Kenya County Climate Risk Profile: Kirinyaga County

Highlights

- Agriculture is the largest sector of the economy in Kirinyaga County: 87% of the population earns a living from agriculture, and 72% of households are engaged in the sector.
- Kirinyaga County's agricultural sector is impacted by climatic hazards such as droughts, extreme temperatures, and heavy rainfall.
- Farmers in Kirinyaga County use on-farm adaptation strategies to mitigate their vulnerability to climate hazards, including fodder conservation, water harvesting, soil and water conservation, and irrigation.
- Off-farm adaptation strategies provided by the county government and relevant stakeholders include non-financial subsidies, early warning information, credit and insurance schemes, and others.
- In Kirinyaga County, 76% of male-headed, 74% of female-headed, and 53% of youth-headed households are involved in climate change adaptation strategies (ASDSP, 2014).
- There are various institutions and government agencies working cooperatively on adaptation initiatives in the county.
- The Kirinyaga County Government collaborates with development partners such as the Japan International Cooperation Agency, the Food and Agriculture Organization of the United Nations, and the World Bank on developing adaptation strategies.

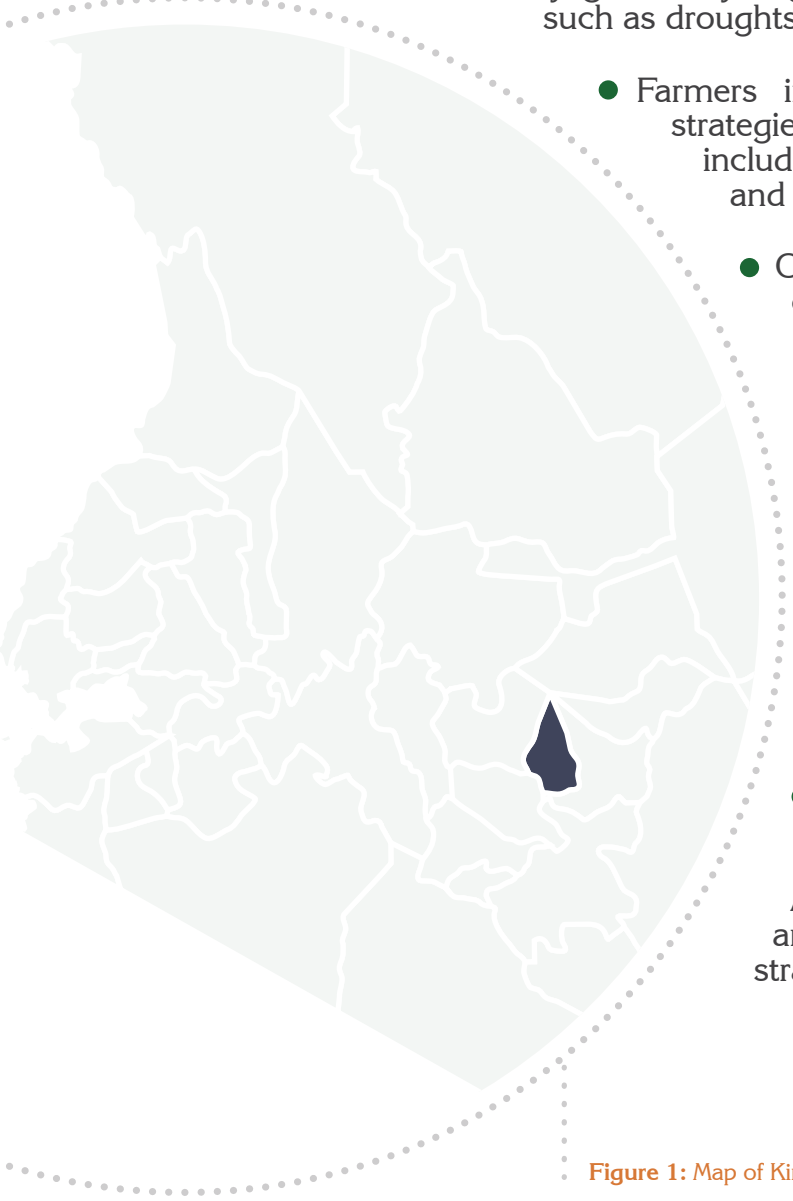

Figure 1: Map of Kirinyaga County

Republic of Kenya

WORLD BANK GROUP

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List of Acronyms

ASDSP- Agricultural Sector Development Support Programme

CDD- Consecutive dry days

CIAT- International Centre for Tropical Agriculture

CIDP- County Integrated Development Plan

GoK-Government of Kenya

IFAD- International Fund for Agricultural Development

IPCC - Intergovernmental Panel on Climate Change

KALRO- Kenya Agricultural and Livestock Research Organization

KEPHIS- Kenya Plant Health Inspectorate

KNBS- Kenya National Bureau of Statistics

LGP-Length of the growing season

NARIGP- National Agricultural and Rural Inclusive Growth

P5D- maximum 5-day running average precipitation

P95- 95th percentile of daily precipitation

PODAGO- Poultry, Dairy, and Goats Cooperative Society

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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1. Introduction

Climate change is becoming one of the most serious challenge to Kenya's achievement of its development goals as described under Vision 2030. Kenya is already extremely susceptible to climate-related events; projections indicate climate impacts are likely to affect the country in the future. In many areas, extreme and variable weather is now the norm. Rainfall is irregular and unpredictable, and some regions experience frequent droughts during the long rainy season or severe floods during the short rains. The arid and semi-arid areas are particularly hard-hit by these extreme changes, putting the lives of millions of households and their social and economic activities at risk.

Kenya Vision 2030 is a national blueprint that seeks to transform Kenya into a newly middle-income country that provides a high quality of life in a safe and secure environment to all its citizens by 2030. The agriculture sector has been identified as one of the key sectors contributing to projected annual national economic growth. However, it has been constrained by inadequate access to quality inputs, marketing inefficiencies, a non-conducive investment environment, declining soil fertility, low mechanization, land fragmentation, 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 highlighted agricultural adaptation priorities. These initiatives are focused on the national level, 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 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 the assessment are to provide information about the current climate and possible future climate scenarios, to pinpoint 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 to deliver adaptation programsThis climate risk profile seeks to inform county governments and stakeholders about climate change risks and opportunities for agriculture so they can integrate these perspectives into county development. This report will help county governments and stakeholders integrate climate change risks and opportunities for local agriculture into county development plans.

The Alliance undertook the assessment in a set of interrelated stages (Figure 2). It first initiated a desk review of the conceptual and analytical context of climate change risks at the 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 also used globally available data sources and collected data from relevant government departments (e.g., Department of Resource Surveys and Remote Sensing (DRSRS), Kenya Meteorological Department (KMD), Drought Monitoring Center, County Development Plans) and data portals (e.g., Kenya Open Data Portal). Data was also collected through focus group discussions, interviews with key informants, climate modeling, and three-day, sub-national stakeholder workshops. The final reports were then presented and validated by national and county level stakeholders.

Figure 2: Stages in developing a climate risk profile

This document presents the Climate Risk Profile for Kirinyaga County. The profile is organized into six sections, each reflecting an essential analytical step in understanding current and potential adaptation options in key local agricultural value chain commodities. The document's first section offers an overview of the agricultural commodities that are key for food security and livelihoods in Kirinyaga, along with presenting major challenges to the development of the agricultural sector in the county. The second section identifies the main climatic hazards based on an analysis of historical climate data and climate projections, including scientific assessment of climate indicators for dry spells, flooding, and heat stress, and other climate hazards for agriculture. The third section analyzes vulnerabilities of the selected value chains to the risks posed by these climate hazards. It continues with a discussion of current and potential on-farm adaptation options and off-farm services. The fourth and fifth sections provide snapshots of the enabling policies and institutional and governance capacity for the adoption of resilience-building strategies. Finally, the sixth section offers pathways for strengthening institutional capacity to address climate risks.

2. County Context

Kirinyaga County is one of the 47 counties in the Republic of Kenya. It is in the central region, and it covers a total area of 1478.1 km^2, of which 308.2 km^2 are under forest cover (County Government of Kirinyaga, 2018). The total land area under agricultural production is 801.7 km^2 (KNBS, 2019a). Kirinyaga County borders Nyeri County to the northwest, Murang'a County to the west, and Embu County to the east and south. The county lies between 0.6591° S, 37.3827° E (County Government of Kirinyaga, 2018). The study area is divided into five administrative sub-counties: Kirinyaga West, Kirinyaga Central, Kirinyaga East, Mwea East, and Mwea West. These are grouped into four constituencies, namely Mwea, Ndia, Kirinyaga Central, and Gichugu. Kirinyaga County is home to 610,411 people (County Government of Kirinyaga, 2018).

Kirinyaga County has three ecological zones: lowland areas, which lie 1158-2000 m above sea level; midland areas, within 2000-3400 m above sea level; and highland areas of 3400-5380 m above sea level. The lowland zone is characterized by gentle rolling plains that cover most of Mwea constituency. The midland zone includes Ndia, Gichugu, and Kirinyaga Central constituencies. The highland zone covers the upper regions of Ndia, Gichugu, and Central constituencies and the whole of the mountain area (County Government of Kirinyaga, 2018).

2.1 Economic Relevance of Farming

Agriculture is one of Kirinyaga County's most important economic sectors. Key enterprises include dairy production, crop production, poultry keeping, and fish farming. Dairy production is the largest agricultural subsector, contributing 14% of the agricultural gross domestic product (GDP) of Kenya, with an annual growth rate of 4.1% (Odero-Waitituh, 2017). Dairy production is widely practiced: 48,488 households (24%) keep exotic cattle, and 55,022 households (27%) keep indigenous cattle (KNBS, 2019a). The total population of dairy cattle in Kirinyaga County is 69,183; their value of production is 3.2 billion Kenyan shillings (KSh)[1] (KNBS, 2015). The main cash crops produced in Kirinyaga County include tea, coffee, rice, bananas, avocados, and horticultural crops. Kirinyaga County is the main producer of rice in Kenya. Food crops include maize, beans, potatoes, sorghum, and cowpeas.

The value of the crops that mainly contribute to the agricultural GDP include coffee (KSh 16 billion), tomatoes (KSh 305 billion), bananas (KSh 2 billion), avocados (KSh 321 million), and potatoes (KSh 44 million). Poultry farming is another a vibrant sector in Kirinyaga County. Egg and meat production contribute also significantly to the economy. There are 762,680 birds in Kirinyaga County, with a production value of KSh 24 billion (KNBS, 2015).

Kirinyaga County has also embraced aquaculture; it has 1,281 fishponds (County Government of Kirinyaga, 2018). In 2014, 23 tons of tilapia and catfish were harvested, an amount valued at KSh 7 million. This was an increase over 2013, when 20 tons were harvested, with a value of KSh 6 million (KNBS, 2015). Fishing is also carried in the town of Sagana, which lies along the Tana River; river fisher folk use hooks to catch fish, primarily tilapia, catfish, and mudfish.

