES ■ NO □

9. If yes, explain

APPENDIX VII: SUMMARY OF KEY INFORMANT INTERVIEWS RESULTS

Key informants interviewed

1. Male local area Community Forest Officer (CFA). Held on 10/02/2015
2. Female Kariara Ward Social Development Volunteer Officer and Chair lady AIPCEA Church - Gatanga Deanery. Held on 01/10/2015.
3. Male elderly farmer aged 87 years and who had lived in Kimandi since birth**.** Held on 16/10/2015
4. Male Kimandi-Wanyaga Assistant Chief. Held on 16/10/2015.
5. Female Kenya Tea Development Extension Officer. Held on 10/11/2015
6. Male Thika Dam Maintenance Officer. Held on 10/02/2015

A. Key informants' Perceptions on climate change and variation during the period 1984 to 2014

i. Rainfall

According to one elderly key informant, rainfall had become erratic. Rainfall amounts and frequency had reduced while timing had become unpredictable. Sometimes the rains were heavy while other times the rains fell below crop growth requirements. The two normal cropping seasons of March to May and October to December had been disrupted. In the past, rainfall used to be predictable and adequate for crop growth such that farmers could plan when to prepare land and plant their crops. There used to be heavy rainfall in every month of April but that did not happen anymore. By 2014, rainfall amounts and frequency had declined and timing had become unpredictable. If the farmers planted crops at the beginning of the rains, the rains often stopped at the middle of the season or fell heavily for a few days. This led to poor crop growth and sometimes total crop loss. Heavy rainfall often caused landslides in the area as in the case of 1987. River water volumes had also reduced.

According to the area assistant chief rainfall had declined due to cutting down of trees which attracted rains. Deforestation in Aberdare forest had been done both legally and illegally. Population increase had also led people to encroach on forested areas thereby cutting down trees. Tea farming expansion has also led to fewer trees since tea crop is grown pure stand with tree planting on tea farms highly discouraged. Any trees grown on tea farms are grown on the sides or along lines separating sections of tea bushes to act as windbreaks. He added that dry spells had increased and they were also lasting longer than in the past. This led to livestock feed shortage and reduction in tea and food crop yields. Residents had resorted to growing short season crops such as cabbages (*Brassica oleracea*) courgettes *(Cucurbita pepo)* potatoes, *sukuma wiki* (kales). He added that since the 1996/1997 el Niño, rainfall amounts and frequency had reduced.

ii. Temperatures

According to the elderly key informant, local seasons had changed. Temperatures had become very unpredictable. One could not tell whether it would be warm or cold or when the cold season would start or end. Sometimes it got warmer than expected while other times it became too cold. In the past, there used to be fog *(thatu)* every July, and the month used to be too cold making it the coldest month of the year. Currently (2014) the month of July has become relatively warm. The cold spell sometimes occurred in August (a month that used to be rainy) extending to as late as October. Another key informant reported that temperatures were fluctuating in an unpredictable manner citing 2015 as the year when the temperatures rose quite high making the days in August and September to be very hot and the nights very cold. Frost bites also occurred although they were not very severe. He cited the year 2010 when frostbite occurred (mostly at dawn) causing serious damage to tea leaves forcing a local tea factory (Ngere tea factory) to reduce the number of tea picking days from six to three. Irish potatoes *(Solanum tuberosum)* tomatoes and Napier grass (livestock fodder) were also destroyed, reducing yields highly. Cabbage (*Brassica oleracea*) being resistant to frostbite were not affected.

B. <u>Key informants' perceptions on resultant climate change impacts</u>

i. Floods

The key informants unanimously agreed that floods were not very common in the area due the steep terrain. However, during heavy rainfall, floods occurred along river valleys submerging crops such as vegetables. Soil erosion was also common during heavy rains.

ii. Landslides

According to one key informant, many landslides happened in the 1970s and 1990s. The resultant impacts included loss of farming land and crops. On one farm, livestock were buried alive, a grave was cut away and some houses were buried leaving family members badly traumatized. He also cited a landslide that occurred in the Kimandi area resulting into formation of a small lake where two boys drowned while swimming. Communication was also disrupted as roads were cut off by the sliding soil. In one of the homesteads, livestock were buried alive and a grave was swept away leaving family members badly traumatized. No compensation took place because landslides were considered natural disasters. Only when the landslides resulted from waste water from roads did the government compensate affected families. Affected areas had been rehabilitated by planting trees such as blue gum and bamboo *(Bambusoideae)* species since they were fast maturing. However, use of the bamboo *(Bambusoideae)* species was highly recommended due to their vigorous regeneration under continuous harvesting. Bamboo *(Bambusoideae)* also produces a lot of waste materials which act as mulch. However, he added that landslide occurrence in the area had reduced due to declining rainfall which they considered the main cause of landslides. He said that:

