Kenya County Climate
Risk Profile Series

Kenya County Climate Risk Profile: Kiambu County

Highlights

- Agriculture is the leading economic activity in Kiambu County, contributing about 17% of the population's income. The area under agricultural production is 1880 ha, which is 74% of the total land area.
- Agricultural productivity in Kiambu is greatly affected by land degradation, poor access to agricultural inputs, limited credit access, crop and livestock diseases, and climate hazards.
- The main climatic hazards and risks in Kiambu County are droughts, flooding, extreme temperatures, and soil erosion.
- Underling factors, such as limited access to land and other resources, agriculture inputs, training and extension services, limit the capacity of women and youth to adapt to climate change impacts. They are, thus, the most vulnerable to climate change.
- The county government is working in collaboration with the national government departments and agencies such as Kenya Meteorological Department and the Kenya Agricultural and Livestock Research Organization, among others, to support the adoption of climate-smart agricultural interventions to address climate change impacts in Kiambu County. The county government also collaborates with Development partners, including the Japan International Corporation Agency (JICA), the Food and Agriculture Organization of the United Nations (FAO), and the World Bank to support these activities.
- Promising adaptation strategies include water harvesting and conservation, integrated soil fertility management, agroforestry, staggered cropping, and crop diversification. Feed conservation, forage diversification, changing forage types, and value addition are important for livestock production.

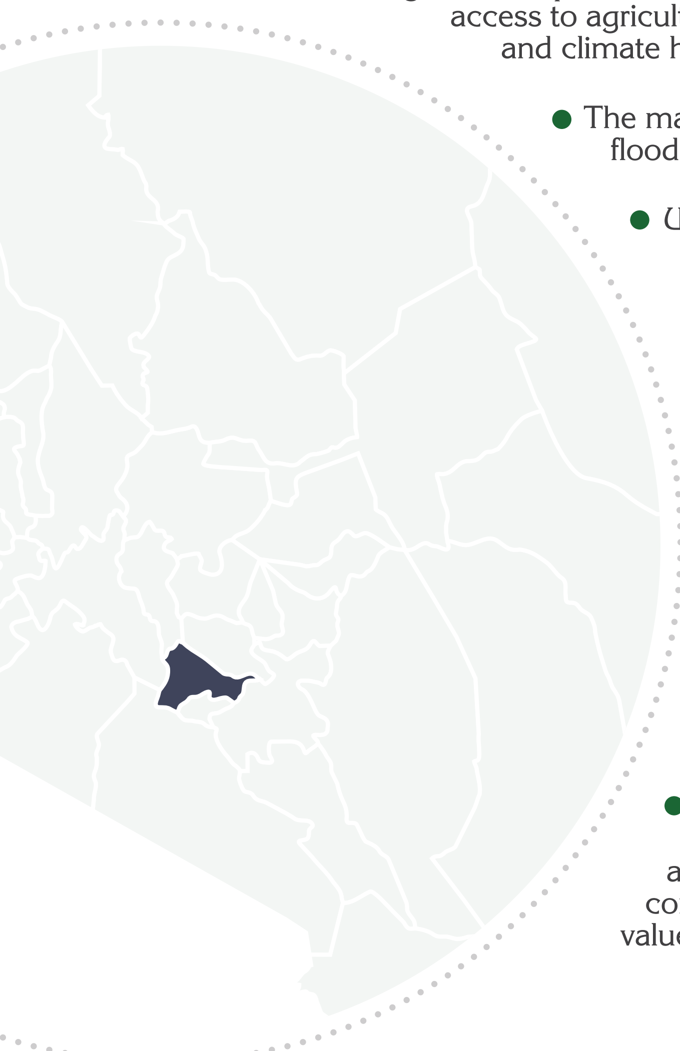

Figure 1: Map of Kiambu County

Republic of Kenya

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List of Acronyms

ASDSP – Agricultural Sector Development Support Program

CDD- Consecutive Dry Days

CIAT- International Center for Tropical Agriculture

CIDP– County Integrated Development Plan

CSA– Climate-Smart Agriculture

FAO– Food and Agriculture Organization of the United Nations

GoK – Government of Kenya

JICA– Japan International Cooperation Agency

JKUAT - Jomo Kenyatta University of Agriculture and Technology

KALRO – Kenya Agricultural and Livestock Research Organization

KDB – Kenya Dairy Board

KEPHIS– Kenya Plant Health Inspectorate Service

KMD – Kenya Meteorological Department

KNBS – Kenya National Bureau of Statistics

LGP- Length of Growing Period

NARIGP– National Agricultural and Rural Inclusive Growth

NCCRS– National Climate Change Response Strategy

VCCs- Value Chain Commodities

Kiambu

Foreword

The mandate of the Ministry of Agriculture, Livestock, Fisheries and Co-operatives is to create an enabling environment for sustainable development of agriculture and co-operatives for economic development. This objective underpins our desire and commitment to transform Kenya into a newly industrializing, middle income country providing a high quality of life to all its citizens in a clean and secure environment as envisaged in our development blueprints, the Kenya Vision 2030, the Big Four Agenda and the Agricultural Sector Transformation and Growth Strategy (ASTSG 2019 – 2029). The sector remains high on the national development agenda in terms of food and nutrition security, income generation, employment creation, saving and investment mobilization and export earnings. To realize the country's aspirations of food and nutrition security, the Government through this Ministry is implementing the National Agricultural and Rural Inclusive Growth Project (NARIGP) with the support of the World Bank. The development objective of the project is to increase the agricultural productivity and profitability of targeted rural communities in 21 counties and in the event of an eligible crisis or emergency, provide an immediate and effective response.

The agriculture sector is however, highly vulnerable to the impacts of climate change and extreme weather events. Responses that would enable the country to cope with these risks are outlined in the Kenya Climate-Smart Agriculture (CSA) Strategy and in the commitments of the Kenya Nationally Determined Contributions (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC). In 2010, the Government developed the National Climate Change Response Strategy (NCCRS) which recognized the impacts of climate change on the country's development. This was followed by the development of the National Climate Change Action Plan in 2012. The focus of these initiatives include the development of county-level climate risk profiles to mainstream climate change perspectives in programs and development plans at county level. The Ministry has developed county climate risk profiles in 31 counties and NARIGP is supporting the development of profiles for an additional 14 counties. The purpose of the profiles is to inform county governments and stakeholders on the climate change risks and provide opportunities for integration into respective county development plans and processes.

This climate risk profiles study will be used as a basis to climate proof projects or any other developments in fourteen counties (Samburu, Turkana, Kitui, Narok, Kirinyaga, Kiambu, Muranga, Bungoma, Trans Nzoia, Nandi, Vihiga, Kisii, Nyamira and Migori). The study provides information on current and possible future climate scenarios, climate-related vulnerabilities and risks for key major agricultural value chains, policy landscape and the institutional capacity to deliver adaptation programs. Each profile presents adaptation and risk reduction options that can transform and reorient agricultural systems in the counties to increase productivity, enhance smallholder farmers' resilience and mitigate against climate change.

Finally, I call upon all stakeholders for their cooperation and support for adoption of CSA production practices that maximize the triple wins: increases productivity, enhanced resilience and reduced greenhouse gas (GHG) emissions. Through the adoption of new technologies and improved practices, we will realize the desired goal of Kenya being a food and nutrition secure country, fostering socio-economic development and improved livelihoods of Kenyans.

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Principal Secretary

State Department for Crops Development and Agricultural Research

1. Introduction

Climate change is becoming one of the most serious challenges to Kenya. The country is currently susceptible to climate-related events, and projections indicate that climate impacts will continue to affect the country in the future. In many areas, extreme and variable weather is now the norm. Rainfall is irregular and unpredictable: some regions experience frequent droughts during the long rainy season or severe floods during the short rains. Arid and semi-arid areas are particularly vulnerable to these extreme changes, endangering the lives and socio-economic activities of millions of households.

Kenya Vision 2030 is a national blueprint that seeks to transform Kenya into a middle-income country that provides a high quality of life in a clean and secure environment to all its citizens by 2030. Agriculture has been identified as one of the key sectors contributing to projected annual national economic growth. However, this sector has been constrained by inadequate access to quality inputs, marketing inefficiencies, a non-conducive investment environment, declining soil fertility, low levels of mechanization, land fragmentation, and—most significantly—climate change.

In 2010, Kenya developed a National Climate Change Response Strategy (NCCRS) which recognized the importance of climate change impacts on the country's development. This was followed in 2012 by the National Climate Change Action Plan (NCCAP), which provided a means for implementing the NCCRS and which highlighted agricultural adaptation priorities. These initiatives are focused on the national level, however, and climate change considerations still need to be mainstreamed in county-level policies, programs, and development plans. Locally relevant, integrated adaptation responses with the active involvement of local stakeholders are necessary to achieve this goal.

Through the Ministry of Agriculture, the Government of Kenya (GOK) is implementing the National Agricultural and Rural Inclusive Growth Project (NARIGP) with support from the World Bank. The project's development objective is to increase the agricultural productivity and profitability of targeted rural communities in selected counties. To address the climate change risks and vulnerabilities that negatively impact agricultural production, the Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT) completed a climate risk assessment in 14 counties supported by NARIGP. The aims of this assessment are to provide information on current and possible future climate scenarios; to identify climate-related vulnerabilities and risks for major agricultural value chains and specific groups of people involved in agriculture; to identify adaptation options that address climate risks and vulnerabilities; and to assess the institutional capacity for delivering adaptation programs.

This climate risk profile aims to inform county governments and stakeholders about the climate change risks and opportunities for agriculture so they can integrate these perspectives into county development. It will help county governments and stakeholders integrate climate change risks and opportunities for local agriculture into county development plans.

The Alliance implemented the assessment through a set of interrelated stages. It first initiated a desk review of the conceptual and analytical context of climate change risks at national and county levels. Efforts were made to involve a wide range of institutions that have previous and ongoing work on climate change at national and regional levels. The team used globally available data sources as well as data collected from relevant government departments (e.g. Department of Resource Surveys and Remote Sensing (DRSRS), the Kenya Meteorological Department (KMD), the Drought Monitoring Center, and county development plans) and data portals (e.g. Kenya Open Data Portal). This assessment also represents data collected through focus group discussions, interviews with key informants, climate modeling, and three-day-long stakeholder workshops conducted at the sub-national

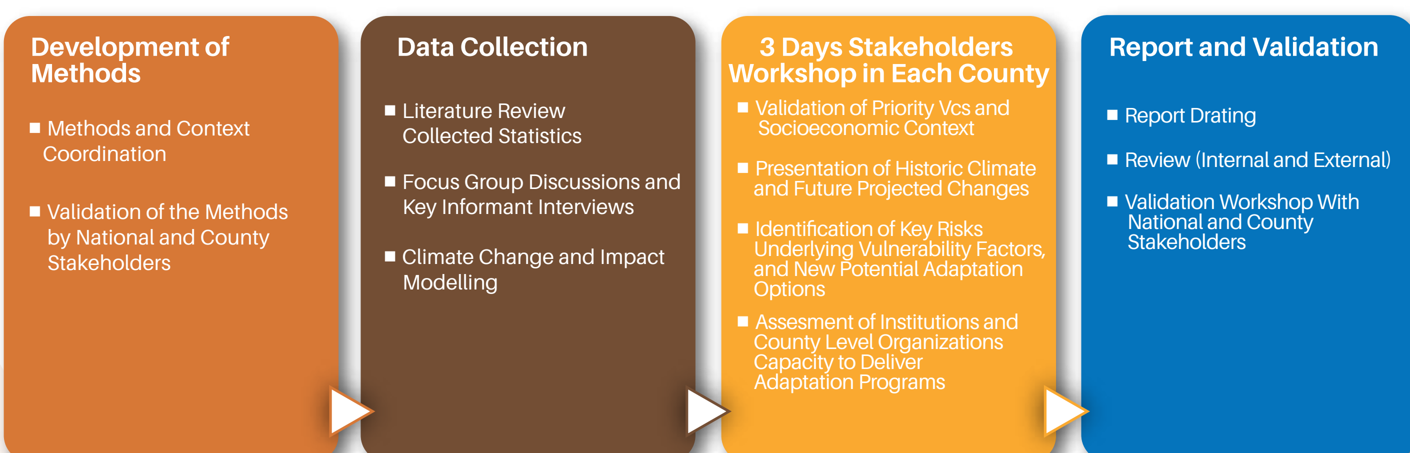

Figure 2: Climate Risk Profile (CRP) development process

level. The final reports were then presented and validated by national- and county-level stakeholders.

This document presents the Climate Risk Profile for Kiambu County. The profile is organized into six sections, each reflecting an essential analytical step in understanding current and potential adaptation options for key local agricultural value chain commodities. The first section offers an overview agricultural activity in the county, including its main agricultural commodities, commodities that are key for food security and livelihoods, and major challenges to agricultural sector development in the county. The second section identifies the main climatic hazards based on analysis of historical climate data and climate projections. Measures include climate indicators for dry spells, flooding, and heat stress, and others. The third section analyzes the risks posed by these changes and the vulnerabilities of the respective value chains. Based on these vulnerabilities, current and potential on-farm adaptation options and off-farm services are discussed. The fourth and fifth sections provide snapshots of enabling policies and the institutional and governance context in the county for the adoption of resilience-building strategies. Finally, the sixth section lays out pathways for strengthening institutional capacity to address climate risks.

2. County Context

Kiambu County is one of the 47 counties in the Republic of Kenya. The county lies between latitudes 00°25‘and 10°20‘S of the equator and longitude 360°31‘and 370°15‘E. It is a peri-urban county located in the central region that covers a total area of 2,543.5 km^2 (County Government of Kiambu, 2018). Of this area, 476.3 km^2 are under forest cover, 1,878 km^2 are under cultivation, 649.7 km^2 are non-arable, and 15.5 km^2 are covered by bodies of water. Kiambu is divided into ten sub-counties and is home to an estimated 2.4 million people, according to the 2019 Kenya Population and Housing Census. Kiambu County borders Nairobi and Kajiado Counties to the south, Machakos to the east, Murang'a to the north and northeast, Nyandarua to the northwest, and Nakuru to the west (Figure 4).

2.1 Economic Relevance of Farming

Agriculture is the predominant economic activity in Kiambu County, contributing 17% of the population's income (Kiambu County Government, 2013). Most households in the county undertake dairy production, poultry keeping, pig farming, and crop production. Until the mid-1990s, plantation-grown coffee and tea were the dominant cash crops. Subsequently, there was a shift to livestock production, especially dairy and poultry, due to the poor performance of the coffee and tea markets. High demand for milk and poultry products in surrounding urban centers, such as Nairobi, has influenced this shift (Okello et al., 2010). After dairy farming where there are 250,000 cattle, pig and poultry rearing are most common, with 2,600,000 and 53,000 animals, respectively (County Government of Kiambu, 2018). Fish farming is also practiced in Kiambu County; the main species are catfish and tilapia. The county has also seen an increase in honey production through the adoption of beekeeping by more farmers. The total value of agricultural products produced in Kiambu County annually contributes 4.7% of the county's gross domestic product (KNBS, 2019a).