Agriculture contributes to the income of 72% of households, and 87% of the total population depends on the sector to earn a living (County Government of Kirinyaga, 2018). Approximately 68% of all households, or 139,866, practice farming (KNBS, 2019a). Around 32% of the population, or 193,257 people, are employed in the agriculture sector, compared to 4% engaged in wage employment. The area of agricultural land under subsistence farming is 52,890 ha, while the area under commercial farming is 26,670 ha (KNBS, 2019a)

2.2 People and Livelihoods

The population of Kirinyaga County is 610,411 people with an annual growth rate of 1.5%. The population is approximately 49% male and 51% female. The rural population represents about 78% of the total population (KNBS 2019b).

[1] The current currency exchange rate, as of 12/2/2020, stipulates that 1 USD equals KSh 109.50.

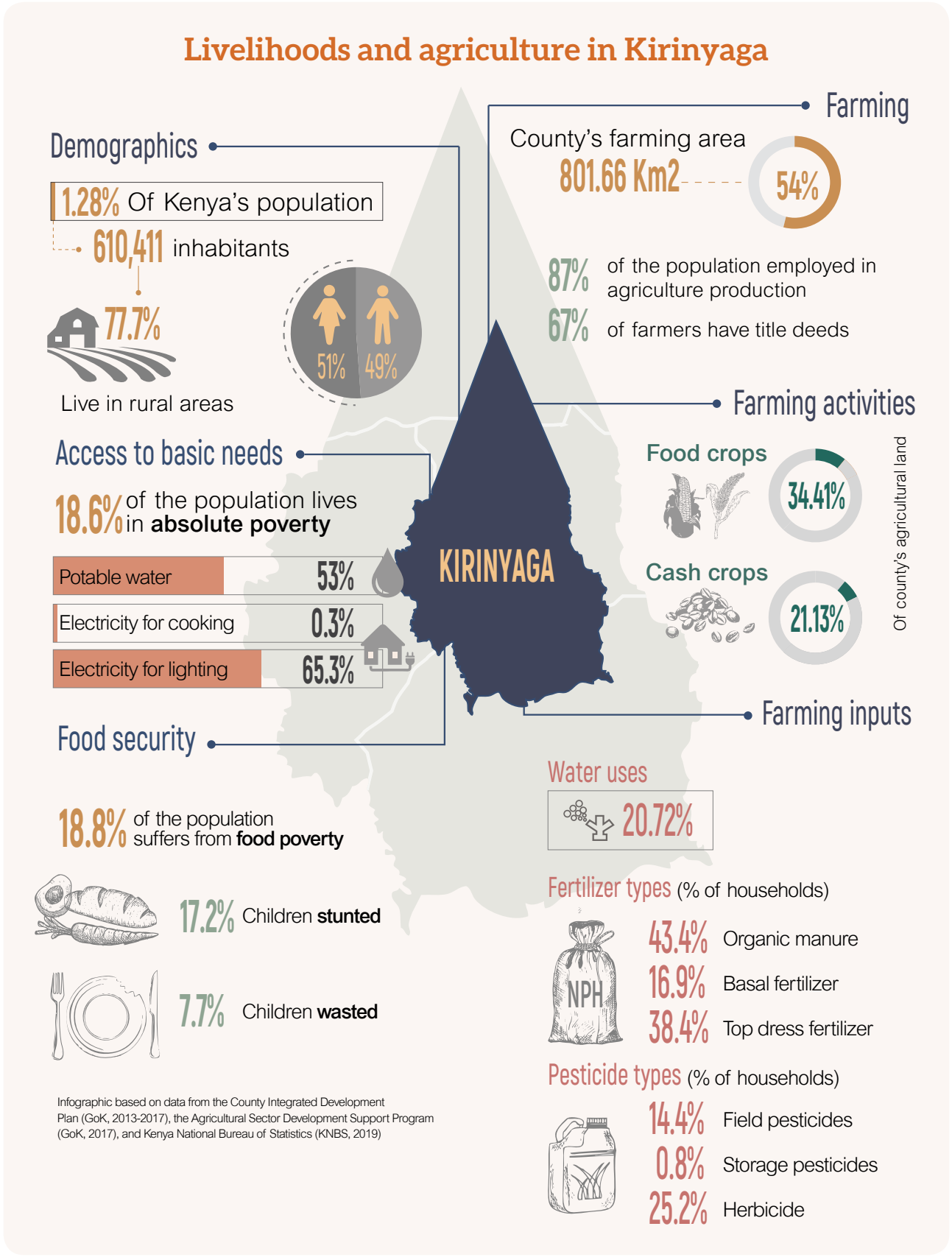

Figure 3: Agriculture and livelihoods in Kirinyaga County

Residents of Kirinyaga County enjoy access to basic necessities such as food, water, and education. Around 19% of the population suffers from absolute poverty while approximately 26% live below the poverty line (US$1.90 a day), and most of these people are rural (KNBS, 2014). The urban population relies on daily wages to make ends meet. In urban areas, 60% of the population is employed in the labor (KNBS, 2019c). In Kirinyaga County, 65% of households have access to electricity for lighting. Electricity is connected to all major urban centers and towns, such as Sagana, Kerugoya, Kutus, Kagumo, and Wang'uru. However, the major sources of energy in Kirinyaga County are firewood, charcoal, and gas. About 65% of households rely on firewood for cooking, while 4% rely on charcoal, and 24% rely on gas.

About 53% of the population has access to potable water (Ngugi, et. al., 2013) The primary water sources in Kirinyaga County the Sagana, Nyamindi, Rupingazi, Thiba, Rwamuthambi, and Ragati rivers. These drain into the Tana River. Additionally, Kirinyaga County has 29 unprotected springs, 208 shallow wells, numerous boreholes, and protected springs. There are also 12 water pans and three dams. The upper parts of the county are endowed with numerous springs which provide good water quality. In the lower parts, fertilizer and pesticide runoff enters important water sources, namely the Thiba and Nyamindi Rivers, compromising water quality. There are 12 established Water Resource User Associations in Kirinyaga County, which are organized along various sub-catchments (County Government of Kirinyaga, 2018)

Food poverty affects almost 19% of the population. The prevalence of stunting in children under five years of age is about 17%, while the prevalence of wasting in children under five years is 4% (KNBS, 2014). Most of the population derives its income from agricultural activities, which account for 72% of household income. Non-agricultural income sources include small retail businesses and casual employment. Crop production is undertaken by 64% of households, and 48% keep livestock. About 4% of households practice fishery (KNBS, 2019a).

2.3 Agricultural Activities

Of the land in Kirinyaga County, 54% is under agriculture; this accounts for 0.8% of the total land area under agriculture in Kenya. The county has 116,980 ha of arable land, or 79% of the county's total land area. Large-scale farms are, on average, 5 ha; small-scale farms are 1 ha, on average. A projected increase in population and land fragmentation due to inheritance patterns are likely to reduce farms sizes in the future. The area under food crop production is 34% of the total land area, while the area under cash crop production is 21% (KNBS, 2019a).

Climate, water availability, and available arable lands all influence farming systems in Kirinyaga County. Its main farming systems are mixed farming, arable farming, subsistence farming, and plantation farming. Within the mixed farming system, intercropping produce with different maturity periods e.g. tea or coffee bushes with avocado trees is quite common. Arable farming, where farmers grow crops on a piece of land designated for vegetables, legumes, grains, etc., is also widespread. Subsistence farmers mostly produce food crops such as maize, beans, and potatoes. Plantation farming involves growing one type of crop (e.g., tea, coffee, rice, or avocadoes) at a large scale for commercial reasons. Plantation farming requires a substantial amount of capital. It mostly occurs in the upper areas of the county, where tea and coffee are cultivated, and in the lower regions, which are given over to rice production (County Government of Kirinyaga, 2018).

About 67% of farmers in Kirinyaga County have title deeds. The lower zones of Mwea East and Mwea West sub-counties fall under the Mwea irrigation scheme; and 23% of farmers carry out farming activities on this land, which is owned by National Irrigation Board. The total area under the irrigation scheme is 12,161 ha. Of this, 8,903 ha are under paddy rice production. The remaining area is utilized for settlement, public utilities, and growing subsistence crops.

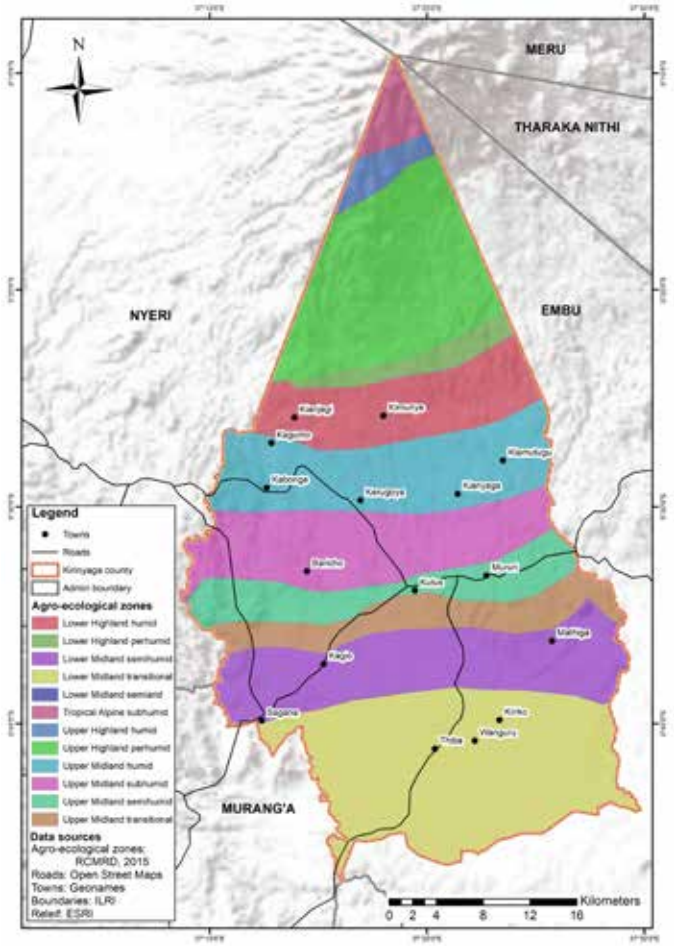

Figure 4: Map of agro ecological zones in Kirinyaga County

Farming in the Kirinyaga County is largely assisted by basin, sprinkler, and furrow irrigation systems. In Mwea sub-county, furrow-and-basin irrigation, which involves flooding water into rice paddies, is common. Furrow-and-sprinkler irrigation is common in Kirinyaga East, while sprinkler irrigation widespread in Kirinyaga West and Central. Kirinyaga County cultivates a wide variety of crops grown under irrigation, including tomatoes, rice, sweet potatoes, onions, French beans, and bananas. Arabicum flowers are also currently grown in Mwea East and West; this crop utilizes overhead irrigation until the flowering stage and then drip or surface irrigation thereafter. The rivers that primarily support irrigation in Kirinyaga County are the Thiba, Tana, Nyamindi, Rwamuthambi, and Ragati.