> "In my lifetime, I have witnessed about five landslides in this area mainly due to the steepness of the area coupled with heavy rainfall that loosens the soil. Others occur near stream sources during heavy rainfall which softens the soil making it to fall over. The main landslides occurred in the 1970/1980s. However, many landslides are still happening in the neighbouring Kandara sub-County."

iii. Crop production

The elderly key informant said that crop growth had changed from the past. He cited Irish potatoes *(Solanum tuberosum)* that could not be grown without use of fertilizers and agro-chemicals for spraying against diseases. Maize also could not be grown without use of agro-chemicals and fertilizers or manure because of deteriorating soil fertility, proliferation and emergence of new pests and diseases and pests. He cited the cutworm pest which cut down vegetable seedlings during germination adding that vegetables had also started turning yellow which never happened in the past. Another key informant said that crop prices in the area were determined by the forces of supply and demand which were a function of weather conditions. He noted that favorable weather led to bumper harvests leading to oversupply of goods in the markets resulting in low prices. Brokers exploited the situation by buying the excess produce at low prices to sell at high prices in large towns such as Thika and Nairobi while farmers depending on food crop farming as a business suffered losses. The situation was compounded by high perishability of their farm produce and poor storage means which resulted in high postharvest losses. During unfavorable weather, farm produce supply was low hence high market prices. Regarding tea production, he noted that heavy rainfall favored tea productivity, noting that the effects of frostbite on tea lasted for approximately three months since the bushes took long to recover. He also noted that some food crops that grew well in the past like maize, sugarcane *(Saccharum officinarum)* , sweet potatoes *(Ipomea batata)* and arrowroots, had constantly reduced in productivity resulting in low yields.

iv. Changes in Crops Grown

The key informants unanimously agreed that the range of crops grown in the past was narrowing. Furthermore, the level of production of some crops such as sugarcane *(Saccharum officinarum)* pumpkins (*Cucurbita moschata)* and sweet potatoes *(Ipomea batata)* had reduced. They noted that sugarcane *(Saccharum officinarum)* was grown in plenty in the past to use in brewing of a famous traditional beer known as *muratina.* Currently (2014) sugarcane *(Saccharum officinarum)* production has been limited to kitchen gardens. There was also very little cultivation of arrowroots, sweet potatoes *(Ipomea batata)* and Irish potatoes *(Solanum tuberosum)* which used to be abundant in the past. Arrowroot production had also been highly reduced with the original Kikuyu variety becoming extinct. A wild variety of arrowroot locally known as *kigoi* and commonly eaten during food shortages was still scantily growing in the wild. By 2014, farmers were cultivating improved arrowroot varieties whose palatability the consumers considered inferior compared to those grown in the past (i.e. the past varieties were dry and tastier while the improved varieties were soft and watery). The farmers were now using manure and mulch to grow the improved varieties compared to the past when arrowroots grew on their own with very little attention. *Managu* (*Black nightshade*) used to grow wild and was mainly eaten by laborers working for colonial farmers. The laborers who were only supplied with maize flour to make *ugali* (thick porridge) harvested *managu (black nightshade) terere* (*Amaranth spp*.) and *togotia (Dandelion greens)* which grew in the wild to cook as vegetables. The key informant said that local people lowly regarded cultivation of such vegetables, considering them as wild food. One village elder said that he could not imagine his wife going to the farm to plant *managu (Black nightshade)* and *terere (Amaranth spp.)*. However, People from outside the county who had migrated to offer labour had started cultivating the vegetables. Regarding farm acreage, the key informants said that land pieces were quite expansive in the past and most of them were covered by natural forests. A range of fruits such as *ndunda (Passiflora adulis) matuya (Myrianthus holstii) ngoe (Syzygium guineense) mbiru (Vangueria madagascariensis) ngambura (Dovyalis abyssinica) and ndare (Rubus pinnatus)* grew in the forests and people freely harvested them for consumption. On tea farming, one key informant reported that a drop in tea prices during the period 2010 to 2013 from 40 to 20 shillings due to political disruptions in the traditional world tea markets such as Egypt had forced some farmers to uproot tea and plant other crops such as Napier grass for livestock feed, tree tomatoes and avocados *(Persea americana)*.