In Kiambu County, 27% of households are engaged in farming activities (KNBS, 2015). Vegetables cultivated in Kiambu County include kale, cabbage, garden peas, tomatoes, snow peas, carrots, and spinach. Herbs and spices are grown for both local use and export. These include rosemary, parsley, asparagus, coriander, and basil. The county also produces pineapples, mangoes, avocados, and bananas. Additionally, flower production for export is increasing in Kiambu County (County Government of Kiambu, 2018). Growth in the agriculture subsectors has been attributed to ready markets in Nairobi, Kiambu, Ruiru, and Thika and access to processing factories such as Kenchic Company Limited, Palmside Dairies, Githunguri Dairies, Farmers´ Choice Limited, Limuru Milk, Brookside Dairies, and Ndumberi Dairies (County Government of Kiambu, 2018). The increased commercialization of agriculture and the county's proximity to major outlets in Nairobi have brought focus to market issues. However, local and regional market potential has not been fully exploited (Kiambu County Government, 2013).

The total area under agricultural production in Kiambu is 90,218 ha. The area of land under subsistence farming is 66,642 ha which is 74% of the total agricultural land. The land under commercial farming is 22,24 ha which is 25% of the total area under agriculture. Some subsistence farmers sell off their produce in order to purchase what they do not produce. The value of production for cattle milk is Kenyan Shillings (KSh) 5 billion; for beef, KSh 7 billion; for poultry eggs KSh 700 million; for poultry meat, KSh 143 million; and for pork, KSh 631 million (Kiambu County Government, 2013).[1]

2.2 People and Livelihoods

The population of Kiambu County stands at 2,418,000 people. Males make up 49% and females 51% of the population. The population is projected to be 3,899,000 people by 2028. The rural population is currently 711,400 individuals, evenly divided between males and females (KNBS, 2019b).

The absolute poverty rate in the county is 25% while the 24% of Kiambu population live below the poverty line (US$1.90 a day) and the majority are from the rural areas (County Government of Kiambu, 2018). The urban population relies on daily wages, with 51%

[1]At the current exchange rate as of 11/30/2020, KSh 109.50 equals US$ 1.

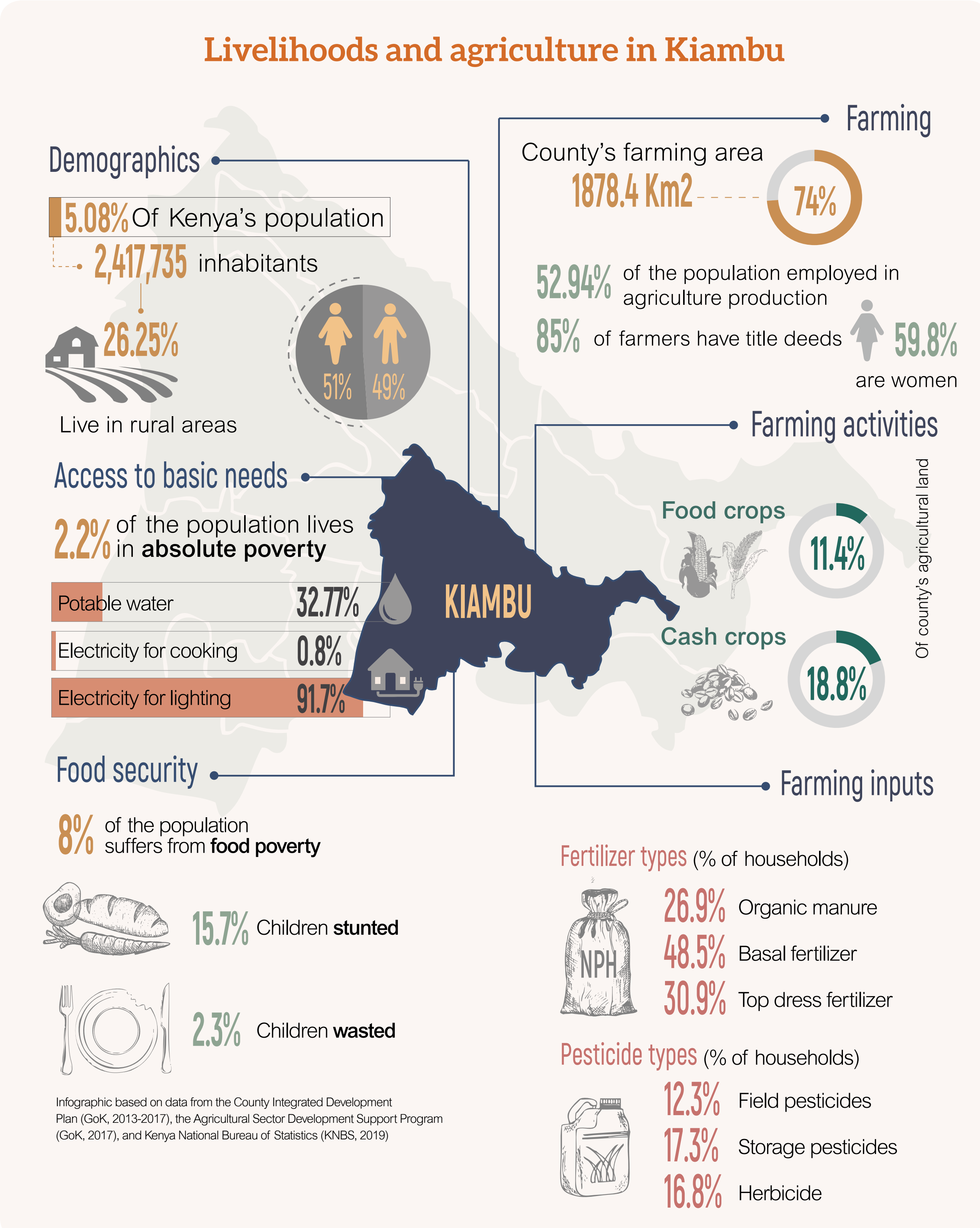

Figure 3: Agriculture and livelihoods in Kiambu County

working in the labor force (KNBS, 2019c). Kiambu County residents enjoy access to basic needs such as water, electricity, and education. The percentage of households with access to electricity for lighting in Kiambu County is 92%, a number due to efforts by the county and national government (County Government of Kiambu, 2018). Approximately 33% of households within Kiambu County have access to potable water. The county is well-endowed with both surface and sub-surface water sources. The Nairobi River sub-catchment, Kamiti River sub-catchment, and the combined sub-catchment of the Thiririka and Aragua Rivers provide adequate water to the population (County Government of Kiambu, 2018). Kiambu County residents have good access to education within the county's 948 primary schools, 365 secondary schools, and 34 vocational training centers. Tertiary institutions include one public university, six private universities, and 26 colleges. The teacher-to-pupil ratio in primary schools is 1:38 (County Government of Kiambu, 2018). Projected population increases suggest a need to increase the capacity of the schools and vocational training centers.

In regard to food security and nutrition, 8% of the county's population is food-poor (African Women's Studies Centre, 2014). Kiambu County has 252,770 children under 5 years old, 16% of whom experience stunting, 2.3% experience wasting, and of whom 5.1% are underweight (KNBS, 2014). Most of the urban population access food in market centers where it is easily accessible at fair prices (County Government of Kiambu, 2018). Examples include Kagwe Market, Ruiru Sub-County Market, Githurai Market, Gatukuyu Market, and Kahawa-West City Council Market. Rural areas are the source of most of food in the county. The highest concentration of farming households is in the sub-counties of Gatundu North (21,532), Gatundu South (25,074), Githunguri (29,745), Lari (25,602), and Limuru (19,202). Poor road networks in some areas hinder access to the food produced, particularly during the rainy season (Kiambu County Government, 2013). Kiambu county has a total of 5533 Km of roads network with 865km being paved and 4468km being unpaved. Rural road access has 4km of paved road network and 137km of unpaved roads (County Government of Kiambu, 2018).

The major livelihood activities in Kiambu County are crop farming, small retail business, livestock keeping, and casual employment. The agricultural sector directly or indirectly employs 304,450 people (Kiambu County Government, 2013). The population of self-employed people who have set up businesses and small-scale industries in the urban centers is 384,940. In rural areas, 157,470 residents are self-employed and engage in agricultural activities for their livelihoods. Kiambu County has 902,850 wage earners, who represent 52% of total household income (Kiambu County Government, 2021). Gender-specific strategies, such as the Smallholder Rural Youth Farming Initiative, have been put in place to support the livelihoods of women and youth.

2.3 Agricultural Activities

Kiambu County has 188,000 ha of arable land, of which 21,450 ha are under food crop production and 35,367 ha are under cash crop production. Population growth and the cultural practice of land inheritance subdivision have decreased average farm sizes. Small-scale farms average 0.4 ha while large scale farms average 70 ha. Smallholder farmers are often marginalized due to their limited access to capital, assets, information, technology, and resources (Murphy, 2012). Smallholder farmers struggle to be competitive, either because their endowment of assets is less favorable than more efficient producers, or because they confront missing or under-developed markets (Brooks et al., 2009). Small land holdings are mostly found in the upper parts of Kiambaa and Limuru which are located in the upper highland humid agro ecological zone; Kikuyu sub county in the lower highland semi humid zone; Gatundu North and Gatundu South sub-counties found in the upper midland sub humid agro ecological zone (Figure 4). The large land holdings are especially found in Juja sub-county which is in the upper midland transitional agro ecological zone and the upper highlands in Limuru and Lari sub-counties in the upper highland humid zone (County Government of Kiambu, 2018).

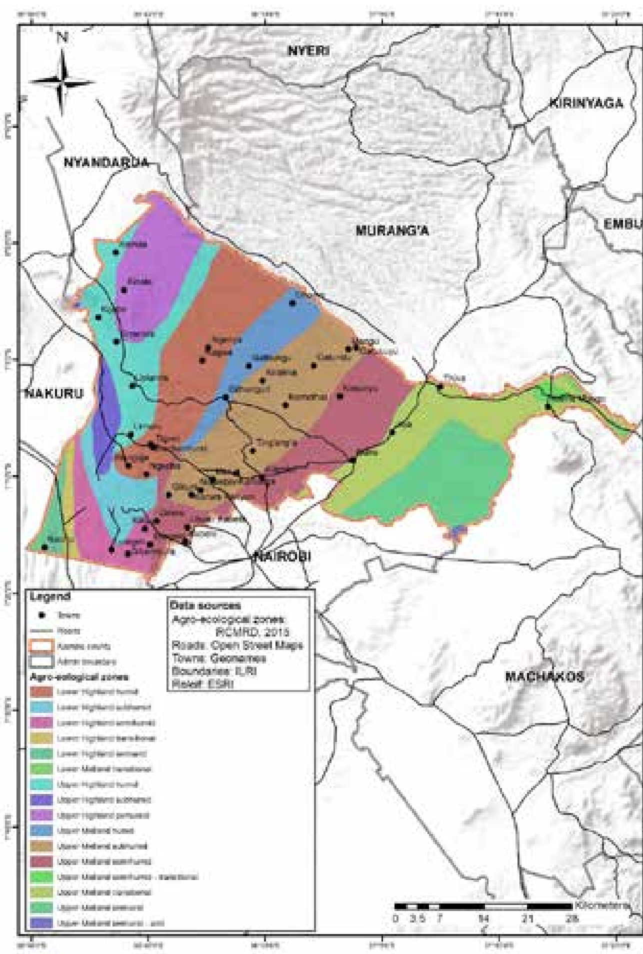

Figure 4: Map of agroecological zones in Kiambu County

The main food crops grown in Kiambu County are beans (17,430 ha), maize (45,980 ha), cabbages (1,100 ha), Irish potatoes (9,200 ha), and bananas (3,520 ha) in small scale farms in the upper highland semi humid, lower highland semi humid, and upper midland sub humid agro ecological zones shown in figure 4. Pineapple is also a major food crop grown mostly in Gatundu North and Gatundu south sub counties found in the upper midland sub humid agro ecological zone. The major cash crops are tea (17,840 ha) and coffee (9,800 ha) commonly grown in the upper and lower highlands (County Government of Kiambu, 2018). The number of households involved in farming these food crops is as follows: 120,890 households for beans, 74,810 for bananas, 144,130 for maize, 108,460 for Irish potatoes, and 41,120 for cabbages. For the cash crops, 20,960 households are involved in tea production, while 32,150 households produce coffee.

In Kiambu County, land ownership is 95% private, 0.01% communal, and approximately 5% public. Of landowners, 85% have title deeds to their land. The process of titling subdivided land is ongoing as more people acquire land (Kiambu County Government, 2013)

Farmers in Kiambu County employ various agricultural inputs during production of value chain commodities: fertilizer, seeds, pesticides, farm machinery, livestock feeds, and fish feeds. The percentages of households using agricultural inputs is as follows: 74% use seeds or planting material, 17% use herbicides, 62% use planting fertilizer, 31% use top-dressing fertilizer, 27% use organic manure, 10% use irrigation water, 12% use field pesticides, and 17% use storage pesticides (ASDSP, 2014). Access to input products and services is strongly affected by prices. The rising prices of fertilizers have been prohibitive which is why more farmers depend on organic manure. Productivity has been negatively impacted by rising prices. Soils are generally fertile, but over-application of synthetic fertilizers has made some soils acidic leading to falling crop productivity (Kiambu County Government, 2013).

Irrigation agriculture is mainly carried out on large-scale farms. The number of households practicing irrigation is 14,840 (KNBS, 2019b). Individual farmers use modern systems like pressurized drip and sprinkler irrigation, especially for high-value export crops such as coffee and horticultural crops. Farmers are also introducing improved irrigation water management systems, improving existing furrow irrigation systems with lined canals, and planting drought-resistant crop varieties to increase water use efficiency. An example of how irrigation is being practiced in Kiambu County is in the production of African Indigenous Vegetable (AIVs). Production of AIVs and other vegetables is an attractive economic activity in the county due to the proximity of city markets, small land holdings, and favorable agro ecological conditions (Mwangi and Crewett, 2019). The county government has initiated nine irrigation projects, namely Kawira, Gatina, Karia, Kiruiru, Nyamuku, Kamwamba, Wamoro, and the Waruhiu agricultural training center.