Horticultural produce is grown under irrigation for domestic use; the surplus is sold in local trading centers by small-scale farmers. Crops like tea, coffee, rice, and avocadoes are commercialized.

Input use in Kirinyaga County is variable: 20% of households use herbicides, 66% apply planting fertilizer, 55% utilize top dressing fertilizer, 55% use organic manure, 22% utilize irrigation water, 19% employ field pesticides, and 13% use storage pesticides (ASDSP, 2014).

2.4 Agricultural Value Chain Commodities

Among the diversity of commodities grown in Kirinyaga County, several are prioritized by the County Integrated Development Plan (CIDP), development programs such as the NARIGP, the Agricultural Sector Development Support Programme (ASDSP), and government institutions such as the Kenya Agricultural and Livestock Research Organization (KALRO). For the development of this profile, a list of the major agricultural value chain commodities (VCCs) in Kisii County was compiled using the following prioritization indicators: productivity characteristics, including harvested area, production, and production variations in the past five years; economic value (KSh); and nutrition characteristics like dietary energy consumption (Kcal/capita/day) and protein, iron, zinc, and vitamin A content. The team presented this list to stakeholders during a three-day workshop for in-depth analysis and selection. We further honed the selection using a set of criteria which were first determined with the stakeholders. The criteria were resilience to current and future climate change impacts, on a scale from low to high; the percentage of population involved in the value chain (%); and involvement in the value chain of economically and socially vulnerable groups such as poor people, women, and youths, again measured on a scale from low to high. First, we assessed each value chain against each criterion. Then, we selected the value chains that involved the highest percentage of the population and engaged poor people, women, and youths. The value chain commodities selected through this stakeholder process are dairy (milk), chicken, banana, avocado, and tomato (Figure 5).[2]

2.4.2 Dairy

Dairy production contributes significantly to the economy: almost 78 million liters of milk produced in Kirinyaga annually, valued at KSh 3 billion (KNBS, 2015). Smallholder farmers who own 0.4-1.2 ha of land (Njonge, 2017) mainly practice dairy farming. Dairy production is high in Kirinyaga East, Kirinyaga West, and Kirinyaga Central sub counties, where farmers keep both exotic and indigenous cattle. Approximately 14% of households' rear exotic dairy cattle and about 13% rear indigenous cattle (KNBS, 2019a). Zero grazing is the main management practice due to land constraints.

For the provision of inputs, farmers and agro-input suppliers are the most important actors. Agro-dealers are located everywhere in Kirinyaga County, making them easily accessible to farmers. Feeding, artificial insemination (AI) services and veterinary services are the principal activities. Feeding entails providing the animals with quality feeds, fodder, and supplemental minerals, feed quality is directly connected to milk production. AI involves farmers, inseminators, and the suppliers of inputs such as liquid nitrogen, necessary for the long-term storage of semen and embryos, and semen. AI is important for the continuity of stock and improvement of breeds. The county veterinary officers provide veterinary services. Other actors include farmers and vaccine and drug suppliers. Veterinary services are essential to maintain proper animal health and prevent diseases.

Production, predominantly by small-scale farmers, is constrained by limited resource endowment in terms of capital, assets, information, and technology. Produce is mainly destined for household consumption. Fodder production and conservation are carried out on farm to lower production costs and guarantee adequate, quality feeds during the dry season.

At the post-harvest stage, key activities include transporting, processing, and bulking. Transporting involves milk distributors, who distribute to retail and commercial customers. Farmers sell to traders who deliver their milk to market centers. Farmers in cooperatives sell their milk to existing producer organizations. These producer organizations then sell to processors via bulking centers, processing plants, and by retailers at milk bars. Transporters, distributors, and retailers play an important role in ensuring the milk reaches the market safely.

Another key activity in the post-harvest stage is milk processing, which involves producer organizations, processors, and retailers such as milk bars. Milk is mostly sold by cooperatives to processors outside

[2] All information discussed in this section results from stakeholder engagement through workshops, interviews and focus group discussions.

Kirinyaga County. Small-scale processors in Kirinyaga County include the Poultry, Dairy, and Goats Cooperative Society (PODAGO), Jufved, Karithathi, and Timisy; Meved Dairy Farm is a typical large-scale processor. PODAGO has over 2,800 members, with a daily milk collection of 5,400 liters currently, compared to daily collection of 25 litres in 2005. This improvement encouraged the county government to provide an additional cooler to the cooperative to support their operations. The average milk production on Meved dairy farm is 20 liters per cow from about 40 cows; the farm produces over 900 liters of milk per day. Processing extends the milk's shelf-life, increases profitability, and reduces post-harvest losses (personal communications).

The market stage involves pricing and selling, promotion, and linking farmers to service providers. Promotion increases awareness of dairy products and their benefits to drive sales. The government, together with processors, non-governmental organizations (NGOs), and farmers, promotes dairy in towns, at market centers, and through media platforms. Linking farmers to service providers might entail putting them in touch with banking institutions and insurance providers for financial support, and with NGOs and government researchers for technological and technical information. This process occurs through stakeholder forums and on field days for producer organizations and the government.

2.4.2 Chicken

Chicken production occurs in all the sub-counties; and 61-80% of the population is engaged in the chicken value chain. Production systems are mainly small-scale and involve rearing both local chickens and improved varieties. The average farm household keeps 3-20 chickens. Around 36% of households' rear indigenous chickens in Kirinyaga County, while 2.3% rear exotic laying chickens and 1% rear exotic chicken broilers (KNBS, 2019a). The poultry population in Kirinyaga County stands at 762,682, and the value of egg production is KSh 25 million.

For the provision of inputs, activities include construction of housing structures and brooders, feed provision, and veterinary services. Proper housing on raised foundations is important to withstand climatic hazards such as flooding. Installation of gas brooders in the housing structures is also necessary to regulate temperature. Most farmers keep free-range chickens, allowing them to roam freely and gather food for themselves. This reduces demand for feeds; consequently, feed suppliers are small-scale. However, feeding increases chickens' growth rate and thus productivity. Many farmers are learning to make their own feeds using raw materials such as whole maize meal. Agro-dealers across the county provide equipment such as feeders, gas brooders, and water basins. Veterinary officers, extension officers, and agro-dealers in the county offer vaccines and antibiotics for the prevention and cure of disease. Hygiene and cleanliness are also important to prevent diseases. Keeping newly arrived chicks warm, called brooding, is essential for their survival. Hatching, or the production of chicks in incubators, is also a notable activity. Incubators are more efficient for large-scale producers than placing eggs under a hen to hatch. Slaughtering live birds is mostly done by farmers at home. The slaughtered birds are then taken to the marketplace directly, or they are stored in deep freezers awaiting transport to the market.

Farmers and middlemen sell the live birds and eggs for income generation. Their produce goes to wholesalers and local retailers such as grocery stores. Eggs are also sold through the Kirinyaga Investment Development Authority, the county organ responsible for promoting and marketing the county's investments. It looks for customers who require regular egg supplies of eggs such as public and private institutions and businesses. Farmers have an additional marketing channel associated with chickens, namely, selling the manure collected from their housing structures.

2.4.3 Bananas

The agro ecological conditions in Kirinyaga County are favorable for banana farming, and the popularity of banana fruits makes them a good cash crop for smallholder farmers. Bananas are a perennial that farmers sometimes intercrop with potatoes, vegetables, or even coffee. Bananas are grown across the whole county, and banana production covers 3,627 ha (KNBS, 2019a). In Kirinyaga County, 36% of households are involved in banana farming. In 2019, they produced 183,479 tons, valued at KSh 2.3 billion (KNBS, 2015). Farmers in Kirinyaga grow Giant Cavendish, Grand Nain, Williams hybrid, and Mkono tembo varieties, among others.

At the input supply stage, the use of organic or inorganic fertilizer is crucial to sustain soil fertility and productivity. These inputs are sold by agro-dealers and manure vendors. Farmers access funds to purchase inputs from financiers such as banks, monetary financial institutions, and group lending. Transporters convey fertilizer to farmers. Suppliers and farmer groups with banana hardening nurseries provide clean and certified planting materials to farmers that are free from diseases and have short maturing periods. Tissue culture banana technology is quite common in Kirinyaga; KALRO, Jomo Kenyatta University of Agriculture and Technology, and Aberdare Technology all have tissue culture labs. Hardening nurseries include Karinga Self-Help Group in Kirinyaga Central, Murindi Self-Help Group in Kirinyaga East, Migombeini in Kirinyaga West, and Murinduko in Mwea East.

Land preparation is key to eradicating perennial weeds. The application of organic or inorganic manure sustains soil fertility and supports harvesting. Agro-

dealers are also involved in on-farm pest advisory services, while extension officers from the Department of Agriculture and private institutions offer extension and advisory services to farmers and farmer groups in Kirinyaga County.

Farmers, transporters, loaders, and off-loaders are all involved in post-harvest activities to ensure timely delivery of produce to the market. Produce is sold locally to markets in Kirinyaga and to urban markets such as Nairobi. Small millers and processors are involved in processing the produce for value addition. Value-added products, such as banana flour used for porridge, are sold to supermarkets, grocery stores, and local retailers. Farmers due to scant promotion of value-added produce do value addition at home. Farmers and retailers are also involved in ripening for value addition for better returns.

Farmers promote their products through self-advertising or are involved in farmer groups such as the Banana Growers Association of Kenya. Of the farmers in Kirinyaga County, 60% are aggregated into marketing groups and associations. Several actors are involved in linking farmers to buyers, including brokers, the media, producer associations such as the Banana Growers Association of Kenya and the Kenya National Farmers Federation. This is important for market promotion, better prices and reducing the supply chain. Information Communication Technology (ICT) has also had a huge impact on farmers' ability to sell produce using mobile money. Farmers receive payment through mobile money transfers then transport their produce directly to buyers, therefore increasing their customer base. Nor do buyers need to be physically present at selling points. Selling occurs through wholesalers, retailers, brokers, and local authorities. About 70% of the wholesalers and retailers are medium-scale, and 30% are large-scale, such as Twiga Foods Ltd. and Meru Greens, whose market is nationwide with plans to expand operations.

2.4.4 Avocadoes

Avocadoes are grown across most of Kirinyaga County. They are a perennial crop and are often intercropped, for example with tea and coffee. The production area of avocadoes covers 816 ha, or 1% of the total area of the county. The total number of households growing avocadoes is only 10%, but 41-60% of agricultural actors in Kirinyaga County are involved in the value chain in some way. In 2019, 12,965 tons of avocadoes were produced, valued at KSh 320 million (County Government of Kirinyaga, 2019). The major varieties grown in Kirinyaga County are Fuerte and Hass avocadoes. These are primarily grown for export and the latter variety is generally preferred because of its outstanding shelf life.