The female key informant reiterated this saying,

> Traditionally, *terere (Amaranth spp.)* and *managu (Black nightshade)* were considered as 'food for the poor' as they mainly grew in the wild. They are not cultivated as vegetables and those being consumed are normally obtained from the forest where they grow wild on their own. Culturally, people here still consider the vegetables with low regard. Though some people are consuming them today, very little importance is being attached to their cultivation.

v. Changes in Trees

According to the key informants, many indigenous trees such as *muthaiti (Cinnamomum camphora) podo (Podocarpus falcatus) muiri (Prunus Africana/red stinkwood) mugumo (Ficus craterostoma)* and *mukoe (Syzygium guineense)* that were very common in the past had disappeared. *Muthanduku (Acacia mearnsii)* a very common exotic tree in the past, and a key income source since its bark was sold to tanneries in Thika while the tree was used for charcoal burning and firewood was fast disappearing. *Muiri (Prunus Africana/red stinkwood)* mainly used to make vehicle boards and *muthaiti (Cinnamomum camphora)* which was good hard wood for furniture making were almost becoming extinct. *Ithanji (Phragmites)* usually found on wet/marsh lands and used for thatching houses had become scanty as most of the wetlands had been reclaimed for crop farming. Although *Mugumo (Ficus craterostoma)* was traditionally considered by the community as a sacred tree for offering sacrifices and cutting it down was a serious taboo, some local people had started cutting it down for firewood and charcoal burning. *Murangi (Bambusoideae*) had become a very popular tree among the community due to its multipurpose use for fencing, fuel wood and making of tea plucking baskets, chairs, chicken houses/drinkers/feeders and a range of other house decorations.

vi. Forests

The key informants unanimously agreed that most of the animals found in the neighbouring Aberdare forest in the past were fast disappearing. They noted that there used to be plenty of elephants, *nguyo* (Black and white Colobus monkey) *thwariga* (Mountain reedbuck) *ndongoro (Tragelaphus eurycerus isaaci) thiya* (Bush buck) which had become very rare by 2014. The forest officer cited an incident when tigers from the forest started to attack local residents necessitating fencing off of the forest and subdividing the forest into forest reserve and forest area and hence the emergence of forest management. Forest guards were tasked with tracking the man-eaters and guarding the forest against illegal loggers who invaded the forest. Offenders were arrested and prosecuted. They expressed concern on poor forest management decrying that most of the forest managers were participating in illegal logging. The key informants were hopeful that proper protection of the forest could allow tree seedlings to regenerate, making the forest to thrive and regain its lost glory.

vii. PELIS Programme

In collaboration with the forest management including Kenya Forest Service (KFS) and Community Forest Association (KFS) a program dubbed Plantation Establishment and Livelihood Improvement Scheme (PELIS) had been implemented to enhance sustainable forest management and food production among forest adjacent communities (FACs). Under this arrangement, willing households are allocated forest land to grow crops alongside planting and caring for tree seedlings. When tree seedlings grow to about 1m tall and form a canopy, the farmers move to other areas and continue with the same process leaving the trees to grow undisturbed. The forest regenerates and the farmers grow food crops for family use or sale of surplus for an income. Crops grown include Irish potatoes *(Solanum tuberosum)* carrots (*Daucus carota*) green peas *(Pisum sativum)* beans *(Phaseolus vulgaris)* and maize *(Zea mays)*. They also undertake controlled fire wood cutting, beekeeping for honey and bamboo *(Bambusoideae)* tree harvesting for making tea picking baskets and other sculptures for income generation. Through the programme, access feeder roads to Kimakia forest are being constructed. The local youth also benefit from offering labour for the roads maintenance. A female key informant confirmed that the community's main source of firewood was Kimakia forest. Some farmers have planted trees in their compounds which provide firewood and timber for construction. Charcoal is bought from those who burn it.

viii. Past famine episodes witnessed the area

1900: ***Ng'aragu ya ruraya:*** *Ng'aragu* is a kikuyu name for famine. Ruraya is a kikuyu name for foreign. The famine was called "foreign famine" since none of its kind had been witnessed in the area before. Many children died during the famine.

1937: ***Ng'aragu ya karugia mithuru:*** *Kurugia* is Kikuyu name for swinging and *mithuru* for skirts. The famine was therefore named after the 'swinging of skirts' by women who kept moving to various places in search of food for their families. Many of the women died of hunger and fatigue in the process.