2.4 Agricultural Value Chain Commodities

Several of Kiambu County's agricultural commodities are prioritized in the county's integrated development plan and development programs such as the National Agricultural Rural Inclusive Growth Project and the Agricultural Sector Development Support Program, and government institutions such as the Kenya Agricultural and Livestock Research Organization. Researchers compiled a list of the county's major agricultural commodities, or value chains, by assessing criteria such as productivity, harvested area, production, production variations in the past five years, economic value, calorie content, protein content, iron content, zinc content, and vitamin A content. This list was further honed by stakeholders, who judged criteria such as the value chain's resilience to climate change, the percentage of the county's population who are involved in the value chain, and the value chain's effects on economically and socially vulnerable groups The four value chains which were selected for this report are maize, dairy cows, sheep, and local chicken.

The stakeholders validated four value chains, similar to those selected by the NARIGP project. The four selected VCCs for Kiambu County are dairy (milk), local chicken, bananas, and Irish potatoes.

2.4.1 Dairy

Kiambu County is one of Kenya's leading milk production regions, producing 350 million Kgs. annually (County Government of Kiambu, 2018). Kiambu has a number of dairy processors, such as Brookside Dairies, Limuru Milk, Githunguri Dairies, Ndumberi Dairies, and Palmside Dairies. Many families in Kiambu County are small-scale farming households that keep an average of 2-3 cows under zero grazing systems for milk production. Exotic cattle are reared by 67,014 households for dairy, while 10,511 rear indigenous cattle (Kiambu County Government, 2013; KNBS, 2019b). The county's overall production has increased from 264,774,000 L in 2013 to 308,819,000 L in 2016. To facilitate value addition, the county government has procured 11 bulk milk coolers, which have cumulative capacity of 39,000 L. Milk coolers facilitate value addition by reducing the risk of microbial contamination. These milk coolers have been issued to farmer dairies including Gatamaiyu, Githiga, Bibirioni, Karatu, Ndumberi, Kiriita, Mangu, Muguga, and Ngewa. Pasteurization also facilitates value addition by killing pathogenic bacteria in milk products that may cause infections in consumers and by increasing shelf life. Two pasteurizers, with capacities of 5000 L per hour, have been installed in Muguga and Kiambaa. The pasteurizers were procured by the county government (County Government of Kiambu, 2018).

At the input supply stage, the most important actors are artificial insemination (AI) providers and feed suppliers. There are several large-scale feed manufacturers such as Jubilee Feeds, Chania Feeds Ltd and Bindip Ltd, but most of the suppliers are commercial feed retailers and wholesalers. Adult male involvement at the input stage is very high, while youth involvement is medium, and women's involvement is low. This production stage includes critical activities such as feeding, breeding, and the control of disease and pests. Dairy production in the county is highest in youth-headed households and lowest in female-headed households (ASDSP, 2014). The low yields in the female-headed households are attributed to low access to livestock technologies, extension, veterinary, and AI services. Processors in Kiambu County are important actors in the post-harvest stage. Githunguri, Kiambaa, and Limuru Milk collect about 20,000 L per day. The involvement of men at the post-harvest stage is medium and that of the youth is low; however, women's involvement is very high. Other important actors in the dairy value chain include farmer cooperatives, wholesalers, and retailers, who play key roles in the marketing and commercialization of dairy products at the output market stage. Wholesaling is done by large- and medium-scale processors and collectors, while bulk milk is handled by milk traders. Wholesaling occurs where the milk is bought by processing plants to be resold later for a profit. Bulking involves the collection of milk at centers where it is weighed and stored in cans for cooling. Overall, male involvement in output market activities is very high, while the involvement of youth and women is medium.

2.4.2 Local Chicken

Local chicken is a prioritized value chain in Kiambu County; 92,250 households keep birds in free-range (traditional), semi-intensive (backyard), and commercial-intensive production systems. Poultry production is concentrated in the western parts of Kiambu, particularly in Kikuyu, Ndeiya and Limuru sub-counties (Okello et al., 2010). Indigenous chicken is the most common type, reared by 92,250 households (KNBS, 2019b). The poultry population in Kiambu stands at 2,600,000; the value of egg production is KSh 700 million and the value of meat production is KSh 143 million (County Government of Kiambu, 2018). Advances in breeding have introduced birds that are more productive and that meet specialized purposes but which require expert management. Such breeds include the KARI Kienyeji, bred from a range of indigenous chickens (KARLO); Kuroiler, which entered Kenya from Uganda but originates in India; Kenbro, a breed by Kenchic Limited; and the rainbow rooster, a multi-colored breed from India (Farmers Trend, 2017). The development of breeding and processing technologies has encouraged the poultry industry and its associated feed industry to scale up rapidly to integrate vertically. These structural changes have introduced contract farming, which allows farmers to gain access to advanced technology in the rearing phase of broiler production with a relatively low initial investment (FAO, 2019).

Major actors in local chicken production include farmers, agricultural input suppliers (feed suppliers, vaccination service providers, governmental extension services, private veterinary services), institutions, processors, and hatcheries. Farmers can purchase day-old chicks from hatcheries such as Kenchic, Western Hatcheries, Kenbrid, Bixa North Coast, and Muguku.

Most poultry production is not contracted. This means that the majority of farmers are responsible for meeting all production costs that arise and handling all aspects of marketing after they have reared their poultry. Farmers have the freedom to work independently but some choose to be part of formal producer and/or marketing organizations. The farmers who use these organizations are relieved of marketing responsibilities and gain access to technical assistance through training. However, only approximately 10% of uncontracted farmers belong to these organizations (Okello et al., 2010).

2.4.3 Bananas

The popularity of the banana crop, coupled with favorable agro ecological conditions in Kiambu County, makes it a good cash crop for smallholder farmers. The foliage and pseudo stems are used as cattle feed during droughts. Banana leaves are also used as packing and roofing material. Bananas are mainly grown in the sub-counties of Gatundu North, Gatundu South, Githunguri, Lari, Kiambu, and Kiambaa. Bananas are produced on an area of 3,520 ha (County Government of Kiambu, 2018). The total number of households involved in banana farming is 74,810, spread out across the sub-counties as follows: 17,800 in Gatundu South, 16,560 in Githunguri, 12,600 in Gatundu North, 4,900 in Lari, 4,480 in Kiambaa, and 4.230 in Kiambu. Varieties cultivated in the county include Giant Cavendish, Grand Nain, Williams Hybrid, FHIA 17 and 18 hybrids, and apple (sweet/sukari) varieties.

There are various methods of expanding or establishing banana orchards. Farmers use sword suckers—the developing shoots from the main stalk of an established tree—from their own farms or from neighbors to increase their produce. Banana Farmers in Kiambu County also use tissue culture technology, drawing on culture material sourced from registered nurseries, such as Kenya Agricultural and Livestock Research Organization (KALRO) or Jomo Kenyatta University of Agriculture and Technology (JKUAT), or from private companies like Genetic Technologies, Aberdare Technologies, and Africa Harvest Biotech Foundation. Tissue culture seedlings offer advantages including reduced pest and disease risk, uniform banana production, and higher yields. Africa Harvest has provided strong institutional support to banana farmers in Kiambu County through intensive training, technical backstopping, and the promotion of banana ripening facilities, and by linking farmers to high-value markets in the city (Kabunga et al., 2012). ASDSP promotes the banana value chain by encouraging actors to specialize in ripening. Twiga Processors currently ripens bananas for farmers for a fee. This processing results in uniformly ripened bananas in the market, which eases trade and allows farmers to concentrate on production. It also discourages unhygienic methods of ripening used by individual producers or traders and further improves the storage and quality of bananas.

Farmers who belong to organized groups are more likely to adapt to sector challenges. An example of a tissue culture farmer's association is the High-Ridge Banana Growers and Marketing Association (HBGMA). It started in 2002 as a partnership of KARLO (previously Kenya Agricultural Research Institute KARI) and International Service for the Acquisition of Agri-biotech Application (ISAAA) under the project "Biotechnology to Benefit Small Scale Banana Producers in Kenya." Its objective was to make banana plants available to resource-poor farmers in central Kenya, including Kiambu County. The association responds to sector challenges, such as limited access to modern production technologies and low prices for bananas. The association helps farmers to source planting materials and to make planting materials available through local hardening nurseries. The association also provides technical assistance through trainers on banana orchard management and value addition, especially in the production of solar-dried bananas. Farmers have also been linked to Genetic Technologies Limited (Kenya) and hardening nurseries for sourcing tissue culture bananas. HBGMA also sensitizes farmers on producing bananas as a commercial crop in the region (Nyang et. al., 2010).

The National Government Affirmative Action Fund-Kiambu has also entered into an agreement with JKUAT to establish a banana value chain enterprise. This partnership is expected to provide agro-processing expertise and to increase access to tissue culture banana seedlings.

Another important actor in banana farming is NARIGP. It aims to provide advisory services on primary production technologies, innovations, and management practices, such as improved inputs and agronomic practices that increase banana productivity. It also aims to build the capacity of communities (with a focus on common interest groups or vulnerable and marginalized groups) to plan, implement, manage, and monitor community-level micro-projects along the banana value chain.

2.4.4 Irish Potatoes

Irish potatoes are an important food crop that contributes to food security in Kiambu County. Potatoes are produced over two planting seasons –the long rains and short rains - and grow within a period of three months. The main planting season (during the long rains) is usually from March to May; the second season (during the short rains) runs from October to December. The main varieties grown in the county include the "Tigoni" variety, which is tolerant of late blight and which was released in 1998 by KALRO-Tigoni, and the "Shangi" variety, which yields 30,000 to 40,000 Kgs/acre under optimal conditions. In Kiambu County, 14% of households are involved in small-scale potato cultivation. Lari, Gatundu South, Githunguri, Limuru, and Kikuyu sub-counties have the highest number of households in potato production (KNBS, 2019b). The area under production in the county is 9,200 ha and annual production is 101,180 tons (County Government of Kiambu, 2018).

Seed potato production in Kenya under the seed and plant varieties act, Chapter 326, is regulated by Kenya Plant Health Inspectorate Service (KEPHIS). Other vital stakeholders that contribute to the seed potato value chain include researchers, breeders, seed multipliers, "ware" potato producers, consumers, traders, transporters, processors and extension service providers (NPCK, 2018). Farmers and agricultural input suppliers are the main actors at the input supply stage. The activities of this stage include the acquisition of certified potato seed and other inputs, such as fertilizers and pesticides. Clean seed tubers can be obtained from KALRO Tigoni, from seed growers identified by the Ministry of Agriculture, Livestock, Fisheries, and Cooperatives, and from authorized farmers' groups that receive advisory inspection support from Kenya Plant Health Inspectorate Service (KEPHIS). Commercial clean seed is expensive and mostly not available. The involvement of men and youths at the input supply stage is very high, while women's involvement is very low.

Production is mainly done on a small scale because of limited resources, including farmers' low access to land and low financial capacity for acquiring inputs. The main activities during the production stage include land preparation, such as destroying weeds and pests, and crop management practices, such as planting, weeding, spraying, and fertilizer application. The maturity period ranges from three to four months after planting, depending on the variety. The final activity in this stage is harvesting. Female involvement at this stage is very high, while male youth involvement is medium and low, respectively.

The post-harvest stage involves an array of activities. Tubers harvested while still immature usually have low dry-matter content and suffer more skin damage, making them more susceptible to infection by fungal and bacterial pathogens. However, seed potatoes are harvested early to avoid viral infections that may occur during the latter part of the growing season. Proper storage is necessary to maintain quality. Sorting and grading are major activities in this stage. Diseased and cut tubers are sorted out to prevent storage losses due to rotting. Potatoes are graded based on their size and shape. Malformed tubers are removed. Tubers are graded into three categories: *ware* (beyond 60 mm gauge); *seed* (28-60 mm gauge); and *chats* (less than 28 mm gauge) (KEPHIS, 2016). Farmers either use transporters to take the produce directly from the farm to the market or sell their produce to middlemen, who then transport it to the market or to processors. At the post-harvest stage, there are large-scale processors who are involved in value addition, for example producing potato crisps, to maximize profits. The involvement of men at this stage is medium, while that of youth and women is high.

2.5 Agricultural Sector Challenges

Kiambu County's agricultural sector is faced with institutional, economic, political, geographical, and climatic challenges. Erratic weather patterns have disrupted planting calendars in the County. Overdependence on rainfall, especially in the dry areas of Juja and Thika, exacerbates the disruption of unpredictable weather. Product quality and quantity are adversely reduced by extreme weather events,

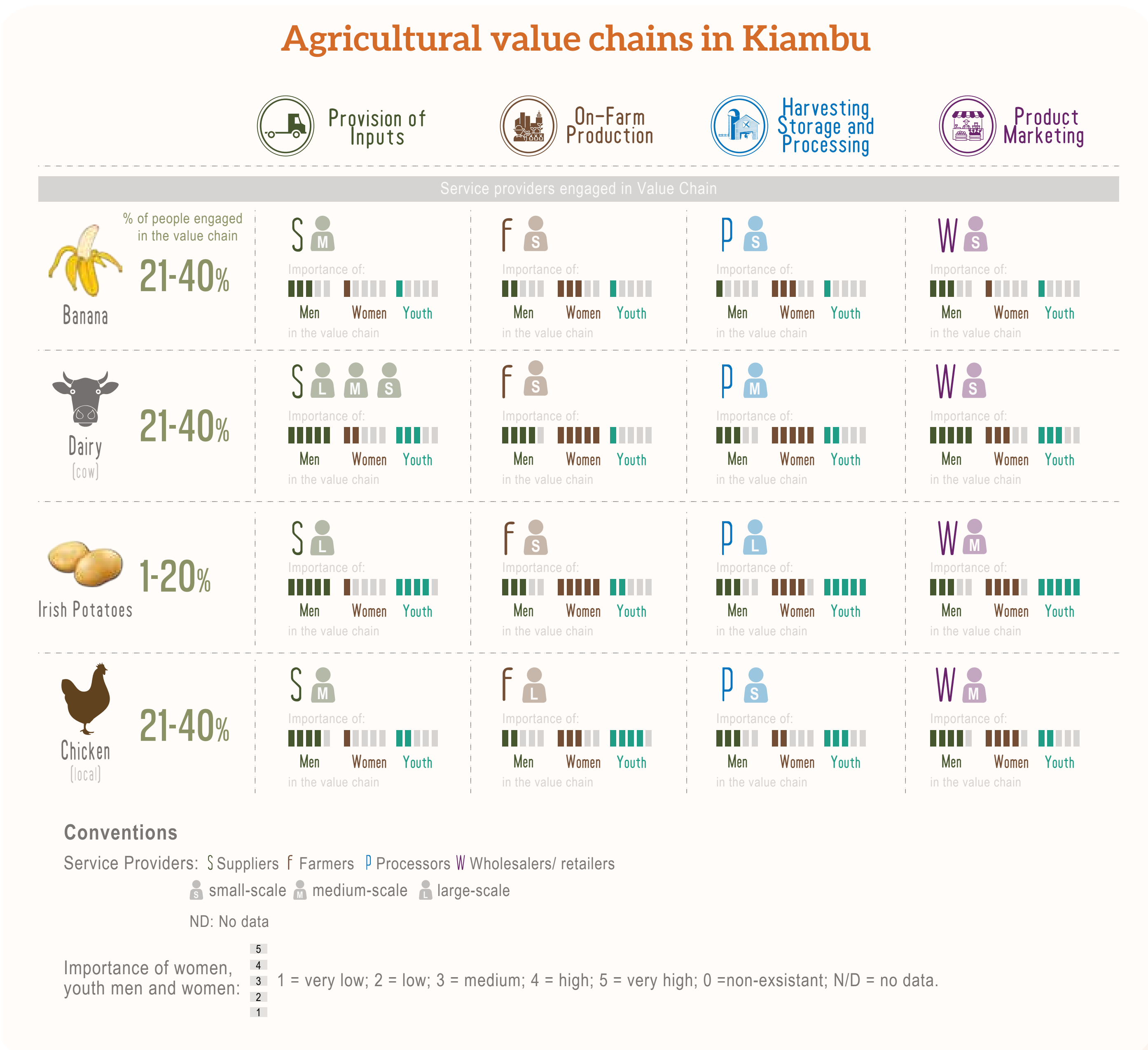

Figure 5: Characterization of the selected value chains in Kiambu County

which in turn impacts farmers' motivation to continue farming. This in turn leads to other, indirect negative effects, such as increased natural resource exploitation for alternative sources of livelihood.