Information sourcing is key for acquiring the right variety of seedlings in terms of quality. Useful information is provided by extension officers, farmer cooperatives such as the Kirinyaga Avocado Growers' Cooperative Society, processors, the Kenya Plant Health Inspectorate Services (KEPHIS) and KALRO. Information is also disseminated through the print and broadcast media, including newspapers, radio and television programs, through short message service (SMS) on mobile phones, and through the internet. Farmers obtain planting materials— in the case of avocadoes, seedlings—from commercial nursery operators and KEPHIS at the low price of about KSh 200; an acre of land will require about 100 seedlings. Organic or inorganic fertilizers provide the crop nutrition requirements and ensure quality and quantity production. Fertilizer is obtained from small-scale suppliers such as agro-dealers who are located all over Kirinyaga County and are easily accessible to local farmers and avocado cooperatives.

Land preparation must adhere to the right time or season for planting. Farmers must design a layout and dig holes strategically for correct spacing. The average small-scale farm size is 1 ha, while the average large-scale farm is 5 ha (County Government of Kirinyaga, 2018). In Kirinyaga, most established avocado trees are rain-fed. Irrigation is, however, required in cases of insufficient rainfall, especially during the flowering stage. An ideal irrigation method would be drip irrigation, where two drip lines are placed along a row of trees and supplied with water from a raised tank; manual irrigation—where individuals carry water using cans and pour on the root area of the tree—is a more labor-intensive option. Mulching is important to allow water retention (Oxfam Organics, 2020). The next activity is planting. With advice from extension officers, farmers mix retained from hole digging with organic or inorganic manure, then replace it in the holes with their seedlings. Harvesting is organized by farmers' cooperatives, which determine the correct harvesting index of size, weight, and quality at the farm level to reduce post-harvest losses. Farmers who are not members of cooperatives sell their produce to middlemen, who collect the harvest at the farms and in turn sell to processors outside Kirinyaga County.

Day laborers are employed to carry out tasks such as harvesting, and cooperatives pay for labor and transportation costs, but these are later deducted from the farmers' earnings when payment is being remitted. The quantity of produce collected is recorded to ensure adherence to appropriate standards and to enforce the cooperative society's agreement with the farmers. The cooperative then gathers all the produce from member farmers and transports it to processors through a procedure known as *bulking*. Bulking is important for three main reasons: cooperatives are granted discounted prices compared to individual farmers, due to the large quantities they handle; bulking encourages proper record keeping and compliance with market requirements; bulking favors organized structures over individual operations by farmers. Bulked avocados are loaded to trucks and transported to Kakuzi and Buyline, both large-scale exporters and processors, for packing. Through the NARIGP, the county government

is planning to establish a pack house and processing plant at the county level. Market linkages occur through cooperative websites and other media platforms as well as through farmers' public meetings.

2.4.5 Tomatoes

In Kirinyaga County, tomato production happens in 19 of 20 sub-counties, covering 1,791 ha. Tomato farms may be small-, medium-, or large-scale, and may use rain-fed systems or irrigation. About 8% of households practice tomato farming (KNBS, 2019a). The share of the population engaged in the value chain, however, is 21-40%. The quantity of production in 2019 was 62,313 tons, valued at KSh 1.6 billion. Most tomato farmers are small-scale (55%); 30% are medium-scale, and large-scale farmers comprise only 15% of the total.

Farmers obtain organic or inorganic fertilizers and pesticides from agro-dealers and manure vendors or producers. Large-scale suppliers include KEPHIS and the Pest Control Products Board. Certified seeds are obtained from agro-dealers all over Kirinyaga County. Using certified seeds helps to ensure high productivity, quality produce, soil fertility management, high returns, and market demand. Manure preparation is done through composting. The recommended rate of application of manure is 5-8 tons/acre (Haifa Group, 2021) Tomato production is a capital-intensive enterprise. Capital is required to buy inputs such as seeds, fertilizers, and pesticides; to pay for labor; and to cover irrigation costs. The price of seeds—12,500 seeds cost about KSh 36,000—is unaffordable to the average farmer according to Ndindiruku Hekima Self Help Group. Financial institutions involved include banks, monetary financial institutions, group lending or table banking and Savings and Credit Cooperative Organizations.

Land preparation, nursery establishment, and transplanting enhance the health of farms and their produce; the use of good-quality seedlings contributes to high productivity and increased returns. Land preparation and planting happen on farms; commercial nursery sites are either local or outside Kirinyaga County. Land preparation and planting involve farmers, agro-dealers, and pesticide spray service providers. The harvesting period determines pricing, which depends on market demand. During the dry season, demand for produce is high and farmers fetch good prices for their produce. From the input stage to the marketing stage, a variety of providers offer extension and advisory services and information to farmers, either on-farm or through platforms such as SMS service and the internet. These providers include the national and county-level government; the private sector, including agro-companies, agro-dealers, NGOs, and community-based organizations; and digital and mainstream media.

Pricing of produce is determined by grading and sorting. Loaders, transporters, and farmers convey produce from the farm to local, regional, and national markets. The standard packaging for tomatoes involves 60 kg crates that sell for KSh 500. However, in the county, 100 kg crates are attracting prices up to KSh 1200, thus maximizing farmers' profits. Currently, there are no processors in Kirinyaga County, but plans are underway to establish a processing plant in Kangai.

Farmers, brokers, middlemen, the digital and mainstream media, buyers, and agro-dealers all engage in promotional activities. Promotion creates market access and raises awareness of produce availability. It takes place in public, open-air markets; through the media; and on-farm through direct sales.

2.5 Agricultural Sector Challenges

Irrigation costs, insufficient knowledge, and pests and diseases are the main challenges to agricultural production. The percentage of households practicing farming is 68% (KNBS, 2019a). Despite Kirinyaga County's current irrigation scheme and its potential for further irrigation, there is still a high dependency on rain-fed agriculture, which makes farmers more vulnerable to weather variability. Livestock disease challenges include foot and mouth disease and the Newcastle diseases.

No adherence to guidelines from agricultural extension officers is a major cause of declining food production in Kirinyaga County. For instance, farmers are encouraged to use 8 kg of 2323 fertilizer to plant 1 kg of maize seed. Some farmers, instead, have been using 1717 fertilizer, which is more expensive and has a lower absorption rate; this drives up the prices of their produce without necessarily adding any benefits. In addition, mismanagement of cooperatives, taking the form of misappropriation of funds or a suboptimal distribution of responsibility, leads to issues such as delayed payments for farmers. Productivity is negatively impacted as many farmers change production to other crops

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 (including flash floods), drought, moisture and heat stress, and the start and length of the growing seasons. The growing season was defined as follows: the first season (long rains) is the 100-day wettest period from January to June, while the second season (short rains) is the 100-day wettest period from July to December (KMD, 2020).

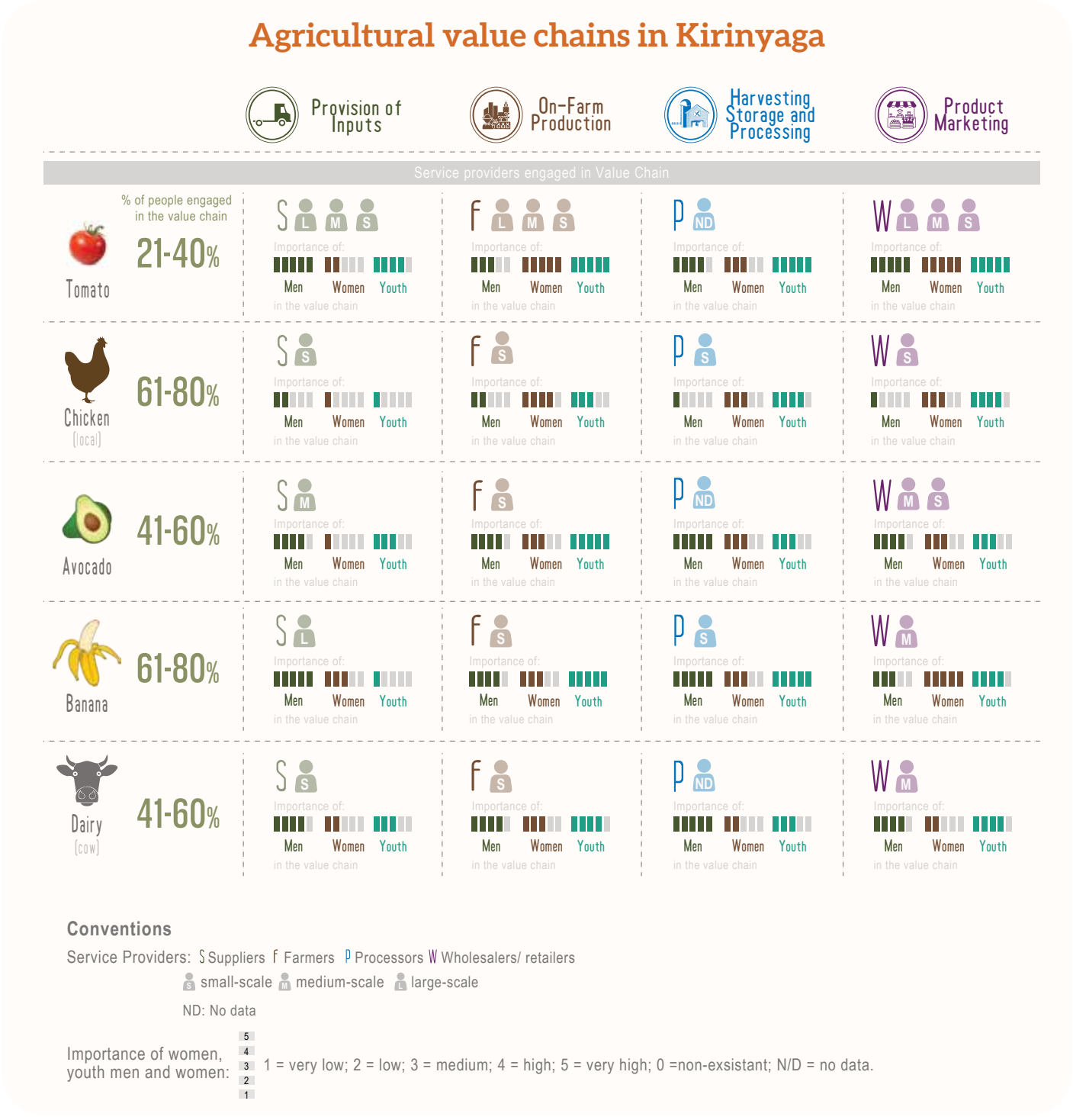

Figure 5: Characterization of the selected value chains in Kirinyaga County

We used Representative Concentration Pathway (RCP) 8.5, one of the four-greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth Assessment Report (AR5) in 2014. Future climate projections were generated based on an ensemble of multiple CMIP5 models (Taylor et al., 2012), using RCP 8.5 for two future periods: 2030 and 2050.[3]

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 using the 5-day running average of rainfall, a measure indicative of floods, and the 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 and was calculated for each pixel.