1943: ***Ng'aragu ya mianga*****:** *Mianga* is the Kikuyu name for cassava *(Manihot esculenta)*. The famine was named 'cassava famine' since cassava *(Manihot esculenta)* was the only food available. Cassava *(Manihot esculenta)* was dried and ground for flour and used for making porridge and ugali (thick porridge). This resulted from a major drought that occurred immediately after the 2nd world war.

1984: ***Ng'aragu ya gathirikari:*** *Gathirikari* means yellow maize. The famine occurred during the 1984 drought episode. It was named after yellow maize which was supplied by the government to ease hunger.

ix. Food Security

One elderly key informant that reduced food crop yields especially for maize had brought food insecurity in the area. He said that they used to harvest enough maize to last them almost all year round adding that every homestead had a granary for storing excess maize produce. Maize was dried in the sun and stored mainly to use in making porridge (gruel) *githeri* (boiled mixture of maize and beans) and *ugali* (hard porridge). Porridge flour was made through a traditional method of grinding using two stones *(ihiga na thiyo)*. The key informants agreed that foods most commonly eaten in the past were *githeri* (maize *(Zea mays)* and beans *(Phaseolus vulgaris*) *waru (Solanum tuberosum) ngwaci* ((*Ipomea batata*) *nduma (Xanthosoma sagittifolium*) bananas *(Musa spp.)* sugarcane *(Saccharum officinarum)* and *noe* (kidney beans). They ranked *Mataha* (mashed maize, beans and vegetables) as a must have food for every homestead in the olden days. A lot of the foods were cooked and stored in granaries. The granaries were constructed outside the main house and were left unlocked to allow family members and visitors free access to the food. They attributed the generosity of the plentiful food those days noting that such granaries and generosity was no more. They reported that currently (2014) most of the foods consumed by the community members were bought from markets mainly from Thika town, local markets/shops or supplied by people from neighbouring Counties such as Nyandarua. They also noted that most of the tea income was spent on buying food and paying school fees adding that households with small farm holdings hence few tea bushes had little to spend on food and other uses forcing most of them work on other people's farms for wages.

They noted that there was general food insecurity in the area since the majority of the farmers did not produce enough food for self-sustenance due to overconcentration on tea farming (their only cash crop) with little effort to diversify food crop farming. Most households produced did last to the next season and therefore. In spite of new food crops such as broccoli *(Brassica oleracea)* , beetroots *(Beta vulgaris)* and courgettes *(Cucurbita pepo*) being grown in the area, not all people could afford to buy them due to inadequate finances. This made the producers sell their produce to outside markets such as Thika town. With many competing needs, households only bought the basic necessities, a situation that compromised their diet quality. The female key informant said that the main source of food was their farms, kitchen gardens, shops, and other markets. She said that most women had formed social groups to save money. Some of the groups had been trained to make energy saving *jikos* (charcoal cookers) to save energy, money, time and conserve the environment by reducing deforestation. Other groups bought indigenous tree seedlings from Kimakia forest and raised tree nurseries for income generation. However, she noted that most members in the groups were not able to take loans since they were unable to repay. Loan payment defaulters had their household goods sold resulting in many family wrangles.

x. Pests and Diseases

Maize weevil attacks were rare. Maize used to be harvested, dried in the sun and then stored in granaries. Dried maize was mainly ground to make porridge flour through a traditional method of using two stones *(ihiga na thiyo).* Currently, high humidity supports proliferation of insect pests and diseases which affect crops such as tomatoes, potatoes. A certain pest called mung'uru (sweet potato flea beetle) is increasingly attacking sweet potatoes *(Ipomea batata).* Moles are also a common pest on sweet potato and arrowroot *(Xanthosoma sagittifolium)* production and have become too expensive to control. Theft has also become a challenge as some people have been stealing food crops from other people's farms especially at night.