Inadequate agricultural extension and technology adoption is another sectoral challenge. Limited adoption of new technologies that would enhance agricultural production and improve food security is still an issue. Most farmers still employ traditional farming technologies. Unfortunately, they may not have knowledge of improved cultivars and livestock varieties due to limitations on the reach of extension services (McCord et al., 2015; Zanders et al., 2013). These factors have limited farmers' adaptation to climate change and variability. Stakeholders in the agricultural sector will need to cooperate to improve adoption strategies and interventions.

Pests and diseases impact agricultural production in the county, increasing the cost of production and reducing the quantity and quality of produce. *Tuta absoluta* is a common pest that attacks potatoes and tomatoes. Crop diseases common in the county include potato blight and bacterial wilt, which mainly attack potatoes. Livestock diseases include foot and mouth disease and Newcastle disease.

Poor access to agricultural services such as extension, Artificial Insemination, credit, and inputs, especially among the youth and women, is a limitation on agricultural production. Low levels of farmer organization, meanwhile, exposes farmers to exploitation by middlemen. Farmers primarily sell individually, especially for horticultural crops such as cabbages, potatoes, and kale. Producer organizations give farmers bargaining power that can facilitate efficient marketing and reduce exploitation by middlemen.

Low agricultural production can be attributed to the sub-division of land into smaller units (on average 0.36 ha) due to population pressure and the increasing value of land. Given this constraint, many farmers practice small-scale farming which is insufficient to meet the county's food demand. Eventually, these pressures lead to a shift from farming activities to residential and commercial estate land use, as many individuals perceive this to be more lucrative than farming.

3. Climate Change and Agriculture: Risks and Vulnerabilities

In generating this profile, we assessed past trends and future projections of precipitation and temperature, and computed several related hazards from these two variables. These hazards included extreme hydrological events like flash floods, droughts, moisture stress, heat stress, and the start and length of the growing seasons, in order to assess climate change and variability in Kiambu County. The growing season was defined as follows: the first, long rainy season is the 100-day wettest period from January to June, while the second, short rainy season is the 100-day wettest period from July to December (KMD, 2020).

We used Representative Concentration Pathway (RCP) 8.5, one of the four greenhouse gas concentration trajectories adopted by the Intergovernmental Panel on Climate Change (IPCC) for its fifth Assessment Report (AR5) in 2014. Future climate projections were generated based on an ensemble of multiple Coupled Model Intercomparison Project (CMIP5) models (Taylor et al., 2012), using RCP 8.5 for two future periods, 2030 and 2050.[2]

To assess droughts and dry spells, we focused on the maximum number of consecutive dry days (CDD), defined as days receiving rainfall measuring less than 1mm (precipitation < 1 mm day-1). We determined heat stress by measuring the total number of days with maximum temperatures greater than or equal to 35°C (NT35). Growing days are the days during a season when average temperatures are greater than or equal to 5°C and precipitation exceeds half the potential evapotranspiration. The start of the growing season was determined by the occurrence of 5 consecutive growing days, while the length of the growing period (LGP) was determined as the total number of growing days.

For each season, heavy precipitation events were captured with 5-day running average of rainfall (P5D), a measure indicative of floods, and 95th percentile of daily precipitation, one indicative of extremely high rainfall over a short period of time that can lead to events like flash floods. The 95th percentile of daily precipitation distribution based on the 100 wettest days per season per year was calculated for each pixel.

To assess how adequate rainfall and soil moisture levels are to meet the potential water requirements for agriculture, focus was placed on drought stress, represented by the number of consecutive days in each season where the ratio of actual to potential evapotranspiration (ETa/ETp) is below 0.5. This was calculated for each pixel per season per year by evaluating the water capacity of the soil and evapotranspiration to approximate the number of days that could undergo a level of stress.

[2]For historical precipitation and temperature trends, we used the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) and Climate Hazards Group Infrared Temperature with Stations (CHIRTS). For future climate projections we used an ensemble of downscaled Coupled Model Intercomparison Project Phase 5 (CMIP5) (Taylor et al., 2012, Navarro-Racines et al 2020), specifically the MOHC_HADGEM2_ES, CESM1_CAM5, GFDL_CM3, MPI_ESM_LR, and MIROC_MIROC5 models

3.1 Climate Change and Variability: Historic and Future Trends

The annual average temperature for the county is 15-23°C (Figures 6). The western areas including the upper midland semi-arid, upper midland semi-arid arid and the lower highland semiarid agro ecological zones experience annual average temperatures greater than 20°C. Temperature values in the country for the year 2020 were higher than the average temperature for the 1981-2012 period which was used by the Kenya Meteorological Department as the base period in the state of climate 2020 report. Most stations in the country observed higher minimum temperatures than the long term means which is consistent with global observation data that recognizes 2020 as one of the hottest years on record (KMD, 2020).

The long rainy season, which runs between March and May, is wetter than the short season experienced between October and December. Dry spells (periods with less than 20 mm rainfall) occur between July and September (Figure 7). April receives the highest rainfall, more than 200 mm (County Government of Kiambu, 2018)

The annual average precipitation in the county is 600-1300 mm. The northern region receives an annual average precipitation of more than 1000 mm. Historical annual average rainfall and temperature records show a directional-spatial trend, with peak values generally appearing in the northern parts of the county for precipitation and western parts of the county for temperatures. In January 2020, the performance of rainfall was significantly above the long term mean and there were severe storms experienced for example the Kabete station recorded 92.5mm on 12th January. In February the Thika station recorded over 125% rainfall above the long-term mean and storms were recorded in several stations including Kabete with 23.0mm. The OND short rains recorded depressed amount of rainfall with the Thika station recording 360.4mm (KMD, 2020).

The total annual rainfall has slightly decreased since 1985 and this will continue up to 2040 for the long rainy season. The trends show that the short rainy season is becoming wetter and projections indicate that the total annual rainfall will continue to increase (Figure 8). The mean annual temperatures trends show an increase since 1985 and this will continue to increase in the future. The long rainy season will remain warmer than the short rainy season (Figure 9).

From 1985 to 2015, the number of CDD been consistent (Figure 10), with a few extreme years, in the range of 20-50 days. Future climatic projections indicate a slight increase in CDD, suggesting it will exceed 40 days more frequently. Increased dry periods will lead to high drought risk in the long rainy seasons between 2020 and 2040. However, CDD is predicted to decrease after the year 2040 due to increases in rainfall.

Flood risk is indicated by the P5D measurement. In the long rainy season, P5D has historically remained low (below 30 mm) with some scattered large values. Between 1985-2015, P5D remained almost constant, oscillating around 30mm. Future climate projections indicate that P5D will reach more than 40 mm and will increase across the county by 6-16 mm, with northern regions experiencing more extreme rainfall compared to southern regions. Overall, the increase in P5D suggests heightened flood risk throughout county.

One indicator of heavy rainfall and erosion risk is the 95th percentile of daily precipitation for a season. In the long rainy season, 95th percentile intensity has historically remained high in the northern regions, with some scattered large values in the central and southern regions (Figure 11). Future climate projections indicate that this risk will mainly affect the northern regions, suggesting increased localized erosion risk. The spatial variation in 95th percentile intensity for future years matches closely with the P5D index, indicating increased precipitation in the central and northern regions. From 1985-2015, the 95th percentile of daily precipitation has shown a level trend, with most years experiencing values between 20-40 mm. Future climatic projections indicate a steady increase. In the future, it is expected that the long rainy season will become wetter, with increasing precipitation contributions from northern regions.

The NT35 indicator shows heat stress. In the long rainy season, NT35 has historically remained extremely low, with no incidence of days above 35°C. However, future climate projections indicate that NT35 will increase drastically in the southwestern regions, suggesting extreme heat events in that could last up to two weeks in some areas.

Moisture stress occurs when the ratio of actual to potential evapotranspiration is below 0.5; it serves as a daily indicator of soil moisture availability for plants. Moisture stress negatively affects the vegetative growth of crops. Historical and future trends indicate that periods of soil moisture stress are expected to increase across the county by 2-10 days per year . The eastern regions will experience significantly higher moisture stress compared to the rest of the county.

The start of the growing season is a date determined by the timing of suitable climatic conditions for crop growth. Historically in Kiambu County, the growing season started between early February and late March. Future climate projections suggest that growing season in the northeastern regions will start earlier, while some parts of the western regions will experience up to 3 weeks of delay. Climate advisory services will become critical to inform farmers about optimum planting windows to avoid crop losses.

The LGP is defined as the time interval when climatic conditions are suitable for crop growth. Historically, LGP in the long rainy season was more than 2 months in some parts of the northern regions of the county.

However, future climate projections indicate that LGP will slightly decrease overall. Some locations will experience losses of more than 10-15 suitable growing days in the long rainy season. Shorter-duration crop varieties will foster adaptation to these changes. Climate advisory services will also play a critical role, informing farmers of the earliest planting windows.

Compared to the historical period (1985-2015), the length of the growing season is projected to decline between 2020 to 2040, with average LGP falling to just over one month. Although the LGP is projected to increase again after 2040, this short window does not provide enough time to grow most cereal crop varieties currently cultivated in the region. Unless shorter-duration crop varieties are introduced, it will be extremely difficult to ensure or improve food security in Kiambu County.

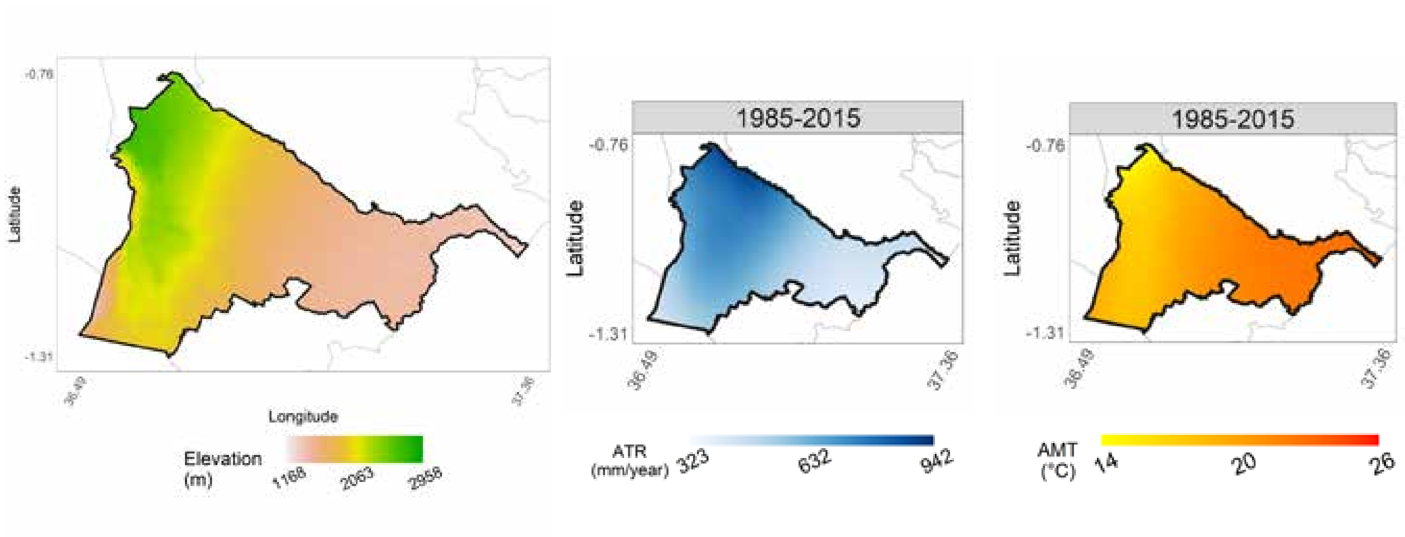

Figure 6: Elevation (left), historical (1985-2015) annual mean precipitation in mm (center), and historical (1985-2015) annual mean temperature in °C (right) for Kiambu County for the long rainy season