To assess the degree of adequacy of rainfall and soil moisture 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 soil's water capacity and evapotranspiration to define the number of days that could undergo a level of stress.

Data and information discussed in the following climate change and variability section on historic and future trends is based on our own climate data analysis using the aforementioned approach and data sources.

3.1 Climate Change and Variability: Historic and Future Trends

The annual average precipitation in Kirinyaga County is 700-1400 mm. The higher-altitude northern region receives an annual average precipitation of more than 1200 mm. Both the historical annual average rainfall and temperature show a directional spatial trend with peak values generally appearing in the northern part of the county, following the elevation (Figures 6). The annual average temperature ranges from 10-25°C. The southern part of Kirinyaga County is significantly drier and hotter than the northern part.

The long rain season of March and May is wetter than the short rain season of October and December (Figure 7). Dry spells with less than 50 mm of rainfall occur between June and September. April receives the highest rainfall at more than 250 mm per month (County Government of Kirinyaga, 2018).

The total annual rainfall has decreased since 1985 for the long rainy season. This will continue until 2040 before it increases again. The short rainy seasons sees more precipitation and this will increase in the future (Figure 8). The annual mean temperature trends show an increase of the temperature in the past which will continue in the future until 2060 for both seasons. The long rainy season will remain hotter than the short rainy season (Figure 9).

The number CDD serves as an effective measure of extremely low precipitation and seasonal droughts. In the first rainy season, most of Kirinyaga County historically experienced less than 40 CDD. In the future, Kirinyaga County will see an overall increase of up to 12 CDD, suggesting a more common incidence of drought throughout county. In the second rainy season, most of Kirinyaga County historically experienced less than 60 CDD. In the future, the county will see an overall decrease of up to 24 CDD, suggesting a far lower incidence of drought overall throughout county (Figure 10).

Flood risk is indicated by P5D. In the first rainy season, P5D has historically remained below 50 mm. Future climate projections indicate that P5D will increase, principally in the northern part of Kirinyaga County, by about 20 mm. This increase in the P5D suggests heightened flood risk throughout the county.

The overall 95th percentile of daily precipitation for a season (P95) serves as an indicator of heavy rainfall due to very wet days; it is linked with erosion risk. In the first rainy season, the P95 has historically remained high in the northern regions. Future climate projections indicate that the P95 will slightly increase in these regions and decrease elsewhere (Figure 11).

The total number of days with a maximum temperature greater than or equal to 35°C for a season (NT35) is an indicator of heat stress. In the first rainy season, the NT35 has historically remained low throughout the county, with few days above 35°C. Future climate projections indicate that the NT35 will increase drastically in the lower-elevation, southern regions of Kirinyaga County, suggesting extreme heat events in the season that could last up to 2-3 weeks.

[3]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.

Moisture stress is estimated by counting the number of days with a ratio of actual to potential evapotranspiration below 0.5. This value serves as an indicator of the available soil moisture for plants. Higher values of moisture stress negatively affect the vegetative growth of crops in the growing season. A comparison of historical and future trends indicates that the occurrence of moisture stress is expected to increase across Kirinyaga County from 3 to 7 days. In the future, we expect a more uniform distribution of the stress.

The start of the growing season is determined based on when climatic conditions become suitable for crop growth. Historically, the start of the growing season in Kirinyaga County has varied widely between March and April. However, future climate projections suggest that the start of the growing season in the northern regions will move earlier by a month, while some areas in the southern regions will face delays of up to 10 days. Climate advisory services will become critical to inform farmers about the optimum planting window and avoid crop loss.

The length of the growing season (LGP) is based on the period when climatic conditions are suitable for crop growth. Historically, the LGP in the long rainy season was low for Kirinyaga County. Future climate projects indicate that the LGP will further decrease throughout Kirinyaga County by 4 to 16 days. Shorter-duration crop varieties will help farmers adapt these changes. Climate advisory services will also play a critical role in informing farmers about the earliest planting window.

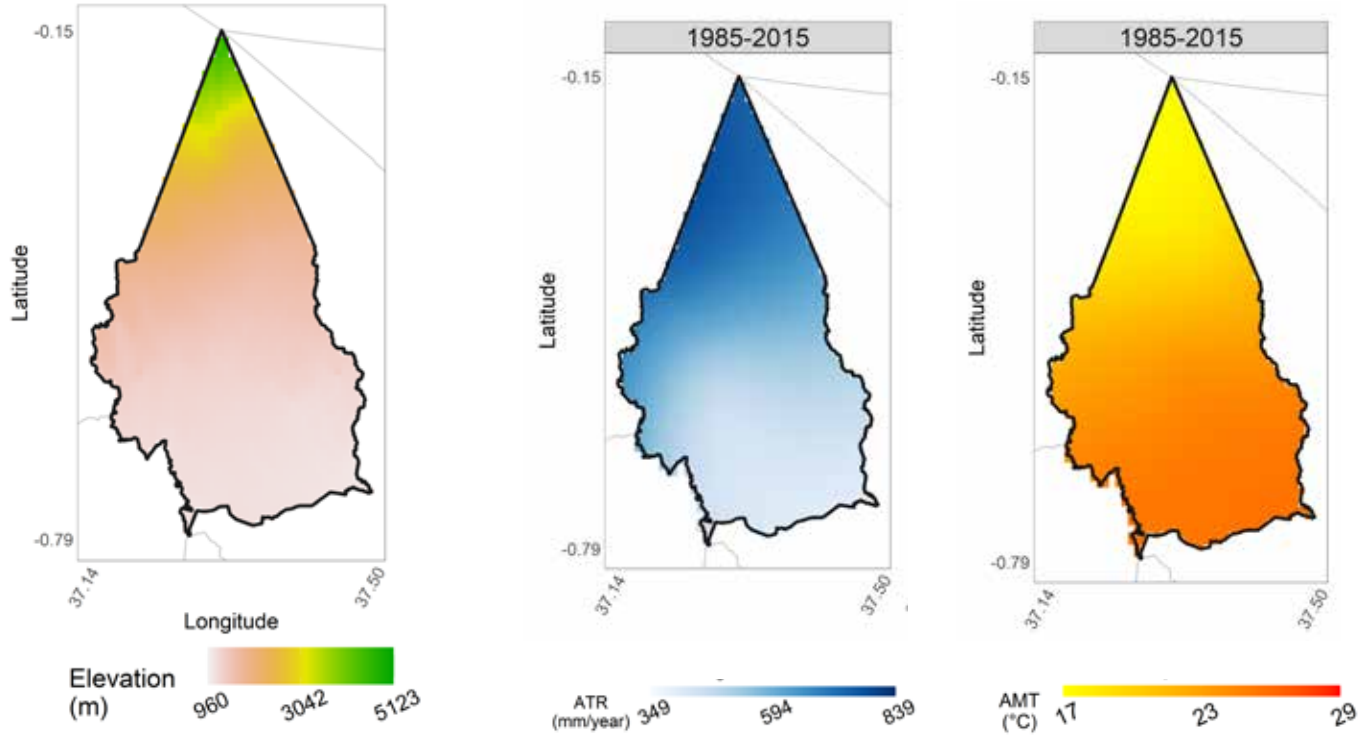

Figure 6: Elevation (left), historical (1985-2015) annual mean precipitation in mm (center), and historical (1985-2015) annual mean temperature in °C (right) for Kirinyaga County for the long rainy season

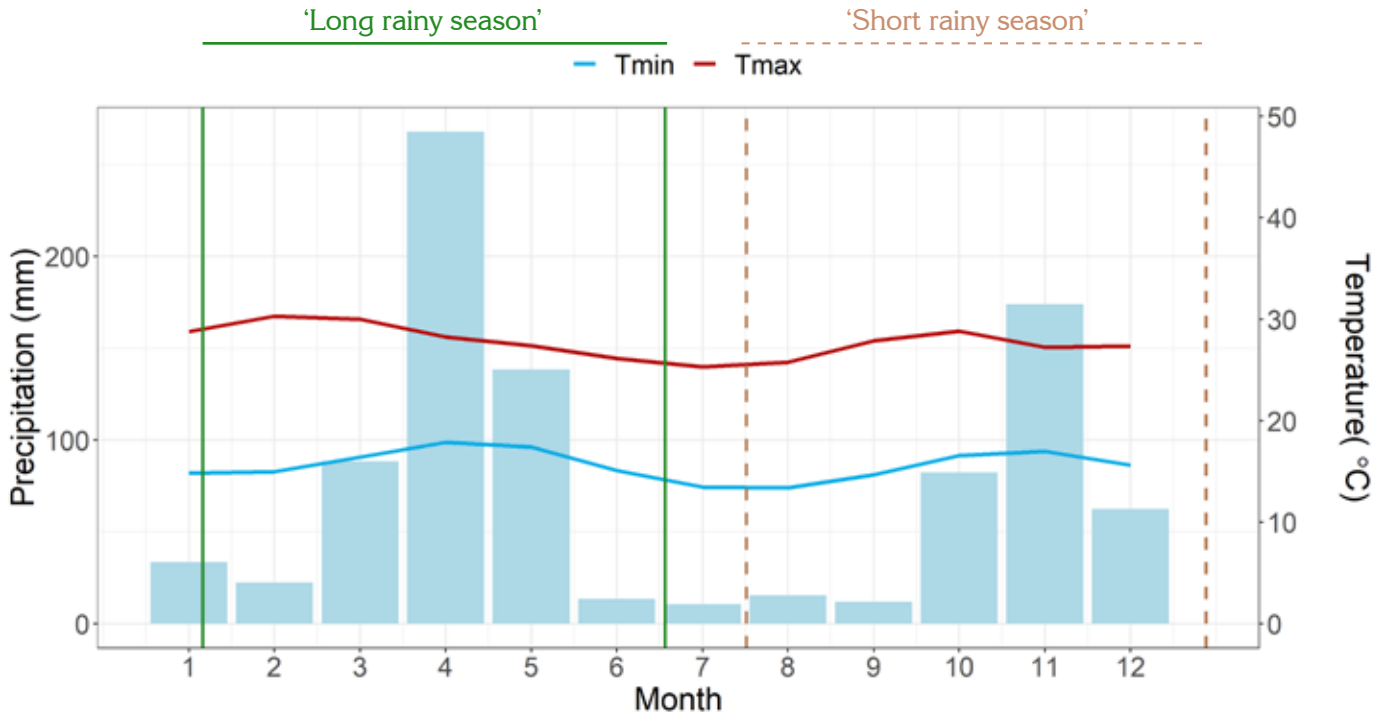

Figure 7: Historical monthly mean temperature and precipitation (average 1985-2015) for Kirinyaga County. The first long rainy season is the 100-day wettest period from January to June, while the second, the short rainy season is the 100-day wettest period from July to December Bars represent total monthly precipitation and lines represent maximum (red) and minimum (blue) monthly mean temperatures