C. <u>Key informants' perceptions on the community's climate change coping mechanisms</u>

The elderly key informant described a traditional hunger coping strategy that was used during serious famine episodes. Desperate mothers harvested and boiled bananas *(Musa spp.)* undergrowth locally known as "*cienja cia marigu " which* resembled arrowroots *(Xanthosoma sagittifolium)*. The undergrowth mimicked arrowroots *(Xanthosoma sagittifolium)* and the long time they took to boil lured children to sleep in the hope of waiting for food to cook. Current (2014) food shortages forced some people to eat a wild form of arrowroot locally known as *kigoi*. According to the female key informant, in times of crisis (e.g. drought) the most vulnerable households got assistance from churches and other community members. During the 1984 drought, they got food assistance from UNICEF in the form of rice, beans *(Phaseolus vulgaris)* wheat flour and maize. One key informant added that people also tended to concentrate on tea production to earn money for food and other expenses. Other farmers rented farms in other agriculturally productive Counties such as Kirinyaga where they cultivated vegetables such as onions, tomatoes and French beans through irrigation for sale. Other farmers participated in PELIS to grow crops for family consumption and sale in case of surplus. Some farmers had sold all or part of their land and migrated to settle in other areas such as Nyandarua

County. However, some of them had faced challenges adjusting to the new environment forcing them to return. He noted that livelihood disruptions had caused some returnees to succumb to depression leaving behind many orphans. The out migration had also made some men leave their families behind and start new families where they settled. This had led to broken marriages.

i. Labour Supply

The key informants said that labour on tea farms was mainly provided by family members. Labour shortage therefore was a challenge ageing households whose grown up had left to fend for themselves. The sick and disabled people also suffered from labour shortage. Majority of local youth, especially men, were also not keen on working on the tea farms. One key informant added that drug abuse and alcoholism was also common among jobless and idle male youth, the majority of whom hanged around shopping centres and bus termini where they easily fell prey to drug traffickers. This highly affected farm labour supply. The female key informant noted that women were generally the ones mostly involved in working on the farms with men having full control of the farm income. The main source of labour for food crop production was family labour with children offering labour only during school holidays. Although some school dropouts offered farm labour, there was a need to hire labour during tea peak periods. Those who could afford usually outsourced labour from other counties especially Kisii, Embu and Kakamega. People from the lower coffee growing zone also supplied labor. Labour payments are based on kilograms of tea leaves picked. Other farm labour was paid daily at a rate of 400/= for men and between 250/= to 300/= for women. The key informants noted that the influx of people from different cultures had brought about changes in the area including intermarriages and introduction of other foods not traditionally consumed in the area particularly vegetables.

ii. Land

According to the key informants, land subdivision had resulted in small uneconomical farm sizes. Most residents were legal owners of the land they occupied. Land ownership was registered under the male household head until succession time when it was passed on to the children. Some female-headed households also existed due to the death of a husband or the woman never married. Female children rarely inherited land except in special cases where one never married or a parent chose to offer them land. Generally, women were the ones mostly involved in working on the farms although men had full control of the farm income. Women also did not make major decisions on land use. For example, trees mainly belonged to men except for widows. A woman could not plant trees and cutting down of trees was only done with the husband's consent and mainly for a good reason like offsetting bills. However, men could plant or cut trees without informing their wives.

However, according to the female key informant, the situation was changing. Some male household heads were subdividing their land to allow their wives to have a piece of land for their own use. Others had allocated some tea bushes for their wives for income. More had subdivided their land among the married sons but still withheld the land title deeds to avoid selling off the land. Most family heads preferred keeping land ownership to themselves only allowing the wife and children to use it. Some families were also giving land to their unmarried daughters although others neglected them. Widows are the beneficiaries of the property left behind although a lot of disputes have been witnessed on property inheritance in the event of a husband's demise.

iii. Food storage facilities

According to the key informants, most of the residents did not surplus food crop produce to store or sell. The little they had was harvested piecemeal. Farmers with surplus food crops such as maize *(zea mays)* and beans *(Phaseolus vulgaris)* for storage usually sun dried them and applied pesticides for storage in plastic containers. Others hung maize on roof tops to dry.

iv. Food sources during drought

In the past, women travelled to distant markets e.g. Muthithi, Mariira to buy food such as maize, beans, and sweet potatoes *(Ipomea batata).* Some carried items such as clay pots to sell and get money to buy food. Sometimes people harvested wild crops such as kigoi arrowroot, *terere (Amaranth spp.) managu (Black nightshade)* and togotia *(Dandelion greens)* during times of food shortage. Wild fruits were also eaten during food shortages. During 1990 to 1995, famine was frequent in the area which forced the government to provide food aid in the form of maize, maize flour, beans *(Phaseolus vulgaris)* and cooking oil. UNICEF also gave 200 bags of maize, 150 bags of beans *(Phaseolus vulgaris)* and 200 bags of rice to Gatanga constituency mainly targeting the most vulnerable including the elderly, orphans and some female-headed households.