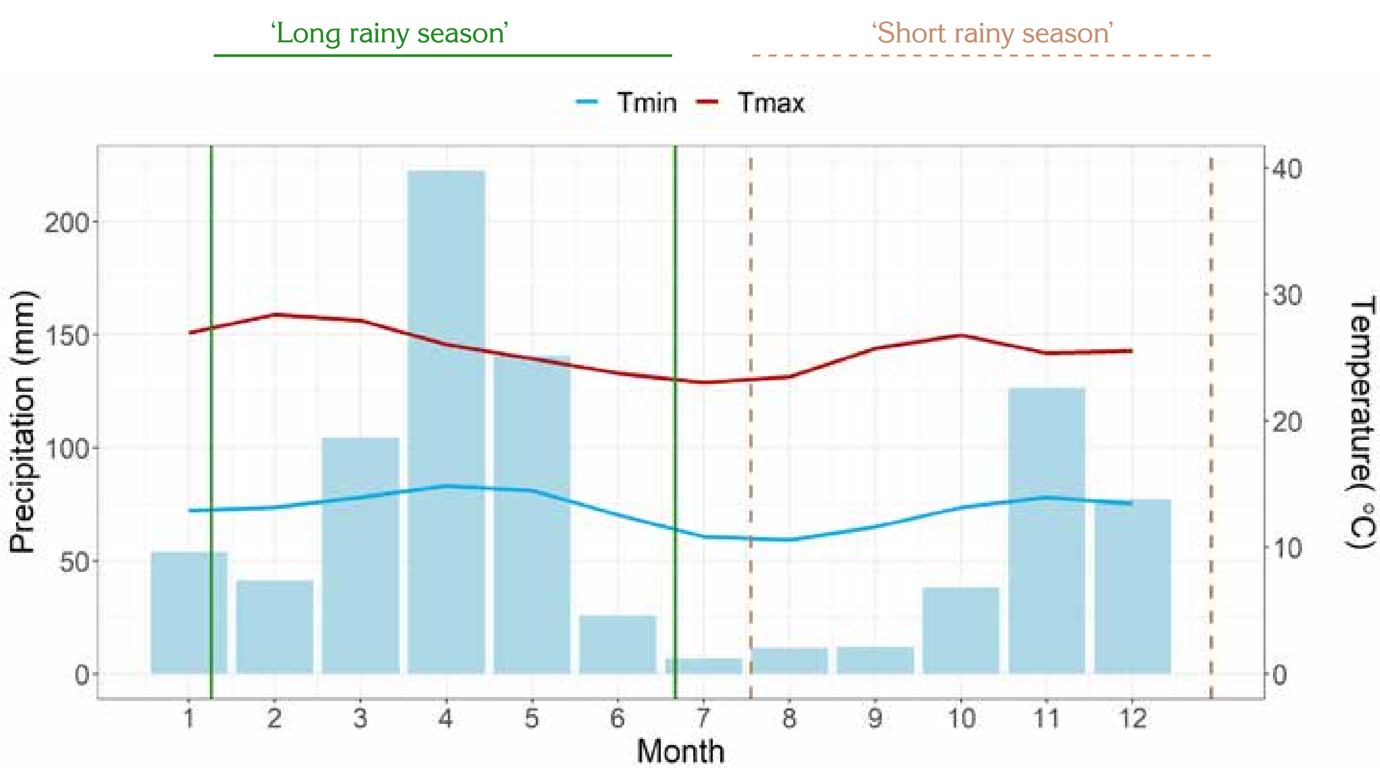

Figure 7: Monthly mean temperature (red and blue lines for maximum and minimum, respectively) and precipitation (bars) over last 30 years (1985-2015) in Kiambu County. The first long rainy season is the 100-day wettest period from January to June, while the second, the short rainy season is the 100-day wettest period from July to December.

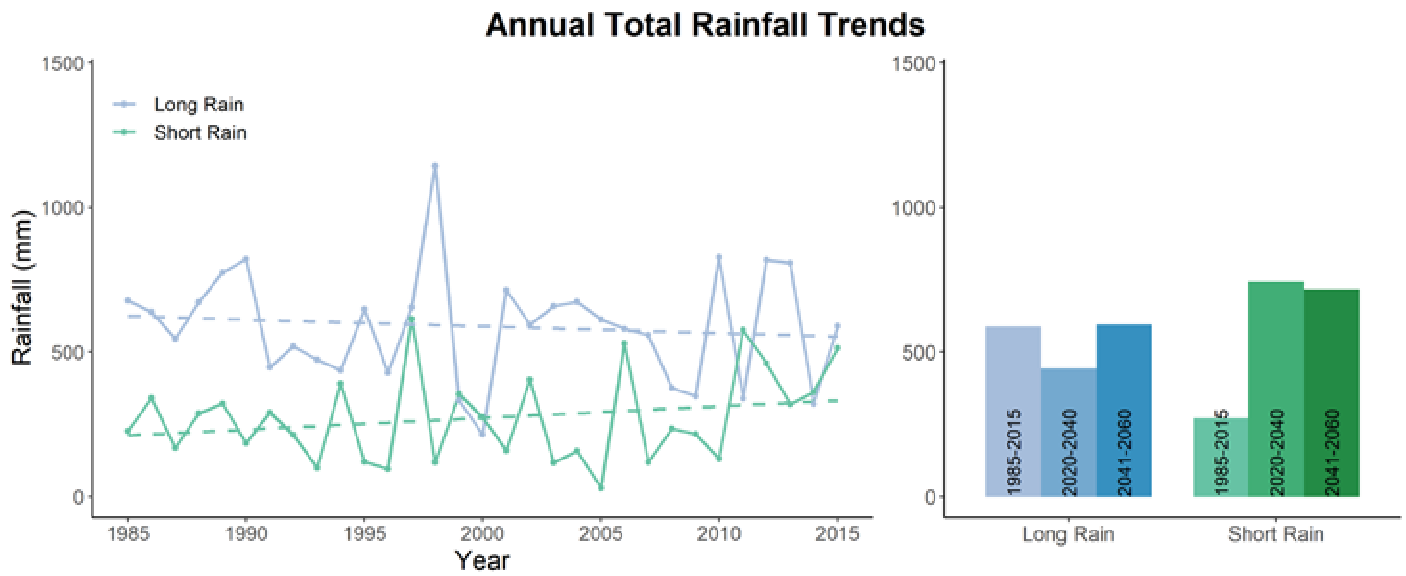

Figure 8: Annual total rainfall trends for the long rainy and short rainy seasons in the past (1985-2015) and in the future (2020-2040 and 2041-2060)

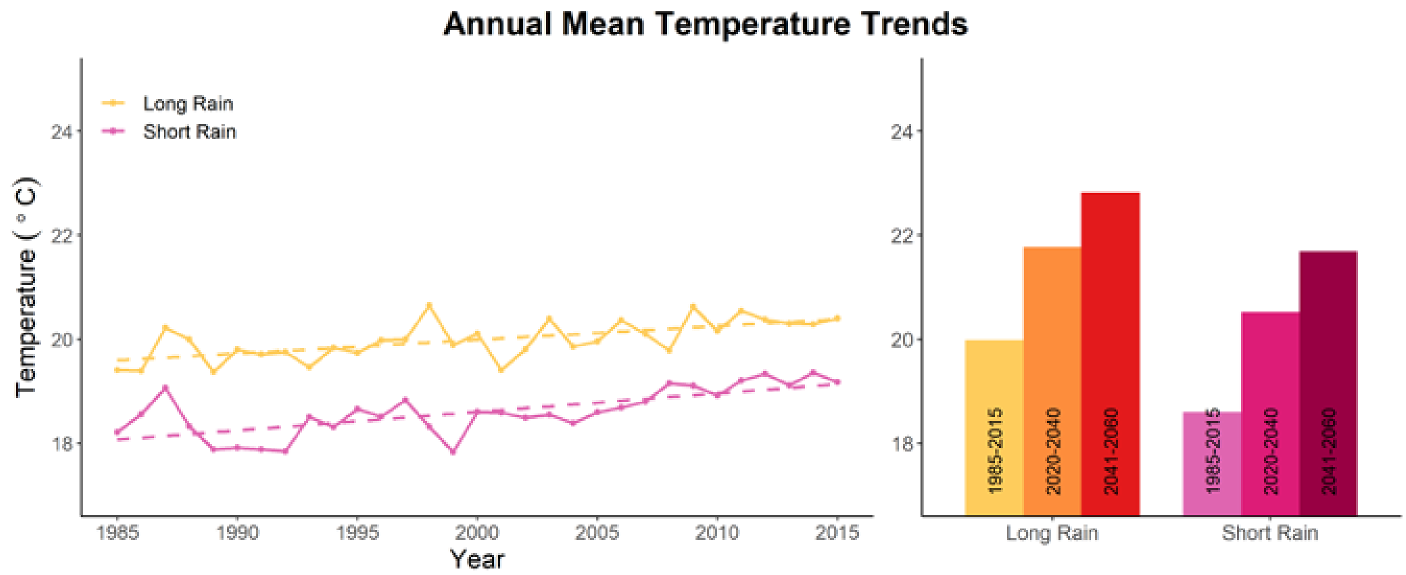

Figure 9: Annual mean temperature trends for the long rainy and short rainy seasons in the past (1985-2015) and in the future (2020-2040 and 2041-2060)

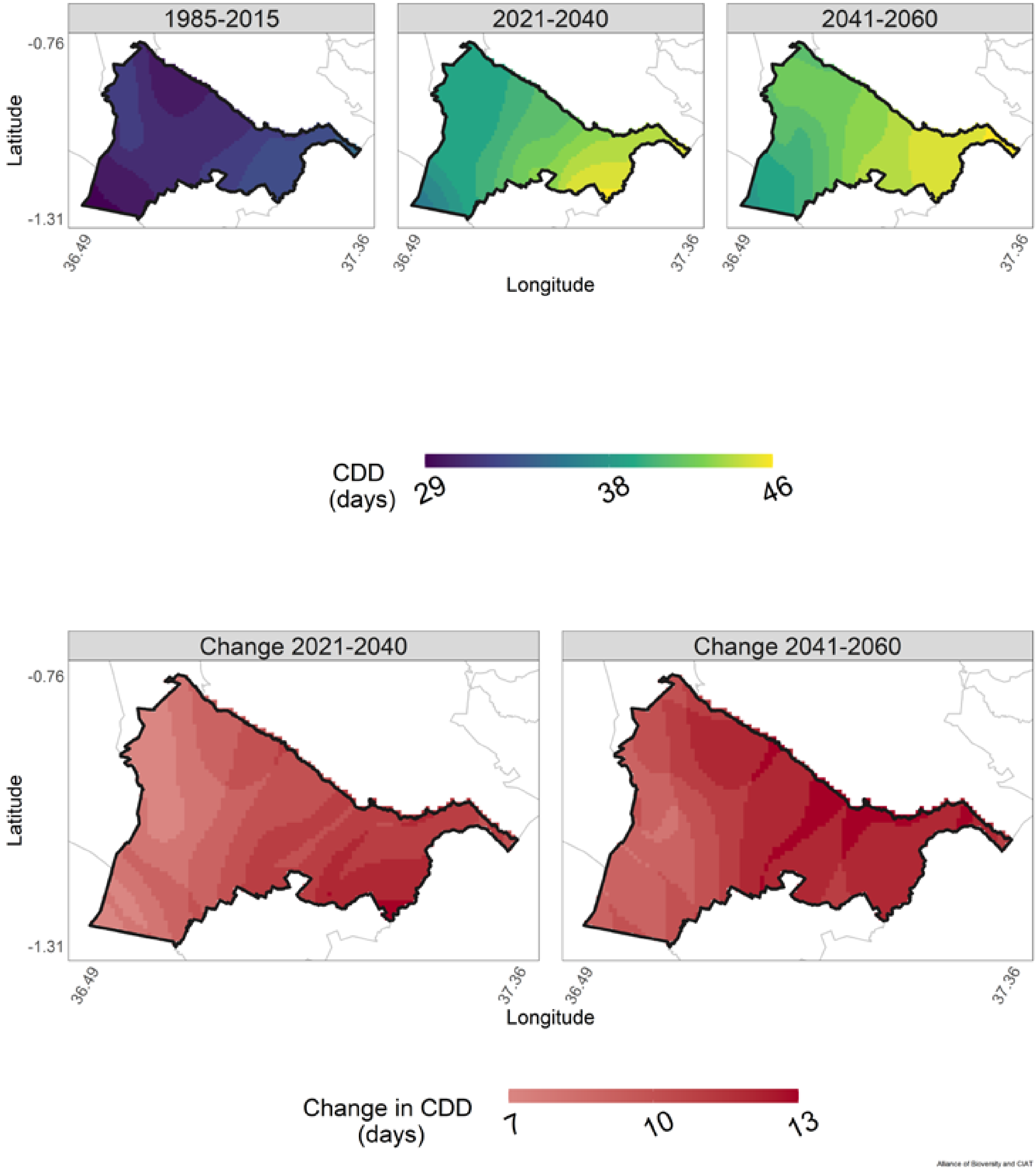

Figure 10: Historical (left, average 1985-2015), future projected (center), and projected change (right) for the number of consecutive dry days in Kiambu County for the long rainy season

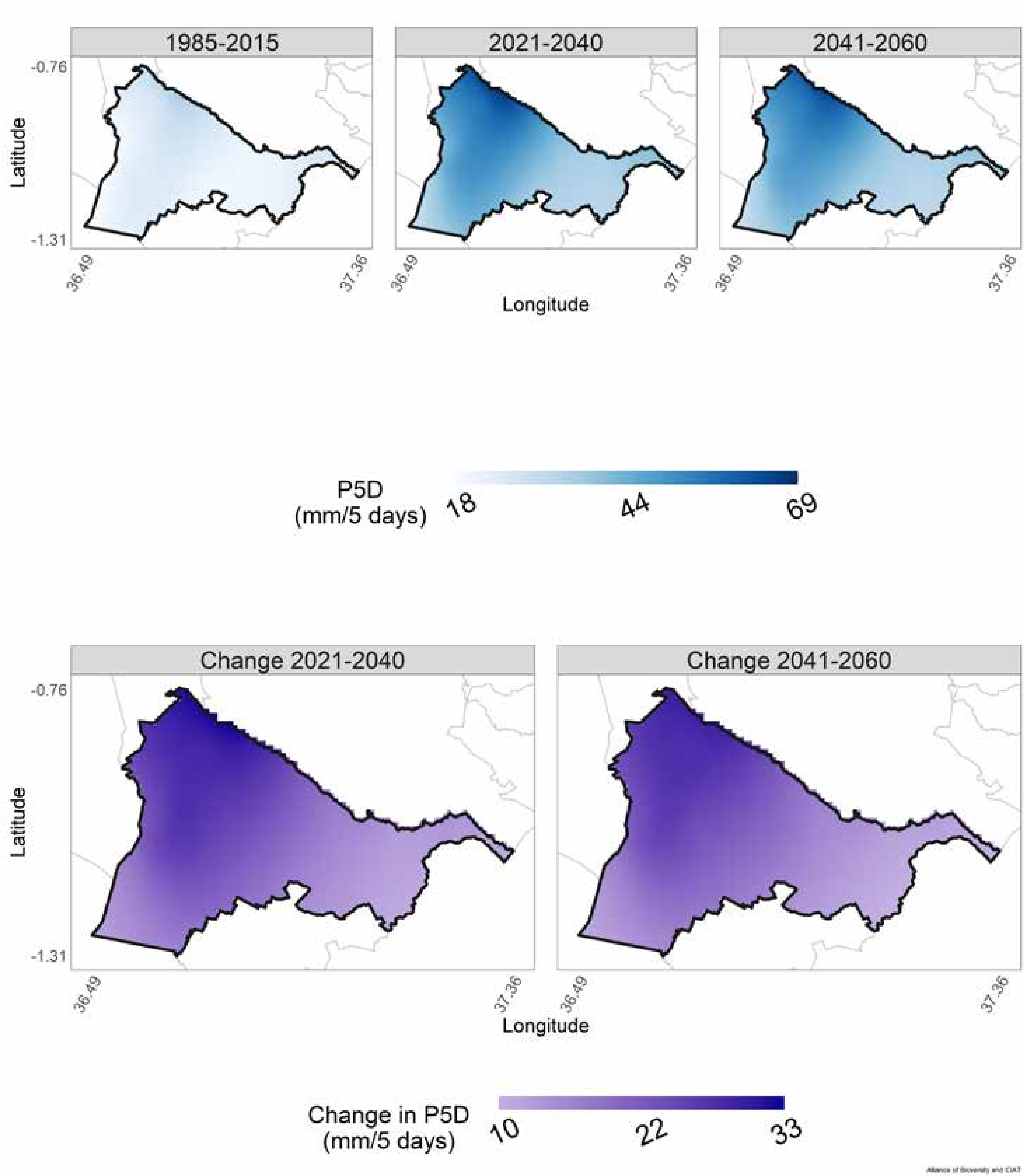

Figure 11: Historical (left, average 1985-2015), future projected (center), and projected change (right) in 95th percentile of daily precipitation in mm for Kiambu County for the short rainy season