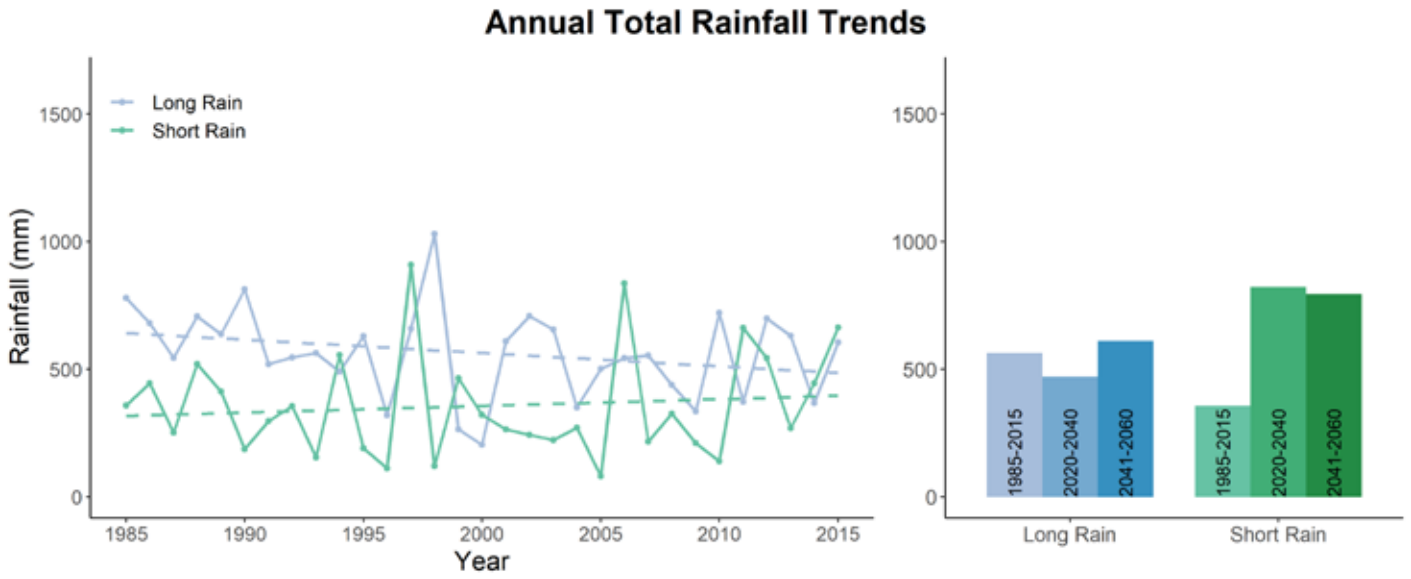

Figure 8: Annual total rainfall trends for the long rainy and short rainy seasons in the past (1985-2015) and in the future (2020-2040 and 2041-2060)

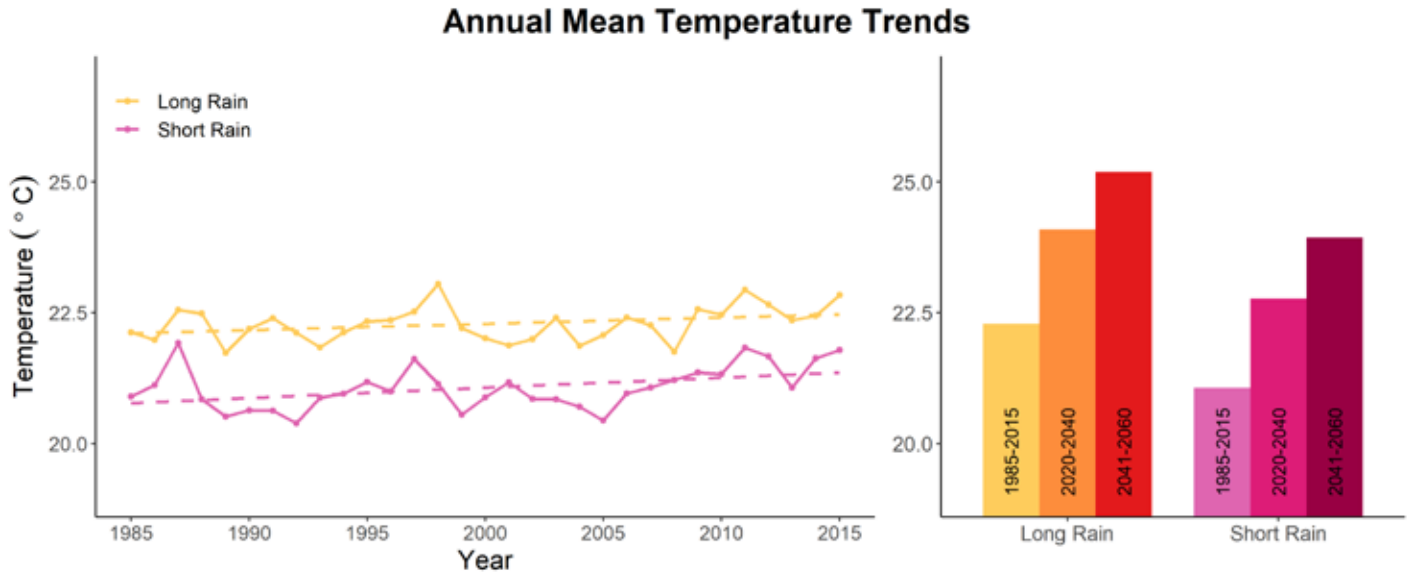

Figure 9: Annual mean temperature trends for the long rainy and short rainy seasons in the past (1985-2015) and in the future (2020-2040 and 2041-2060)

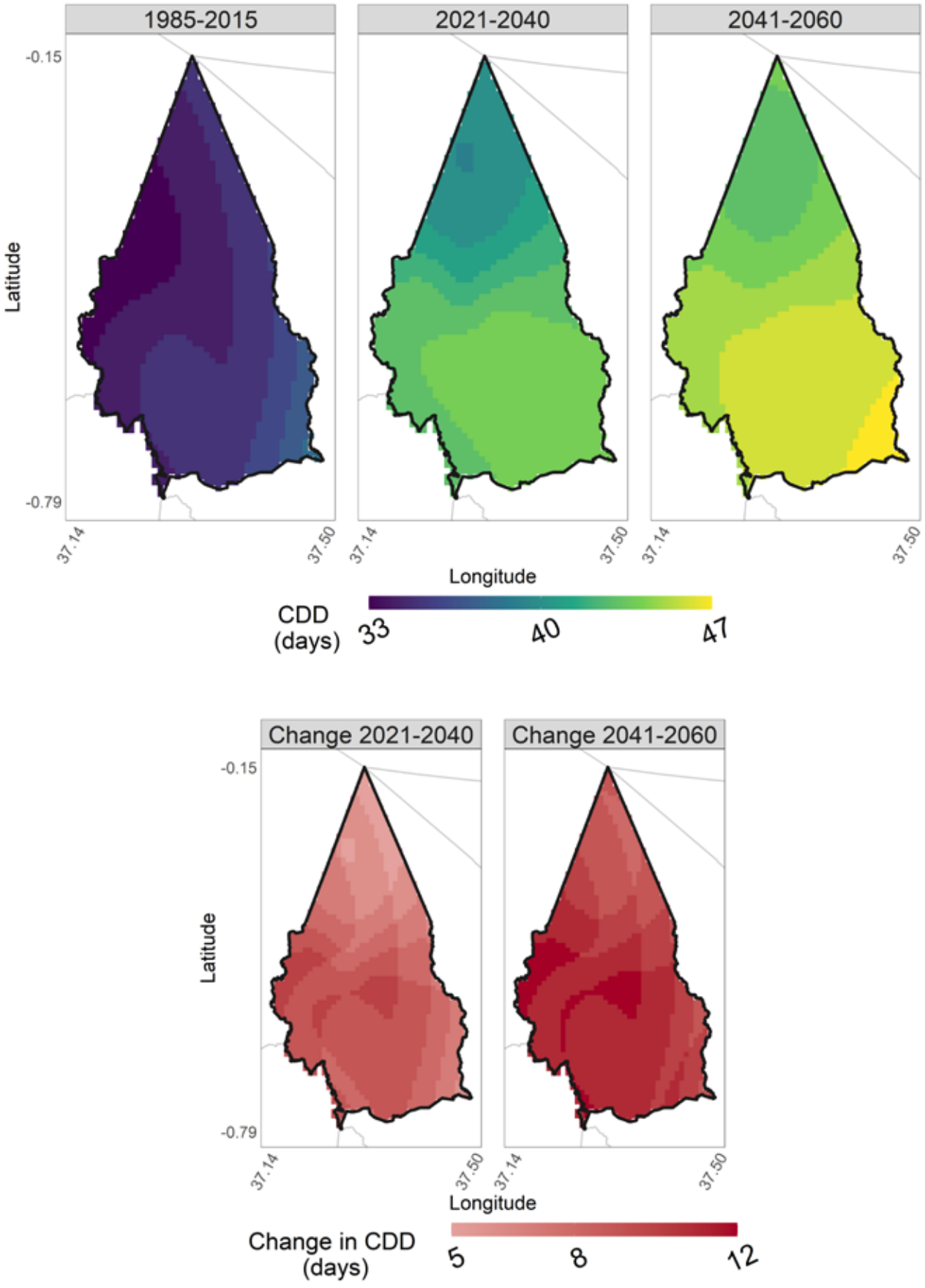

Figure 10: Historical (left, average 1985-2015), future projected (center), and projected change (right) for the number of consecutive dry days for the long rainy season