Currently, most of the food was from buying. Some members intensified crop production along river banks using bucket irrigation. Some women also planted vegetables and arrowroots *(Xanthosoma sagittifolium)* in kitchen gardens around their houses to make use of rainwater dropping from the roofs. During the water crises, they watered their kitchen gardens using kitchen waste water into which they added wood ash to neutralize the soap effect. Wood ash was also used to treat some soil borne diseases, especially those affecting potatoes. Kitchen gardens were considered important because they were easily accessible especially at night and the money obtained from sale of the produce was used to purchase food. Most households also relied on food supplies from self-help groups which contributed money for buying food items such as maize/wheat flour, cooking oil, rice and sugar. During food shortages, such groups targeted the most vulnerable households mainly the elderly, orphans and widows who they regularly visited. A case was given of some HIV & AIDS orphans who were given cows for milk supply and their school fees paid until they became independent.

v. Women credit access

According to the female key informant, most women in the community had formed social groups to save money. Their sources of finances were member contributions from which they obtained loans. Family property such as livestock or household goods such as television sets or furniture were used as collateral. Some women used the money to buy livestock such as cows, poultry and dairy goats for income generation. Others use the money to grow short season crops like cabbages (*Brassica oleracea*) , *sukuma wiki* (kale) courgettes *(Cucurbita pepo)* and beetroot for sale. Loan repayment was monthly at a rate of 10% and defaulters had their household property auctioned to offset the debts. Loan collateral remained a big dilemma for most women who needed to obtain loans.

vi. Local climate change policies

According to the key informants, local administrators advised residents on the importance of tree planting as wood lots, hedgerows, boundary markers or between crops such as tea. Trees planted along boundaries had to be 10ft from the border to avoid border disputes. Due to the heavy water uptake of Blue gum trees, they were planted 10ft away from river banks to avoid drying up of rivers and away from other crops to avoid water stress. The most commonly planted tree species in the area was Grevillea Robusta due to their fast growth. While farming near rivers, a leeway of 10ft or 3m from river bank was left uncultivated to allow for river overflow during heavy rains and to avoid erosion on river banks which caused landslides. Residents were also advised to plant five trees every one tree cut, construct gabions on steep slopes and channel road runoff appropriately to avoid erosion and landslides. Also emphasized was rain water harvesting using gutters and plastic tanks. Accordingly, some NGOs had started providing some schools with plastic tanks for rainwater harvesting. Also emphasized was implementation of water conservation measures such as mulching and terracing.

D. Other factors affecting food crop production

i. Drug abuse and alcoholism

The key informants said that drug abuse, especially among the youth, had become rampant in the area. The most abused drug was bhang (*Cannabis sativa*) mainly sourced from Thika town. More drugs were easily brought into the area by people moving to the area to supply labour. Many drug-abuse related cases had been reported to the local administration through community policing. Many drug users had been jailed although drug abuse cases were on the rise. The main reasons cited for drug abuse were laziness and irresponsibility among male youths, unwillingness to work on farms, ready drug availability and high dependency on parental support. Alcoholism especially from illicit brews was also a problem causing a lot of young men to neglect their families resulting in broken marriages. Women in particular complained of absentee husbands. The local administration through community policing mainly by women were actively dealing with the menace by storming into illicit alcohol dens to destroy the alcohol. Despite efforts by the local administration to stop illicit alcohol trade, the problem kept recurring.

ii. Gender based conflicts related to access to resources

One key informant noted that cultivation of food crops was mainly done by women. Conflicts arose when some men decided to control the sales of the food crops. Tea picking was also mainly done by women although a few men participated. However, tea payments were made through family heads majority of whom were men. Many differences therefore arose when some men received tea payments and spent it without involving their wives. The situation was worse at the end of the year when the tea bonus was paid. Family conflicts also arose when women took loans from self-help groups using household items like furniture, livestock, and utensils as collateral only to default in payment resulting in sale of the items. Other disputes arose in the event of the demise of a husband. Some family members planned to disinherit widows of their property leading to family feuds some of which resulted in loss of lives. Such disputes disrupted farming activities as people were forced to stay off disputed lands for fear of being attacked.

iii. Government extension services

The key informants were of the opinion that government agricultural extension services were inadequate in the area. They noted that in the past, agricultural extension officers frequented farms offering advice to farmers on recommended agronomic practices but that had become rare since the services had become demand oriented. They appealed for enhanced government agricultural extension services to guide farmers on good farming practices such as suitable crops to grow, control of pests and diseases and provide early warning information on weather changes. They added that in spite of the area being a water catchment area, irrigation through use of tap water was prohibited with heavy penalties imposed on anyone caught practicing it. Bucket irrigation was therefore the only mode of food crop irrigation in the area.