3.2 The Climate from Farmers' Perspectives

County-level discussions with farmer groups, individual farmers, and county experts are ongoing, exploring how existing climate change mitigation interventions can be improved. All parties agree that there have been major changes in climate and weather patterns in Kiambu County and that rainfall has become sporadic. The climatic risks necessarily vary by value chain and agro ecological zone. Many farmers in Kiambu County understand the concept of climate change and the impact it has had on agriculture; furthermore, they are willing to adopt climate-smart innovations. The farmer groups that participated in focus group discussions reported noticing changes in environmental trends over time; all farmers stated that they had at least experienced shocks such as the incidence of new diseases and pests, soil degradation, and the drying of rivers during agricultural production due to climate change. The most reported shocks were crop and livestock pests and diseases and poor distribution of rain. In a bid to cushion themselves, farmers employ adaptation strategies that include soil and water conservation, planting trees, and water harvesting. Only 50% of the farmers interviewed used natural resource management practices on their farms. The impact of climate risks on men is quite significant: low production means low income from agricultural produce and increased struggle to take care of their families. When reduced income from farms is insufficient to acquire necessary inputs for crop and livestock production, employing adaptation mechanisms becomes a further challenge. Women and youths are the most vulnerable, due to their limited access to resources that could enhance their livelihoods. Weather unpredictability causes farmers to engage less in agricultural production, which directly affects women because they perform most of the on-farm labor activities; these changes in turn affects their source of income.

Some farmers in Kiambu County rely on traditional knowledge and experience for predicting weather, interpreting climatic and weather changes, assessing and managing soils, selecting quality seeds, employing proper methods of farming and crop protection, and for food crop storage, preservation, and preparation. Their knowledge plays an important role in managing natural resources for domestic food crop production, improving their livelihoods, and developing their communities. Examples of indigenous knowledge applied currently is the planting of traditional drought tolerant crops such as cassava, yams, millet and sorghum, which was planted by the Agikuyu women and men in precolonial times before the introduction of cash crops such as coffee, tea and pyrethrum by the Europeans; observing weather change and climate variation which is done by the elders in order to prepare for the planting of food crops in good time; storage and preservation methods for example *Ikombe (granary)* for storing maize and bean which are uniquely structured to prevented rodents from infesting the harvest. Beans harvest was stored in pods because it was believed to delay the infestation of weevils.

Heavy rainfalls in recent years have resulted in flooding, destroying crops on farms. For example, Bibirioni Irish potato farmers attributed their extremely low yields to heavy rainfall between October 2019 and May 2020. They reported that flooding in the fields caused potatoes to rot. Farmers also indicated that the use of organic manure, fertilizer, pesticides, and other interventions has become difficult due to heavy rainfall and flooding. Inputs are washed away, rendering farmers' interventions ineffective. Erratic rainfall patterns have also disrupted the planting seasons.

At the input supply stage, heavy rainfall leads to the scarcity of certain fodder crops such as Boma Rhodes grass. Dairy farmers in the Kamirithu Block value chain reported that heavy rainfall led to flooding and destroyed on-farm fodder crops, thus impacting the availability of cattle feed. In the potato value chain, storage in heavy rainfall conditions can be difficult due to flooding and moisture levels that cause the produce to rot. Building structures that are hardened against these risks can be expensive. Changing weather patterns lead to low productivity, in turn affecting market prices. Dry spells dry up reservoirs and lead to water rationing. Lari sub-county experienced flooding and landslides due to heavy rainfalls in May 2020, which resulted in destruction of property and severe damage to local crops. Changing rainfall patterns have disrupted planting seasons, requiring farmers to wait for the rains to start planting. Unfavorable weather conditions have led to low productivity which means diminished incomes for farmers and price fluctuations. The high cost of climate change mitigation interventions also leads to higher production costs, disproportionately impacting poor farmers.

3.3 Climate Vulnerabilities across Agricultural Value Chain Commodities

3.3.1 Dairy

The two climatic hazards identified as most impactful on dairy production in Kiambu County are dry spells and excessive rainfall. The impact of a prolonged dry season on dairy production is moderate across all the value chain stages. Dry spells affect the quality, quantity, and cost of feeds such as maize stalks, Napier grass, Boma Rhodes grass, and Lucerne grass. Drought impacts force farmers to switch to alternatives such as commercial feeds. These supplements are less accessible in terms of affordability, especially considering that feeds represent 70-80% of the costs of dairy production (Mbugua et al., 2012). Malnourishment among dairy cows reduces the yield and quality of milk production and increases vulnerability to diseases like foot and mouth disease due to reduced immunity. Dry spells also have an impact on the estrus cycle of cows, causing low conception and high spontaneous abortion rates. Dry spells also generally increase the cost of bulking and collection due to low yields. Milk prices go up due to limited supply.

Excessive rainfall affects the input supply stage moderately compared to, but its impact on on-farm production is minor. At the post-harvest and market stages, the impact is moderate. Excessive rainfall can cause on-farm fodder loss. Impassable roads limit accessibility of feeds and extension providers, and compromise farmers' ability to attend trainings provided by the county government and other local institutions. Provision of AI services is also limited by excessive rains. During the excessive rainfall period between March and May, the incidence of diseases like Rift Valley fever increases; mastitis and pneumonia cases likewise tend to increase during floods, reducing milk quantity and quality. Post-harvest losses due to spoilage increase when milk is exposed to microbial contamination from these diseases. Milk delivery time increases during heavy rainfall. Insufficient capital to employ some of the available adaptation strategies such as fodder conservation poses a great barrier to farmers in Kiambu county.

3.3.2 Local Chickens

The main climatic hazards affecting the local chicken value chain are heat stress due to increased temperatures and flooding caused by heavy and prolonged rainfall. The impact of heat stress on local chickens is major to severe at the input supply stage, and minor to moderate at the on-farm production, post-harvest, and output markets stages. Periods of heat increase the cost of housing, due to the necessity of temperature regulation. Heat stress also affects the layout and orientation of housing structures. The impact of heat stress on feeds is severe. Feed availability declines due to the scarcity of raw materials such as maize and rice, which are also affected by heat stress; this increases the costs of feeds significantly, mostly affecting medium- and small-scale suppliers. Farmers must then use commercial feeds, which increases their production costs. Heat stress causes reduced uptake of feeds, therefore affecting the growth rate and production of eggs, increasing the cost of chicken. During these periods, the water requirements for chicken's increase. Heat requires well-ventilated vehicles for transportation of eggs, to the extent that heat stress has a moderate impact on the transport stage. At the output market stage, the quantity of production for both eggs and meat is reduced by heat stress.

Flooding has a major impact on the input supply stage. During floods, farmers must set up structures on raised foundations and with waterproof materials, increasing their costs of production. Flooding renders roads inaccessible, delaying feed supply and raising prices. At the production stage, flooding severely impacts brooding because extra materials and modified structures are necessary to keep the chicks warm. Farmers who hatch eggs under artificial conditions incur extra costs in setting up proper structures that withstand flooding. Flooding also increases the prevalence of Newcastle disease increasing costs by necessitating veterinary services. The impacts of flooding are felt at the post-harvest stage during transportation and at the market stage, affecting prices. Flooding has effects on housing, brooding, and hatching; increased production costs and decreased production may result in high prices for eggs and meat. Inaccessible roads during periods of intense rain cause delays in transporting eggs to markets, potentially causing farmers to lose many buyers. Low supply leads to high prices.

3.3.3 Bananas

The main hazards to banana farming are moisture stress and erosion risk. Drought is a natural hazard caused by large-scale climate variability and is determined by the number of CDD. Moisture stress has a major impact on land use, tissue culture banana production, and the use of fertilizer and pesticides at the input supply stage. Low soil moisture levels make land unproductive and unfavorable for banana farming. Some of the impacts on tissue culture banana production include low yields, low seedling survival, and low adoption of the technology, because production seems to be low due to moisture stress. There is low use of organic and inorganic fertilizer, since moisture stress reduces nutrient uptake and leads to low yields. At the on-farm stage, the impacts are moderate to major. Most farmers do not have the capacity to purchase quality seeds during planting season and therefore opt for low-quality planting materials which have low survival rates during episodes of moisture stress. Moisture stress delays the maturity period of the banana plantlets, leading to a decreased quantity and quality of bunches, thus reducing incomes. Farmers have increased the use of mulching to reduce soil moisture loss for optimum growth.

The impacts at the post-harvest stage are major to severe. Low production due to moisture stress reduces transporters' business and situates the purchase of produce primarily on the farm. Poor-quality produce resulting from periods of moisture stress does not compete favorably at the market.

The impacts of severe soil erosion due to flood are also a major challenge at the input supply stage of banana production are also a major challenge. Highly eroded soils have low fertility, which in turn means low banana production. Erosion also renders the use of organic and inorganic fertilizer and pesticides both difficult and inefficient. Minerals and nutrients are washed away by surface runoff, resulting in low yields. Mineral leaching can occur due to poor soil structure resulting from soil erosion. At the on-farm production stage, erosion risk has a major to severe impact on the production of bananas. During land preparation, eroded soils have poor workability, increasing the difficulty to prepare for the subsoil. Eroded areas lack topsoil, which stagnates seedling takeoff. The post-harvest stage is not directly affected by soil erosion, although activities like sorting and grading can become difficult when produce quality is poor and unable to attract high market value. This allows for exploitation by middlemen who buy from producers at extremely low prices. The risk of erosion has severe consequences on the market stage of banana production, including a lack of quality produce, resulting weak linkages to buyers, and low adoption of technology and innovations due to the negative production effects of soil erosion.

3.3.4 Irish Potatoes

Flood risks and dry spells were listed by county experts and farmers as the two main hazards impacting Irish potato farming in the county. The consequences of flooding on Irish potato production are major to severe at the input stage, moderate to major at the production stage, minor to major for the post-harvest stage, and moderate to major at the output market stage. The acquisition of certified seeds is challenging during floods, causing farmers to use local or recycled seeds. These are readily available, but they will have low yields. Flooding is another major hindrance to the timely transportation of inputs to the point of use on farms. Flooding delays land preparation at the production level, as farmers must wait until heavy rainfalls have subsided and the fields have cleared to begin. Crop protection practices, for example spraying, cannot be carried out in flood conditions. Moreover, flooding can destroy potatoes at the farm when they rot in stagnant water. Flooding also leaches nutrients and minerals from the soil, therefore reducing fertility. Flooding delays harvesting. During the post-harvest stage, the transportation of potatoes to the market may be affected by roads made inaccessible by flooding. Aggregation activities are also impacted because produce will rot.

Dry spells are another key hazard to potato production. At the input supply stage, dry spells cause moderate delays in the acquisition of certified seed, fertilizers, and pesticides. During these periods, pest and disease pressures increase to the point that they might lead to economic losses if farmers do not employ correct crop management practices. Dry spells have an especially negative impact on potato production if they occur during the flowering stage, leading to low yields. The impacts of dry spells at the post-harvest stage are moderate, but they can result in economic gains during sorting and grading, because aggregation and transportation require less labor and there is reduced rotting. There may also be economic gains at the market stage due to increased market accessibility thanks to clear roads. Farmer-buyer linkages are not limited by dry spells. The only loss exacerbated by dry spells is to processors during value addition, where minor losses occur because stored potatoes deteriorate faster.

4. Adaptation to Climate Change and Variability

4.1 Factors Determining Future Vulnerability and Impacts of Climate Change

There are many factors that determine the severity of climate change consequences at the individual level. They can be found in many realms: biophysical, social, cultural, economic, institutional, policy, and infrastructure, among many others. Women and youth are generally more vulnerable to the impacts of climate change than men because of their limited access to resources such as land. Their decision-making capacity in land sustainability issues is, therefore, limited, making them vulnerable.

Another factor that can cause vulnerability is the existence or lack of farmers' organizations. Farmers who sell through middlemen are more affected by price fluctuations than those who participate in organized market structures.

Limited dissemination of knowledge on the handling of produce after harvesting is also another factor that increases vulnerability. For example, inadequate sorting and grading skills lead to poor prices. Another example is the practice of selling banana produce by the bunch instead of by the kilo, which affects the prices farmers can fetch.

An economic factor that greatly predisposes farmers to the impacts of climate change is a lack of the capital to acquire the necessary agricultural inputs, such as certified seeds, in preparation for the planting season. This also limits farmers' ability to invest in technologies that are suitable to reduce climate change impacts.

4.2 Climate Change Adaptation Options

Climate change has severe impacts on food and agricultural production systems. Climatic occurrences within Kiambu County have become unpredictable. The county government, in partnership with other key stakeholders in the agricultural sector, plays a major role in providing farmers with adaptation strategies to reduce the impacts of climate change. Some of the resources available in Kiambu County to cope with climatic challenges include early warning systems provided by KMD and the participatory scenario planning coordinated by the ASDSP and other government departments. Farmers themselves also employ ongoing adaptation practices to cushion themselves against climate risks. The county government should increase its efforts towards ensuring that potential adaptation practices are also tested to improve resilience.