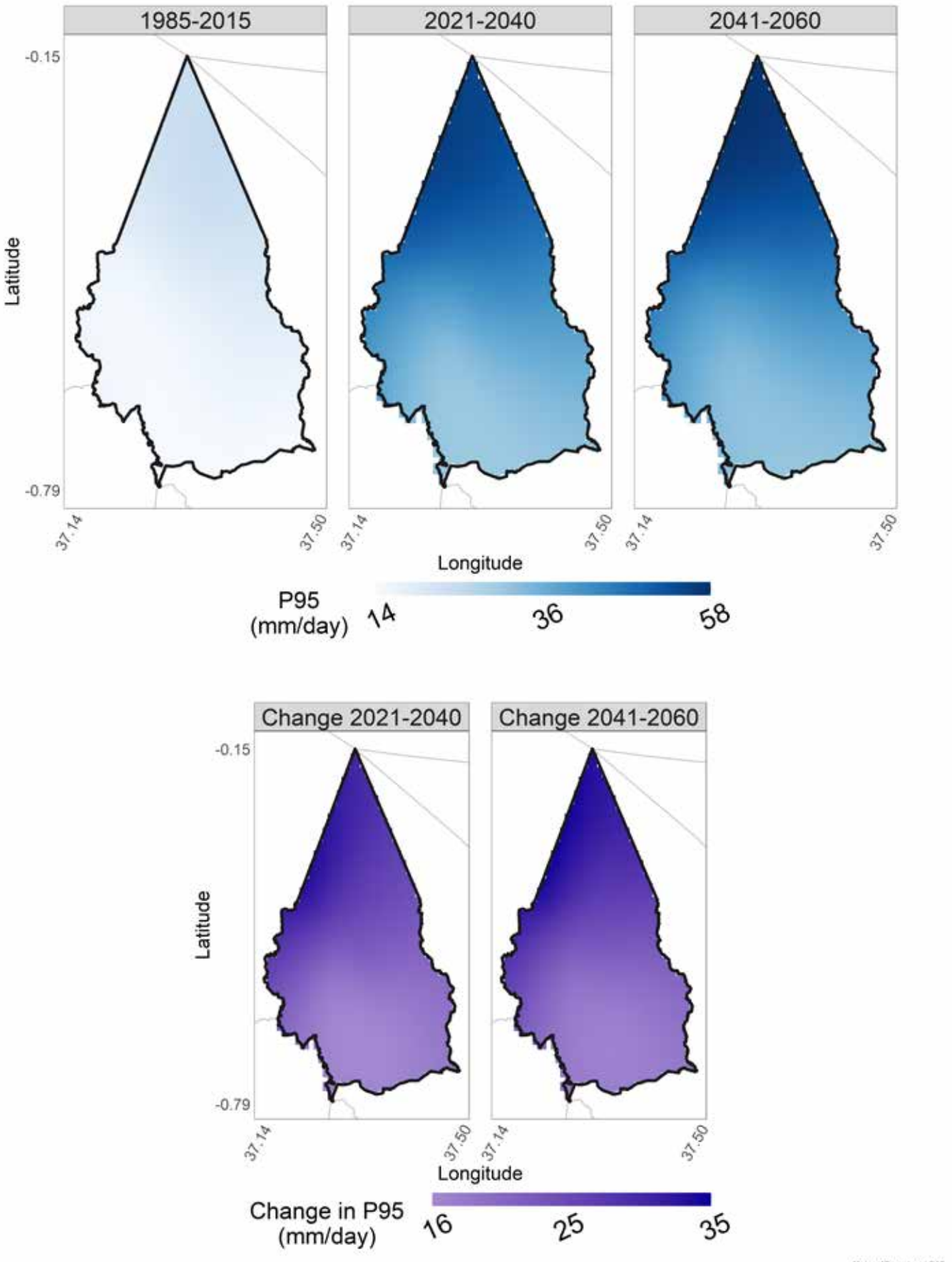

Figure 11: Historical (left, average 1985-2015), future projected (center), and projected change (right) for the 95th percentile of daily precipitation in mm for the short rainy season

3.2 Climate Change from Farmers' Perspectives

Farmers and county experts agree that the climate has changed over time, and factors such as rainfall and temperatures have become erratic and unpredictable. These changes have impacted the production of agricultural commodities, and farmers understand the necessity off focusing on climate change issues.

Erratic rainfall patterns have disrupted the planting seasons. Most farmers in Kirinyaga County depend on rain-fed agriculture and can only plant at the start of the rainy season. The long rains historically began in March and ran through May while the short rains started October and ended December, but this is changing and in some instances the onset of the rains might happen later. In some cases, heavy rainfall results in flooding, which leads to the destruction of farm structures. A discussion with the Kirinyaga Avocado Growers Cooperative Society revealed that heavy rainfall and flooding are major hazards to the avocado value chain. Avocado seedlings rot in stagnant water. Heavy rainfall also affects the flowering of the avocado tree. Another avocado farmers' group stated that hailstorms in January of 2020 had adverse effects on avocado fruits and leaves that meant low-quality produce. The use of inputs such as organic manure, fertilizers, and pesticides during periods of heavy rainfall is difficult because surface run-off washes these inputs away.

High temperatures and heat stress have negative impacts on crop and livestock production, especially in the banana and poultry value chains, leading to low productivity. Extremely low temperatures hinder the production of eggs and the growth rate of chicks, as reported by the Kirwara Pioneer Farmers' Group.

Soils do not retain water during drought periods, and irrigation interventions are, therefore, a promising solution. Most farmers stated, however, that the use of modern irrigation technologies and interventions is expensive.

Farmers also attributed the resurgence and emergence of new pests and diseases to climate change. Pests and diseases such as the *Tuta absoluta* and early blight disease diminish productivity. The cost of interventions is high, however, and very few farmers can afford them. Farmers, especially in the tomato value chain, stated that some pesticides were no longer effective; for instance, pesticides meant to be effective for 14 days would be ineffective after only 7 days, which they attributed to climate change. Pests such as wasps and white flies, meanwhile, affect the avocado value chain; avocado trees also harbor mosquitoes. The use of pesticides and chemicals as interventions to counter pests and diseases, however, is harmful to the environment. It has led to an increase in river pollution because the effluents mostly end up in rivers.

3.3 Climate Vulnerabilities across Agricultural Value Chain Commodities

In addition to the climate hazards affecting Kirinyaga County, in recent times, the county has also been affected by a locust invasion that has posed an unprecedented threat to food security and livelihoods. While mostly reported in Mwea, Ndia and Gichugu, the virulent locusts have destroyed vegetation and crops including nappier grass used to feed dairy cattle. (Kenya News Agency, 2021; FAO,2020).

3.3.1 Dairy

The most significant hazards affecting the dairy value chain are low temperatures and dry spells. At the input supply stage, low temperatures affect the growth of fodder crops, which ultimately leads to decreased milk production. Production costs will increase when farmers must purchase fodder. AI services and breeding are impacted; during periods of low temperatures, very few animals reach "standing heat." Low temperatures also have consequences for post-production activities: processing runs below capacity due to low milk production. Bulking is impacted by the low volumes of milk produced, increasing the operational costs for producer organizations and cooperatives. At the marketing level, the scarcity of milk due to reduced milk production increases pricing due to supply and demand. Because of decreased milk production, most farmers sell in retail, and few people attend the various forums for promotion, which has effects for organizers, NGOs, the government, and producer organizations.

On the other hand, dry spells also have consequences on the different stages of dairy production. At the input supply stage, dry spells affect feeding and fodder production and conservation, potentially resulting in a shortage of fodder crops for livestock. Dry spells also influence the estrus cycle of cows; low conception rates and high demand for AI services increase production costs. Due to poor nutrition during this period, livestock often fall sick, leading to increased demand for veterinary services, thereby increasing production costs. At the post-harvest stage, transporters lose business when there is less milk to transport. Processing runs below capacity due to low milk production, and producer organizations incur high operational costs for transportation when collecting the milk. At the marketing stage, farmers are not linked to financial support services during dry spells due to their decreased capacity to repay loans. Additionally, finances to fund promotional activities are limited, and there is little motivation for promoters.

The locust crisis has also been a hazard for the dairy value chain. The ravenous insects have consumed planted forages resulting to unprecedented low yields and, in turn, reducing farmer's income because of low milk production.

3.3.2 Chicken

The two main climatic hazards impacting the chicken value chain in Kirinyaga County are heat stress and heavy rainfall. Huge losses can occur if measures to combat heat stress are not employed during the construction and operational phases of chicken structures. Farmers can modify these structures to create well-ventilated facilities that can regulate flock temperatures. Heat stress also impacts the choice of equipment used, for example, feeders. Heat stress reduces the uptake of feed, affecting the growth rate of chickens and their production of eggs. Therefore, farmers use equipment that encourages feed intake such as running feeders, pelleting feeds, high-density diets, and continuous lighting programs, which may help offset reduced growth rates. Sales dwindle due to high mortality rates during periods of heat stress.

Heavy rainfall impacts are felt across all stages of chicken production. Heavy rainfall causes flooding, which in turn results in the destruction of structures and the equipment therein. Hygiene in these structures is also affected by the flooding and muddy conditions. During periods of heavy rainfall, suppliers face poor accessibility to farms, so that their supply of equipment may be delayed. In addition, heavy and prolonged rainfall can lead to a delay in veterinary services, reducing the accessibility of drugs and vaccines. Feed quality is reduced, and spoilage may occur. Heavy rainfall can also damage road infrastructure, especially in rural areas, leading to delayed collection, bulking, and the transportation of eggs and live birds from farmers to markets. At the market level, during periods of heavy rainfall, the sale of eggs, live birds, and manure may be more complicated because these products take longer to reach the market due to unpassable roads.

3.3.3 Bananas

Banana production is heavily impacted by excessive rainfall and dry spells. Excessive rainfall leaches nutrients from the soil and reduces the value of organic and inorganic fertilizers. On-farm extension and advisory services are more difficult to provide during periods of excessive rainfall. Activities such as land preparation and harvesting are delayed due to excessive rainfall. Post-harvest infections may also result. Transportation of bananas becomes difficult due to inaccessible roads, and longer periods of storage diminish the quality of the produce. Processing may be delayed, while processing costs may increase due to drying.

Dry spells, on the other hand, affect the planting materials by reducing the quality of seedlings. They cause poor establishment of seedlings on the farms, so farmers must acquire additional seedlings, leading to higher costs. Application of organic or inorganic fertilizers can be delayed due to low soil moisture. Soils do not absorb manure efficiently during dry spells, and droughts cause soil dehydration. At harvesting, delayed maturation of bananas leads to low production and poor-quality bunches.

3.3.4 Avocadoes

Heavy rain and dry spells have consequences for the avocado value chain. Heavy rainfall impacts road infrastructure, limiting access to farm inputs such as organic and inorganic fertilizers, especially in rural areas. Moreover, the application of fertilizers during periods of heavy rainfall can be ineffective because of surface runoff may wash away fertilizer. Unmet contractual obligations adversely affect trade relations, which in turn hinders promotional services.

Droughts also impact avocado production, both positively and negatively. On one hand, during the dry season, farmers have greater access to information because their farms are more easily accessible. On the other, land preparation activities decrease because many farmers are uncertain about the onset of rains. Almost no planting activities are conducted during dry periods; low-quality seedlings yield low-quality produce. Input suppliers see low volumes of business due to farmers' unwillingness to plant during dry spells. Reduced volumes of avocadoes are therefore harvested, and farmers, cooperatives, and buyers are heavily impacted by supply reductions. During dry spells, suboptimal productivity and poor quality produce disrupt bulking activities, reducing sectoral returns. Transporters, meanwhile, lose business due to low production volumes. The linkages between farmers and buyers are compromised due low-quality produce; this can lead to a loss of business, trust, and confidence. Due to low supplies of produce, prices rise. Dry spells make promotion difficult because farmers are unable to meet market expectations. The whole value chain is impacted during dry spells with widespread business losses.