APPENDIX VIII: ON-FARM DEMONSTRATIONS

ACTION PLAN

The experimental (demonstration) sites were located at s, one in Kimandi and one in Wanyaga and were conducted on volunteer farmers' farms. The treatments were a factorial design arranged in a Randomized Complete Block Design (toRCBD) with four factors (no manure or fertilizer, nitrogen fertilizer, manure, nitrogen fertilizer and manure) at two levels for nitrogen fertilizer (0, 10g /m) and two levels for manure (0, 20kg/8m) (see Tables 3.4 & 3.5). The planting and field management of the vegetables were guided by the Kariara Ward Agricultural Extension Officer.

FIRST DEMONSTRATION AT WANYAGA

Date: 08/12/ 2015 **Time:** 2.00 pm.

Number of participants: Ten local farmers.

Facilitators: Kariara Ward Agricultural/Nutrition Extension Officer, Kariara Ward Agricultural Economics Extension Officer, Ndakaini area Adult Education Officer, one male conversant with cooking of the selected vegetables and the researcher.

Training skills transferred: Land preparation, spacing, manure application, planting, field management, harvesting, cooking, nutritional value, drying and storage of the selected vegetables. The basics of climate change and climate adaptation for food security were also discussed. Participating farmers were provided with seeds to plant on their farms. Farm follow-ups were made by the agricultural extension officer and the researcher.

Pairwise preference ranking of the vegetables

Participating farmers ranked the vegetables according to preference. A pairwise preference ranking exercise was conducted where farmers compared two vegetables at a time. A stepwise development of the pairwise preference ranking table was developed as described below.

1. A table was drawn on a Manila paper (see Plate 9).
2. Leaves of each of the five vegetables were placed against the vegetable names for ease of identification. Two vegetables were selected at a time and the participants were asked to choose the one they preferred between them by show of hands. Pictures were taken.
3. The scores were recorded on the boxes drawn as shown on the table below. The vegetables were ranked according to the number of scores obtained.
4. The reasons for the choice of the vegetables were given and recorded.

Pairwise Preference Ranking Table Developed

VEGETABLE NAME	***TERERE (Amaranth spp.)***	***MANAGU (Black nightshade)***	***SAGET (Cleome gynandra)***	***MURENDA (Corchorus olitorius)***	***COW PEAS (Vigna unguiculata)***
TERERE (Amaranth spp.)		*Managu*-9 (winner) *Terere*- 1 Undecided-0	*Saget*-4 *Terere*-5 (winner) Undecided-1	*Murenda*-3 *Terere*-6 (winner) Undecided-1	*Cowpeas* -6 (winner) *Terere*-3 Undecided-1
MANAGU (Black nightshade)	*Terere*-1 *Managu*-9 (winner) Undecided-0		*Saget*-4 *Managu*-5 (winner) Undecided-1	*Murenda*-1 *Managu*-6 (winner) Undecided-3	*Cowpeas* -6 (winner) *Managu*-4 Undecided-0
SAGET (Cleome gynandra)	*Terere*-5 (winner) *Saget*-4 Undecided-1	*Managu*-5 (winner) *Saget*-4 Undecided-1		*Murenda*-2 *Saget*-5 (winner) Undecided-2	*Cowpeas* -6 (winner) *Saget*-3 Undecided-1
MURENDA (Corchorus olitorius)	*Terere*-6 (winner) *Murenda*-3 Undecided-1	*Managu* -6 (winner) *Murenda*-1 Undecided-3	*Saget*-5 (winner) *Murenda*-2 Undecided-2		*Cowpeas* -9 (winner) *Murenda*-0 Undecided-1
COW PEAS (Vigna unguiculata)	*Terere*-3 *Cowpeas* -6 (winner) Undecided-1	*Managu*-4 *Cowpeas* -6 (winner) Undecided-0	*Saget*-3 *Cowpeas* -6 (winner) Undecided-1	*Murenda*-0 *Cowpeas* -9 (winner) Undecided-1	

SECOND DEMONSTRATION AT KIMANDI

Date: 01/12/2015 **Time:** 2.00 pm.