4.2.1 Ongoing Adaptation Practices

Farmers in Kiambu County use various interventions to combat climate change. For example, they might plant drought-tolerant fodder crops, e.g., Boma Rhodes grass, Brachiaria, or desmodium, which do well in areas receiving less than 900 mm of rainfall. These grasses are very palatable, are good for haymaking, and are popular in cut-and-carry systems. Fodder can be conserved as silage and hay for use in unfavorable weather conditions. These interventions increase the fodder supply for livestock at the input supply stage of dairy production. Currently, only 36% of households use fodder, hay, silage, or crop residue for livestock production (ASDSP, 2014). Extension services provide an array of benefits to farmers, including fodder conservation knowledge.

The livestock department in Kiambu County practices disease control through vaccinations, hide and skin vector control, and disease surveillance. Another common intervention is the use of AI technology for breed improvement, which leads to increased quality and quantity of product.

Farmers use certified seeds to achieve high yields and good-quality harvests. Agricultural input suppliers play a major role in selling certified seed to farmers; however, poor farmers cannot afford these seeds and therefore plant traditional varieties, with low yields as a result. Agricultural inputs, such as fertilizers and manure, are applied to farms at the input and production stages to increase the chances of improved quality and productivity. To control pests and diseases, for example early and late blight in potato production, farmers use pesticides. The percentage of households that have received training in pest control in the county is 67%.

Promotion of climate-smart agricultural technologies by the county government, for example rainwater harvesting for crop production and irrigation interventions, reduces dependence on rain-fed agriculture. This is most beneficial at the input and on-farm production stages, where water input is needed for the proper growth of seedlings. These interventions will enable farmers to cope during drought seasons and boost the production of crops which are quite sensitive to weather changes, like bananas. Another intervention employed in Kiambu County is the planting of improved crop varieties such as tissue culture bananas and earlier-maturing maize varieties.

The county has encouraged the adoption of sustainable land management practices, including the construction of physical structures like terraces and grass strips and soil conservation techniques including crop rotation, cover crops, conservation tillage, and planted windbreaks.

4.2.2 Potential Adaptation Practices

At the input supply stage, several potential adaptation practices can be applied to both crop and livestock production to reduce impacts of climate change. The introduction of modern breeding technology such as sexed semen and embryo transfer can help manage, develop, and increase the size of dairy cow herds. The county government can enhance the enforcement of disease control measures such as vaccination and subsidize livestock vaccination costs. Another potential practice is the outsourcing of feed production and conservation to other counties that have improved varieties. The feed industry can run better if standards and regulations are introduced to ensure quality and avoid exploitation. Another strategy that can be implemented is the establishment of seed incubation centers.

Small plot sizes are a major challenge to farmers in Kiambu County, but not an insurmountable one. On-farm production activities can also be improved in a number of ways. Farmers can be sensitized to cultivate high-value crops, for example, grapes, olive, almonds, herbs, and spices. Farmers can also keep improved exotic livestock breeds to enhance milk production. Traditional knowledge and practice around soil suitability and management, methods of farming, and crop protection should be promoted by the relevant stakeholders. Modern irrigation technologies can also be applied to increase productivity during dry periods.

At the post-harvest stage, the main challenges include storage, collection, aggregation, sorting and grading. There are not yet enough storage facilities in the county to avoid post-harvest losses; the county government and even the private sector can step in here to cushion farmers from incurring huge losses. Cooperatives can initiate the establishment of community storage facilities where members can take their produce in good time to prevent losses. Cooperatives can also help farmers benefit from innovative value addition practices.

On the output market stage, farmers should be encouraged to join cooperative societies that have their best interest in mind, as this usually cuts off exploitative middlemen. Cooperatives can attract good prices from processors and exporters by exploiting economies of scale; they are able to negotiate better prices with large aggregated quantities of produce, as opposed to individual farmers approaching the processors or exporters with small quantities. Relevant authorities should enforce the dairy cooperative society policies, especially minimum payments to farmers. Another potential strategy is the creation of a price stabilization fund that can be used to fund activities that regulate and absorb the extreme changes in the prices of agricultural commodities.

Adaptation strategies used in selected value chains in Kiambu County

Irish Potatoes

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Flood Consequences	Inaccessible certified seeds; low yields; untimely delivery of inputs; low production	Delayed land preparation; destroyed crops and leaching; delayed harvesting; reduced production	Delayed sorting and grading; delayed transportation to market; rotting of produce	Mechanical damage; poor quality and low prices; inflated or exaggerated profit margins; reduced income due to high transportation costs
Magnitude of Impact	Major-Severe	Moderate-Major	Minor-Major	Moderate-Major
Farmers' Current Coping Strategies	Plant from existing seed stock; no fertilizer or pesticide applications; use farmyard manure; creation of storm water drainages	Construction or improvement of drainage channels so farmers are not left waiting for water to drain	Potatoes packed without grading and sorting; farmers selling at the farm gate; constant sorting to remove rotten potatoes	Use of donkey-driven carts or motorcycles; farmers selling at farm gate prices; transportation upgraded from donkey carts and motorcycles to less expensive tractors
Potential Adaption Options	Establish seed incubation centers; improve infrastructure; ensure local availability of inputs; construct water pans; train farmers on sustainable land management practices and water harvesting	Establish storm water drainages prior to rainy seasons; train intensively on sustainable land management practices and the use of weather reports; sensitize farmers to climate change and adaptation measures; collaborate to enhance capacity; build potato storage capacity to preserve quality; establish community storage facilities by cooperatives	Establish community storage facilities by cooperatives; improve road infrastructure and the provision of storage facilities; ensure dehaulming is done before harvesting; ensure foliage dries before harvest	Standardize prices; improve road infrastructure; improve packaging; mobilize farmers to join cooperatives for collective marketing; create consumer lobby groups to advocate for fair prices
Underlying Factors	Geography, soil type; topography; labor-intensive creation of cut-off drains and terraces; inadequate knowledge transfer	Topography; lack of capital for flood control; climate change-related planting delays and increased rainfall intensity	Poor roads; poor drainage systems; economic issues; limited knowledge dissemination on post-harvest handling	Poor infrastructure; climate change-related temperature increases
Dry Spell Consequences	Delayed acquisition of certified seeds and crop management; delayed acquisition of fertilizers and pesticides; lost planting opportunities	Delayed farming practices; increased pest and diseases pressure; positive impacts toward maturity stage; negative impacts during flowering stage	Economic gains due to reduced crop losses, less labor-intensive conditions, lower transportation costs, and avoidance of rotting	Increased buyer access to markets; economic losses due to long storage periods
Magnitude of Impact	Minor-Moderate	Moderate-Major	Moderate	Minor-Major
Farmers' Current Coping Strategies	Purchasing seeds locally; use of farmyard manure and rabbit urine spray	Labor-intensive individual land preparation; use of rabbit urine spray; dehaulming by farmers	Use of casual labor for sorting and grading; individual transport of produce to market; aggregation at the farm gate	Farm-gate sales; cold storage for large processors; a lack of cleaning for small processors; direct purchase from producers
Potential Adaption Options	Promote rainwater harvesting; construct and improve seed storage; upscale indigenous knowledge; practice irrigation; construct water pans; and promote agroforestry	Promote conservation agriculture; build soil structure by manure application; promote indigenous knowledge; discourage dehaulming by farmers	Promote use of graders; promote collective marketing; establish collection centers	Promote collective marketing, the construction of storage facilities, cost efficiency, renewable energy, and aggregation at collection centers
Underlying Factors	Low rainfall; soil type; water retention; economic status; literacy level; limited knowledge of adaptation measures	High temperatures and increased pest occurrence; economic status; availability, accessibility, and affordability of knowledge	Favorable weather conditions; adequate infrastructure or storage; proximity to ready markets	Favorable weather conditions; good road networks; increased tuber preservation costs

Banana

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Moisture Stress Consequences	Low productivity; low yields; low seedling survival; low adoption of tissue culture technology; low organic or inorganic fertilizer adoption; low yields	Untimely preparation and hard pan development; use of low-quality planting; lack of investment in expensive seed; low survival rate; low quantities of poor-quality bunches; delayed maturity period; low income	Lack of transportation demand; tedious transportation methods; farm-gate sales; difficult sorting and grading; reduced sales; exploitation by middlemen; no quality grade for processing	Lack of quality produce to promote; difficult producer-to-market linkages; low adoption of technology and innovation
Magnitude of Impact	Major	Moderate-Major	Major-Severe	Severe
Farmers' Current Coping Strategies	Use of farmyard manure; use of cover crops; sourcing good-quality planting material from certified institutions; sourcing quality fertilizers; subsidies from the government; use of organic pesticides	Use of machinery for deep soil tillage and structure; use of appropriate technologies; adaptation of moisture-conserving methods; use of recommended planting guidelines; fertilizer application	Use of proper handling techniques; use of appropriate equipment and skills during grading and sorting;	Appropriate packaging and marketing techniques; quality analysis of products; collective marketing; collective crop enterprise management; establishment of producer organizations; improved transfer of technology and innovation management practices
Potential Adaption Options	Composting; soil testing and analysis; establishment and strengthening of satellite hardening nurseries; strengthening of research institutions; creation of crop-specific fertilizers; low-residue pesticides	Appropriate tillage, harvesting, and planting techniques; technical capacity building; relevant extension services	Construction of collecting sheds; higher-capacity graders; value addition	Use of appropriate packaging; use of technology, social media platforms, and print media advertisements; establishment of cooperatives; upscaling of technological innovations; use of farm-level management practices
Underlying Factors	Slope; vegetation cover; limited access to extension services; lack of access to land for women	Lack of funds; slope; unsuitable road networks	Lack of knowledge on crop handling during harvesting, transportation, and storage	Marketing organization; inadequate knowledge of sorting and grading; varying sale units
Erosion Risk Consequences	Low fertility; low production; low yields; mineral and nutrient loss	Poor soil workability; low survival rates of plantlets; poor-quality bananas; delayed maturity; low income; limited adoption of technology and innovations	Poor-quality produce; limited high-value marketability; exploitation by middlemen; difficult grading and sorting; a lack of quality grade for processing	A lack of quality produce; reduced activities at the promotion level; weak linkages to buyers
Magnitude of Impact	Major	Major-Severe	Major-Severe	Major
Farmers' Current Coping Strategies	Construction of soil and water conservation structures; use of good-quality planting materials; use of quality manure and low-residue pesticides	Use of machinery for proper tillage; use of planting guidelines; contour planting on slopes; rehabilitation of infrastructure	Improvement of infrastructure; development of cottage industry; capacity building of producer groups	Use of appropriate packaging; formation of producer organizations; transfer of technological innovations, management practices at the farm level
Potential Adaption Options	Construction of conservation structures; enhancement of TC production for consistent and uniform production; composting technologies	Use of proper machinery for tillage; use of contour technology in sloping areas; construction of roads	Creation of collecting sheds; addition of drying equipment infrastructure; value addition; appointment of qualified sorting and grading teams	Use of appropriate technology and advertising; use of cooperatives; upscaling of technology innovations and management practices
Underlying Factors	Slope; low capital and capacity	Land slope and degradation; low capacity for soil and water conservation; inadequate extension services on land use and land management	Eroded roads; low yields	Low-quality produce; reduced bargaining; inadequate adoption of technology and innovations

Chicken (Local)

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Heat Stress Consequences	Increased housing and feed costs; increased need for capital	Decreased productivity; lower brooding costs; improved health status of poultry	Prolonged collection period; increased difficulty with transportation	Lowered production; increased cost of chicken
Magnitude of Impact	Major-Severe	Minor-Moderate	Minor-Moderate	Minor-Moderate
Farmers' Current Coping Strategies	Use of ventilation; use of self-milled feeds	Increased watering; natural brooding	Increased collection at the household level rather than collection centers; use of open rooms with shades; transportation on motorcycles	Individual selling, which affects prices
Potential Adaption Options	Installation of mechanized cooling systems; bulking of feeds for storage at the household level; purchase of mechanical ventilators	Use of vegetables as supplemental feed; use of mechanized heat regulation for brooding; veterinary inspections during heat stress	Improved collection at the household level to prevent breakage of eggs and early brooding; improved cage systems to prevent overcrowding and preserve biosafety; installation of well-ventilated structures on motorcycles and pick-up vans	Formation of cooperatives to ensure a steady supply to the market
Underlying Factors	Lack of capital; inadequate housing infrastructure	Farmers' age, knowledge, and skills	Farmers' gender; farm-scale production	A lack of policy to control pricing; farm-scale of production
Flood Consequences	Increased housing costs; increased feeding cost; increased need for capital	Disrupted delivery of inputs; feed rationing; increased cost of hatching; heightened rates of disease; elevated costs of vaccines and treatments	Delayed collection and transportation	Decreased supply; increased prices; loss of buyers
Magnitude of Impact	Severe	Moderate-Major	Minor-Major	Minor-Severe
Farmers' Current Coping Strategies	Construction of wood and iron cages; use of motorcycles to supply feeds; use of drainage for run-off water	Use of feed rationing; reliance on natural breeding; use of small-scale rearing; use of vets at an individual level	Use of a free-range storage in an open room (whole chickens); use of trays for eggs; use of motorcycles for transport	Increased individual sales; use of bargaining
Potential Adaption Options	Construction of durable climate-proofed cages; purchase of feeds before the onset of rains; construction of raised structures with good drainage	Bulking of feeds; use of mechanical brooding; formation of cooperatives	Adoption of battery cages; improved drainage around storage rooms; use of temperature regulation; requesting improved infrastructure and accessibility in rural areas	Unification of market transportation; government intervention to regulate prices
Underlying Factors	Economic status; farmers' knowledge and skill level	Access to institutional services; ability to improvise equipment and facilities	Land topography; economic status	Scale of production level; pricing

Dairy (Cow)