Number of participants: Twelve local farmers.

Facilitators: Kariara Ward Agricultural/Nutrition Extension Officer, Kariara Ward Agricultural Economics Extension Officer, Ndakaini area Adult Education Officer, a female conversant with cooking of the selected vegetables and the researcher.

Training skills transferred: Land preparation, spacing, manure application, planting, field management, harvesting, cooking, nutritional value, drying and storage of the selected vegetables. The basics of climate change and climate adaptation for food security were also discussed. Participating farmers were provided with seeds to plant on their farms. Farm follow-ups were made by the agricultural extension officer and the researcher.

Pairwise preference ranking of the vegetables

Participating farmers ranked the vegetables according to preference. A pairwise preference ranking exercise was conducted where farmers compared two vegetables at a time. A stepwise development of the pairwise preference ranking table was developed as described below.

1. A table was drawn on a Manila paper (see Plate 9).
2. Leaves of each of the five vegetables were placed against the vegetable names for ease of identification. Two vegetables were selected at a time and the participants were asked to choose the one they preferred between them by show of hands. Pictures were taken.
3. The scores were recorded on the boxes drawn as shown on the table below. The vegetables were ranked according to the number of scores obtained.
4. The reasons for the choice of the vegetables were given and recorded.

Pairwise Preference Ranking Table Developed

VEGETABLE NAME	*TERERE (Amaranth spp.)*	*MANAGU (Black nightshade)*	*SAGET (Cleome gynandra)*	*MURENDA (Corchorus olitorius)*	*COW PEAS (Vigna unguiculata)*
TERERE (Amaranth spp.)		*Managu*-5 (winner) *Terere*-5 Undecided-2	*Saget*-4 *Terere*-4 (winner) Undecided-4	*Murenda*-3 *Terere*-9 (winner) Undecided-0	*Cowpeas* -10 (winner) *Terere*-2 Undecided-0
MANAGU (Black nightshade)	*Terere*-5 *Managu*-5 (winner) Undecided-2		*Saget*-4 *Managu*-7 (winner) Undecided-1	*Murenda*-2 *Managu*-9 (winner) Undecided-1	*Cowpeas* -7 (winner) *Managu*-5 Undecided-0
SAGET (Cleome gynandra)	*Terere*-4 (winner) *Saget*-4 Undecided-4	*Managu*-7 (winner) *Saget*-4 Undecided-1		*Murenda*-4 *Saget*-6 (winner) Undecided-2	*Cowpeas* -9 (winner) *Saget*-3 Undecided-0
MURENDA (Corchorus olitorius)	*Terere*-9 (winner) *Murenda*-3 Undecided-0	*Managu* -9 (winner) *Murenda*-2 Undecided-1	*Saget*-6 (winner) *Murenda*-4 Undecided-2		*Cowpeas* -10 (winner) *Murenda*-2 Undecided-0
COW PEAS (Vigna unguiculata)	*Terere*-2 *Cowpeas* -10 (winner) Undecided-0	*Managu*-5 *Cowpeas-7* (winner) Undecided-0	*Saget*-3 *Cowpeas* -9 (winner) Undecided-0	*Murenda*-2 *Cowpeas* -10 (winner) Undecided-0	

Summary of the importance of traditional vegetables according to the demonstrations participants

1. The vegetables are more nutritious compared to exotic vegetables such as kales, cabbages (*Brassica oleracea*) spinach (*Spinacia oleracea*) and lettuce.
2. The vegetables grow well wildly or under cultivation.
3. The vegetables are more tolerant to a wide range of climatic conditions especially drought compared to exotic vegetables.
4. Cultivation of the vegetables requires little or no fertilizers.
5. Cultivation of the vegetables requires minimal field management and input use.
6. The vegetables are more resistant to most pests and diseases
7. The vegetables can be grown for home consumption and surplus sold for income.
8. The vegetables fetch higher prices than other vegetables such as *Sukuma wiki (Kale)* cabbages (*Brassica oleracea*) spinach (*Spinacia oleracea*) and lettuce *(Lactuca sativa)*
9. The vegetables contain high medicinal properties since they are rich in nutrients such as proteins, calcium, iron and vitamins A and C. This factor therefore made many doctors to recommend consumption of *Terere (Amaranths spp.)* and *Thabai (Urtica urens)* as immunity boosters for HIV and AIDS patients.
10. The vegetables' high yielding capacity, minimal field management and low input requirement makes the vegetables good for food security.