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Dry Spell Consequences	Negative attitude towards extension; unreliable feed supply, poor-quality feeds; expensive feeds; low conception rates; irregular heat cycles; abortions	Low conception rates; irregular cycles; abortions; unreliable supply of feeds; low production and productivity; decreased fertility of animals; reduced pests and diseases; increased incidence of metabolic diseases	Increased spoilage from high temperatures and dust; low processing amounts; elevated costs of bulking and collection	Avoidance of small-scale farmers by suppliers; high prices; discrimination in some market segments; flooding of markets
Magnitude of Impact	Moderate	Moderate	Moderate	Moderate
Farmers' Current Coping Strategies	Provide village-based advisor; train farmers in breeding; provide free AI services; use on-farm feed formulation and seed conservation	Train farmers in modern breeding technologies; provide training in fodder production, conservation, and homemade feed rations; improve surveillance and control of diseases through vaccination and vector control; train farmers in bio-security measures	Provide training on milk handling techniques; install coolers and pasteurizers in collection centers and processing facilities; use refrigerated trucks	Contract farmers with dairy cooperative societies, traders, and processors; organize farmers in price-setting groups; introduce government price stabilization through KCC
Potential Adaption Options	Use of electronic extension; use of sexed semen and modern breeding technologies; standardization and regulation of the feed industry	Adoption of modern breeding technology; outsourced feed production and conservation; regulation and enforcement of disease control measures; subsidized vaccination costs	Use of on-farm milk testing kits; establishment of milk processing to increase shelf life; use of electronic recording and transmission of milk deliveries to collectors	Establishment of selling points in major shopping centers; enforcement of dairy cooperative society policy, especially a minimum buying price; creation of a price stabilization fund
Underlying Factors	A lack of capital, skills, and knowledge; insufficient access to market information and services	A lack of skills; reduced ability to stock in readiness for dry spells; inadequate access to more productive breeds; insufficient infrastructure such as silage holes, electricity, and water; restricted access to information from meteorological departments	Insufficient access to the right collection and processing equipment; inadequate access to capital to deal with overheads and price fluctuations; low institutional capacity to deal with milk shortages	A lack of policy; uncoordinated markets; slow market growth; poor infrastructure; increased transaction costs; inadequate reserves to mitigate market fluctuations
Excess Rainfall Consequences	Inaccessibility of farms by extension officers; unavailability of farmers for training; inability to obtain feeds due to impassable roads; destruction of farms, causing loss of feeds	Impassability of roads; a lack of security; high levels of bloating and aflatoxin; malnutrition; increased vectors that transmit diseases; increased mastitis and pneumonia cases	Impacted silage processing; increased milk spoilage during transportation and bulking; rejection of milk from small-scale producers in remote areas due to excessive supply	Increased cost of milk delivery; decreased price of milk due to excessive supply
Magnitude of Impact	Moderate	Minor-Moderate	Minor-Moderate	Moderate
Farmers' Current Coping Strategies	Utilization of village-based advisors; fodder conservation; training in breeding; utilization of free AI services	Fodder conservation; disease surveillance and control through vaccination, vector control, and observing biosecurity measures	Installation of coolers and milk pasteurizers; home-based milk preservation in case of delayed milk collection	Group sales to reduce transportation costs; milk collection by processors with better transportation vehicles for poor roads
Potential Adaption Options	Use of e-extension; utilization of feed conservation and formulation; introduction of modern breeding technology such as sexed semen and embryo transfer	Regulation and enforcement of disease control measures; subsidized vaccines	Use of butter fat content in pricing; installation of extended shelf-life plants	Establishment of selling points in major shopping centers; creation of price stabilization fund
Underlying Factors	Proximity to poor road networks; lack of capital; poor enforcement of feed quality standards; mismanagement at the cooperative level	A lack of extension policy implementation ; a lack of knowledge about animal husbandry practices; a lack of income, which limits the implementation of vaccination, feeding, breeding, and disease control measures	Poor road networks and limited electricity	Poor roads; excessive supply; selective enforcement of policies and regulation, affecting small traders

Figure 12: Climate variabilities and adaptation strategies across selected value chains in Kiambu County

5. Policies and strategies on Climate Change

The Kiambu County government, together with the national government, international actors, and non-governmental organizations, works in a collaborative effort to provide interventions and strategies to mitigate the climatic challenges threatening the agricultural sector in the county. The county government aligns all its activities with national government policies, but policies have not always been adapted to fit the county context yet. The Kiambu County Department of Energy and Climate Change is in the process of formulating a climate change policy that will form the basis of all county climate change discussions. Table 1 provides an overview of relevant policies, their goals, and challenges.

Table 1: National policies and strategies targeting climate change adaptation and mitigation

Policy	Year	Policy Objective(s) at the County Level	Interventions for Climate Change Adaptation/Mitigation	Challenges and Policy Gaps
National Climate Policy	2016	Formulating a framework for mainstreaming Kiambu's climate change response	Policies and adaptation plans are being formulated by the county's Department of Energy and Climate Change at the current time	
National Climate Change Action Plan (NCCAP)	2013-2017	Increasing forest cover and rehabilitating degraded lands	Conservation and management of riparian areas Forest rehabilitation, riverine protection, spring protection Construction of dams and water pans in the lowlands	Limited funds to carry out climate change adaptation initiatives
National Climate Change Response Strategy (NCCRS)	2010	Assessing the evidence and impacts of climate change; recommending research and technology	Early warning systems	
Kenya Climate Smart Agriculture Strategy (KCSAS)	2017-2026	Enhancing the adaptive capacity and resilience of farmers	Soil and water conservation Conservation agriculture Drought-tolerant and other improved crop varieties	Some beneficiaries do not practice what they are taught during extension and training sessions
Kenya Climate Smart Agriculture Implementation Framework (KCSAIF)	2018-2027	Reducing the vulnerability of agricultural systems against climate change; reducing greenhouse gas emissions	Use of renewable energy sources (e.g., solar) Cushioning farmers by increasing their adaptive capacity	
Agriculture Sector Development Strategy (ASDS)	2010-2020	Developing sustainable value chains for improved income, employment, food, and nutrition security; prioritized chains include dairy, banana, and local chicken	Participatory Scenario Planning Extension services Provision of agricultural inputs such as seeds.	Low adoption rates of technologies due to financial challenges faced by farmers
The Agricultural Sector Transformation Growth and Strategy (ASTGS)	2019-2029	Launching three knowledge and skills building programs focused on technical and management skills	Boosting household food resilience and increasing agricultural output Increasing the opportunities for small-scale farmers, pastoralists, and fisherfolk	Inadequate strategies and structures to domesticate the national policies to fit the county context
Kenya Vision 2030	2008	Transforming smallholder agriculture from subsistence farming to a more commercially-oriented agricultural sector	County Integrated Development Plan 2018 provides essential linkages for the implementation of vision 2030 flagship projects	

6. Institutional Capacity on Climate Change

Institutional resources and capacity are important considerations for improving farmers' adaptive capacity and climate change resilience because they shape resource use actions and outcomes. In Kiambu County, there are many institutions (the government, the private sector, non-government organizations, community-based organizations) working on issues related to climate change, agriculture, water, or food security. Their interventions include research and extension, early warning systems, capacity building, the provision of technology and technology transfer, enhancing market linkages, offering financial and credit services, the provision of agro-inputs (such as seeds, chicks, fertilizers, pesticides), and disease surveillance. Table 2 presents a sample of institutions that are currently supporting and implementing agricultural interventions in Kiambu County.

Table 2: Institutions that are currently supporting and implementing agricultural interventions in Kiambu County.

Off-Farm Services	Institutions	Specific Interventions in Kiambu	Challenges
Agriculture Research and Extension Services	Department of Agriculture, Livestock, and Irrigation Kenya Agricultural Livestock Research Organization (KALRO)-Tigoni	On-farm demonstrations on new crop and livestock technologies, innovations and management practices Potato research: breeding, agronomy, crop protection, post-harvest storage, food processing, and socio-economics Floriculture: germplasm evaluation, agronomy, crop protection, postharvest handling, and marketing	Poor coordination among organizations leads to duplication and overlap of roles and efforts Deliberate operational planning for climate change is still limited Climate adaptation planning is reactive rather than proactive
	Waruhiu Agricultural Training Centre Alliance for a Green Revolution in Africa (AGRA) ToolkitiSkills	Trainings on good agricultural practices Training village-based advisors Training on organic farming, poultry keeping, kitchen gardens, drip irrigation	
	Department of Water, Environment, and Natural Resources	Rehabilitation of community water schemes Connecting households to piped water Drilling boreholes Constructing additional water harvesting structures (e.g., tanks)	
	Kenya Forestry Service (KFS) Kenya Forest Research Institute (KEFRI) Kijabe Environment Volunteers (KENVO) Institute for Culture and Ecology (ICE)	Promoting conservation Protecting water catchment areas Farm and dry land management Working with community groups and schools to promote the role of culture in environmental and resource management	
	National Environment Management Authority (NEMA)	Promoting sustainable environmental management through integrating environmental considerations into development policies, plans, programs and projects	
	Directorate of Livestock Private Veterinary Officers	AI services Selection of animals suitable to different agroecological zones	
	Kenya Plant Inspectorate Service (KEPHIS)	Improved crop seeds	
	Pest Control Products Board (PCPB)	Pests and disease management	
	KALRO Jomo Kenyatta University of Agriculture and Technology (JKUAT)	Varietal and breed development On farm research trials Production, extension, and technology transfer	

Off-Farm Services	Institutions	Specific Interventions in Kiambu	Challenges
Climate Information Services and Agro-Weather Advisories	Kenya Meteorological Department (KMD)	Weekly bulletins and seasonal weather forecasts in the local language via media channels such as local radio and TV stations, social media platforms like WhatsApp, and short message service (SMS) through phones.	Farmers' cooperative societies and associations are often weak or disorganized with no clear governance structure, leaving farmers susceptible to exploitation by intermediaries
Early warning systems and Participatory Scenario Planning	KMD Agriculture Sector Development Support Program (ASDSP)	Issuing warnings on disasters like mudslides and landslides Supporting the planning of farm activities ASDSP coordinates the participatory scenario planning for March April May (MAM) and October November December (OND) rains advisories and facilitates dissemination of the same to the various value chain actors within the county	
Non-Financial Subsidies	Cheer Up Program	Provides seedlings, manure, and water tanks through donors such as USAID	
	Kiambu County Government	Provides subsidized farm inputs	
	East Africa Seeds Co. Ltd., Kenya Seeds Co. Ltd., OSHA Chemicals, Murphy Chemicals Ltd., Bayer East Africa, Amiran Kenya and AGRA.	Distributing and selling agro-chemicals and other farm inputs Providing training and demonstration on the use of these inputs	
	JKUAT	Supplying tissue culture banana seedlings	
Financial Services (e.g. rural credit schemes)	Agricultural Finance Corporation (AFC)	Providing credit facilities, managerial and technical assistance to individual and farmer groups	
	CARITAS	Providing financing to support on farm and input supply	
	Savings and Credit Cooperative Societies	Providing credit solutions	
	Banks	Providing credit solutions	
	Microfinance	Providing credit solutions	
Market Services, Infrastructure and Linkages	Kenya Dairy Board (KDB) New Kenya Cooperative Creameries (New KCC)	Milk value addition Processing and marketing milk	
	Kenya Meat Commission (KMC)	Meat value addition Providing ready markets Increasing productivity and competitiveness	
	Cheer Up Program	Value addition	
	Africa Harvest Twiga Processors	Banana ripening facility promotion; linking farmers to high-value markets in the city Banana ripening	

7. Synthesis and Outlook

This Climate Risk Profile for Kiambu County focuses on four major value chains, based on their importance to the economy, their productivity characteristics, and their contribution to food security. These value chains are dairy milk, bananas, Irish potatoes, and local chickens. The profile identifies two major climatic hazards that heavily impact each value chain: dry spells and excessive rainfall for dairy; moisture stress and erosion risk for bananas; flood risk and dry spells for Irish potatoes; and heat stress and flooding for local chickens. The consequences of these climatic hazards range from minor to severe across all the stages of production in each value chain, potentially affecting food security and livelihoods, a risk increased by the high likelihood of climatic conditions becoming more severe, according to the future climate scenario analysis.

Adaptation strategies to climate change in Kiambu County have been adopted at a low rate, according to the Household Survey conducted in 2014 by ASDSP. Some adaptation strategies that have been implemented by households include water harvesting (38.8%), soil and water conservation (35.1%), planting trees (34.2%), staggered cropping (30.8%), irrigation (19.9%), and feed conservation and diversification (16.9%). The low rate at which climate change interventions are adopted may be attributed to issues including: low utilization of off-farm services such as extension, poor road infrastructure, land fragmentation, limited credit and insurance, and farmers' alignment with short-term coping strategies rather than with long-term interventions. Combined, these factors increase farmers' susceptibility to climate shocks. Existing knowledge systems are not adequate to cope with recurring climatic hazards.

The county government and other key stakeholders are implementing programs and projects to build farmers' adaptive capacity in order to help them cope with climate stresses and shocks. This process is collaborative, built to ensure shared accountability and sustainability. It is also important to address the lack of connection between these policies and programs. For instance, the county government aligns all its policies and programs with the national government's policies, but it is necessary to national adapt policies to appropriately fit the county context. Another major challenge is the weak coordination between public (state) actors and the private (non-state) actors. The county's new Department of Energy and Climate Change is formulating the Kiambu Climate Change Policy Framework, which will be crucial to improving responses to climate change adaptation and mitigation. This framework will support the integration of climate change adaptation into the county's economic and development policies. Other cross-cutting issues that lead to poor implementation of climate-smart agricultural activities include inadequate financing; the limited capacity of women, the youth, and vulnerable groups to participate; unsustainable natural resource management and utilization; and limited human resource capacity to undertake climate-smart interventions.

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10. Annexes

10.1 Glossary

Absolute poverty rate: The monthly adult-equivalent total-consumption-expenditure per person of these households is less than KSh 3,252 in rural and peri-urban areas and less than Ksh 5,995 in core-urban areas (KNBS, KIHBS. 2015/2016f).

Climate change: refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, which persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external factors such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2018)

Climate hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources (IPCC,2018).

Climate risk: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard (IPCC, 2018)

Climate variability: Variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events (IPCC, 2018)

Food poor: These are persons who are unable to meet their minimum food needs. The monthly adult-equivalent food consumption-expenditure per person of these households is less than KSh 1,954 in rural and peri-urban areas, and less than KSh 2,551 in core-urban areas (KNBS, KIHBS. 2015/2016f).

Gross Domestic Product: This is the total monetary value of commodities and services produced within a specific time period within a county's borders.

Stunted growth: Shows percentage of children between 6 months and under 5 that are stunted. "Stunted growth reflects a process of failure to reach linear growth potential as a result of suboptimal health and/or nutritional conditions. On a population basis, high levels of stunting are associated with poor socioeconomic conditions and increased risk of frequent and early exposure to adverse conditions such as illness and/or inappropriate feeding practices." (WHO, 2015)

Undernourished: percentage of a country's population that consistently has a food intake that is less than a minimum dietary energy consumption required for maintaining health and performing light physical activity. This requirement varies by country; it is calculated by looking at the amount of food available in a country and a measure of inequality in distribution developed using household income and expenditure surveys. The minimum requirement for dietary energy is usually between 1750 and 2030 kilocalories per person per day." (WHO, 2019)

Wasted: showing percentage of children between 6 months and under 5 that are wasted. "Wasting or thinness indicates in most cases a recent and severe process of weight loss, which is often associated with acute starvation and/or severe disease. However, wasting may also be the result of a chronic unfavorable condition. Provided there is no severe food shortage, the prevalence of wasting is usually below 5%, even in poor countries. (...) Lack of evidence of wasting in a population does not imply the absence of current nutritional problems: stunting and other deficits may be present (3)." (WHO, 2019)

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