3.3.5 Tomatoes

The two main climatic hazards to tomato production are high temperatures and droughts. During periods of high temperatures, the acquisition of seeds and organic and inorganic fertilizers increases due to crop failure—requiring repeat sowing—and high nutrition demand. Pesticide usage is increased due to the prevalence of pests and diseases. The effects of high temperatures on land preparation, nurseries, and planting are severe: farmers must repeatedly establish nurseries or outsource seedlings from automated, high-tech nurseries. Capital and financing are affected, because farmers alter and reallocate their predetermined budgets due to anticipated high-temperature impacts. Financing requirements are elevated due to high production costs. Tomato production requires extensive knowledge, so it entails high demand for extension and advisory services and information. Harvesting is also impacted by reduced

yields and low-quality produce. Grading and sorting are affected: there are fewer graders, produce is graded lower, and there are substantial post-harvest losses. Without economies of scale transportation costs are high, and fewer trips mean diminished returns for transporters. At the market level, the promotion timeframe takes longer because facilitators must work harder to attract buyers. During these periods, market linkages deteriorate and prices rise due to reduced supply and high demand.

Droughts also have consequences for tomato production. During droughts, less land and nursery preparation takes place, and most farmers opt out of planting. Farmers, input suppliers, and land tillers are severely impacted by this hazard. During droughts, the cost of pest and disease control tends to be high, although the cost of weed control generally falls. Droughts reduce capital investment for low risk-takers and entail greater capital investments for high risk-takers. During post-harvest handling, droughts have major to severe impacts on activities such as grading, sorting, and the transportation of produce. Produce attains poor-quality grades, while collection and bulking activities decrease due to low quantities of produce. Loaders, transporters, and buyers are also acutely affected by droughts.

4. Adaptation to Climate Change and Variability

4.1 Factors Determining Vulnerability to Climate Impacts

There are many factors affect how people are affected by climate change consequences. These include biophysical, social, cultural, economic, institutional, policy, infrastructure, and other factors. Women and youth are more vulnerable to the impacts of climate change than men because of factors like their limited access to resources such as land. Their decision-making capacity on land sustainability issues is, therefore, limited, increasing their vulnerability.

Limited access to funds that would facilitate climate change adaptation interventions such as irrigation usually puts farmers at risk of low production. Insufficient irrigation access also leads to overdependence on rain-fed agriculture, which is becoming a risky venture due to increasing weather unpredictability. Limited funds can also limit farmers' ability to purchase required inputs in time for start of the growing season.

Insufficient or insufficiently developed infrastructure also renders farmers vulnerable to climate change. No major infrastructure (e.g., processing or storage facilities) has been established in Kirinyaga for the post-harvest management of avocadoes and tomatoes.

Institutional challenges also leave farmers vulnerable to climate change consequences. Extension services mostly reach the large- and medium-scale farmers, not small-scale ones. Climate information and technology is not effectively disseminated to all farmers.

4.2 Climate Change Adaptation Options

Kirinyaga County has implemented adaptation strategies and interventions that are key to climate change response coordination. These ongoing adaptation options are helping farmers across the county to cope with changing climatic conditions. There are ongoing efforts toward exploring new potential adaptation options. Some of the resources available in Kirinyaga County to cope with climatic challenges include early warning systems provided by KMD and participatory scenario planning coordinated by the ASDSP and other government departments.

4.2.1 Ongoing Adaptation Practices

One intervention that farmers in Kirinyaga County employ to combat climate change is the conservation of fodder as silage and hay. For example, at the input supply stage, Lucerne fodder grass, is made into silage for use during unfavorable weather conditions. However, at 13% of dairy farmers, implementation of this intervention is still low (ASDSP, 2014). Farmers are also adopting drought-tolerant fodder crops to increase supply during drought conditions. At the county level, the Department of Livestock provides advisory services to farmers to equip them with knowledge about fodder conservation. This effort could be improved by increased coverage and frequency of visits to farmers. The Department of Livestock is instrumental in advising farmers in diversifying their fodder crops and planting drought-tolerant varieties such as Brachiaria.

Farmers have also adopted climate-smart agriculture practices such as rainwater harvesting, irrigation, and soil conservation techniques. These include crop rotation, planting cover crops, practicing conservation tillage, and planting windbreaks. Solar energy is used for water pumps instead of fossil fuels, especially in banana production.

Avocado farmers use agroforestry. They intercrop avocadoes with tea and coffee. Intercropping has long demonstrated the potential to mitigate the impacts of climate change. For instance, agroforestry enhances local climate conditions and improves soil fertility, while also reducing human impacts on natural forests (Mbow Cheikh et al., 2014).

4.2.2 Potential Adaptation Practices

One potential adaptation option is the promotion of input subsidy programs. The county government should invest heavily in the provision of agro-inputs, like certified seeds and fertilizers, to farmers to boost their yields. Existing programs assist farmers, particularly women, youth, and the poor, to carry out farming activities fewer financial constraints on acquiring inputs. The government can also assist in the revision of taxation policy on agro-inputs, as higher prices for inputs inhibit farmers from planting in time.

Contract farming is another potential adaptation practice that can cushion farmers from climate change impacts. In contract farming, farmers and processing or marketing firms reach a contractual agreement regarding production and supply of agricultural products at predetermined prices. This relieves farmers of the necessity of negotiating with buyers or middlemen.

Proper timing of harvests to meet the transport and market thresholds can set farmers in Kirinyaga at a great advantage. Farmers are encouraged to fully utilize the available climate information and weather advisories to make informed decisions. Agro-input dealers can also be included in climate discussions to empower them as another source of timely information for farmers.

Irrigation technologies have the potential to boost agricultural production in areas that receive little rainfall, such as Mwea. However, most farmers reported that irrigation interventions are costly and eventually impact the price of commodities. Therefore, irrigation options, such as solar-powered irrigation, should be adopted to save on production cost.

Other potential adaptation practices include use of appropriate cultivars in designated agro ecological zones, investing in crop insurance, and scaling up value addition facilities to minimize post-harvest losses and improve gains from selling the final products.

To control and contain the locusts, it is important to strengthen early warning systems for locust invasion, to bolster the surveillance capacity as well as have the necessary equipment and staff for aerial and ground spraying of chemicals.

Adaptation strategies used in selected value chains in Kirinyaga County

Tomato

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
High Temperature Consequences	Increased pest and disease prevalence; increased usage of seeds, seedlings, fertilizers, and pesticides; repeated procurements because of crop failure; heightened crop nutrition requirements; alteration or relocation of predetermined farm budgets; high financing requirements due to high production costs; high demand for extension or advisory services and information	Repeated nursery establishment; outsourcing of seedlings from automated hi-tech nurseries; use of more pesticides and high cost of weed control; reduced yields; low quality; fewer casual workers for harvesting	Poor grades; high post-harvest losses; a lack of economies of scale, leading to high transportation costs; fewer trips, hence lower returns for transporters; high costs of collection and bulking	High promotion costs; poor market linkages; elevated prices due to limited supply and high demand; more time consumed in price negotiations; low returns
Magnitude of Impact	Major-Severe	Severe	Severe	Major-Severe
Farmers' Current Coping Strategies	Increased use of farmyard manure; recycling of own seeds; use of technologies such as homemade traps for Tuta absoluta moth; digital borrowing and group lending; reduced acreage under tomatoes; overreliance on agro-dealers for advisory services; farmer	Outsourcing of seedlings from hi-tech commercial nurseries; greater utilization of farmyard manure; use of ash and charcoal dust to control pathogens; enhanced utilization of granular and foliar fertilizer; adoption of high-yielding and pest-resistant varieties	Poor-grade tomatoes fed to livestock to mitigate wastage or loss; seeds extracted for subsequent nursery establishment; produce sold at throwaway prices or donated to neighbors; heightened use of affordable means of transport such as draught power, tuk tuk, and motorcycles; tomatoes sold individually at local markets, sold at the farm gate, or through middlemen	Reliance on middlemen to source for markets and price negotiations; use of telephone market surveys; tomatoes sold at local markets, at the farm gate, or through middlemen; reliance on middlemen
Potential Adaption Options	Increased use of farmyard manure; broader adoption of integrated pest management (IPM); heightened use of certified seed; investment by the government in input subsidy programs; investment in crop insurance; revision of taxation policy on agro-inputs; enforcement of standards on agrovet ownership and personnel; enhanced adoption of Farmer Field School (FFS) training methodology; implementation of exhibition and field days	Localizing automated hi-tech commercial nurseries within the county; enhancement of soil solarization; increased use of lime PH control; broader adoption of IPM and timely crop rotation techniques; improved soil fertility management; greater utilization of recommended chemicals	Agro-processing to prolong shelf life and add value; use of good agricultural practices (GAP) to minimize poor grades through capacity building; creation of additional common interest groups and farmers' organizations to facilitate transport; formation of additional CIGs and marketing organizations; establishment of aggregation centers; improved market surveys	Establishment of marketing organizations to undertake market sourcing and surveys; creation of information hubs digit and digital marketing platforms; establishment of marketing organizations; enforcement of standard units of measurement in price determination and contract farming
Underlying Factors	Time constraints; strict budgets with limited flexibility; taxation policy that puts agro-inputs out of reach for low- and mid-level farmers	Inability of low- to mid-level farmers to finance farm operations; diseases predominantly impacting farmers in the highlands; pests that primarily challenge lowland farmers; preference for males rather than females to apply agro-chemicals; notion that tomatoes do better in lower zones than in the highlands; provision of extension services mostly to high- and mid-level farmers instead of to low-level farmers	Inability to finance GAP; a lack of infrastructure for post-harvest management, e.g., storage and processing facilities; a dearth of policy post-harvest management of tomatoes; shorter maturation periods in the lower zones than in the upper zone	Insufficient market promotion, surveys, and accessibility; a lack of standardization policy on packaging and units of measurement; charges per crate by the local government in open air markets, unlike at the farm gate, which depress returns for produce sold at open-air markets
Dry Spell Consequences	Reduced use of granular fertilizers; heightened use of foliar fertilizers; diminished use of seeds; high use of pesticides; low capital investment for low risk-takers; high capital investment for high risk-takers; moderated demand for extension and advisory services; greater frequency of visits to farmers who have already invested	Decreased land and nursery preparation; reduced acreage under tomatoes; fewer seedlings procured; high costs for pest and disease control; reduced costs for weed control; diminished yields; reduced employment of harvesters	Poor-quality grades; high post-harvest losses; reduced employment of graders and transporters; high costs for transportation; diminished quantities collected and bulked; depressed returns	High-awareness creation and promotion; Prolonged promotion and price negotiation timeframe; High cost on creating of market sourcing and surveys; High produce prices due to low supply and high demand
Magnitude of Impact	Moderate-Severe	Major-Severe	Major-Severe	Major-Severe
Farmers' Current Coping Strategies	Outsourcing of seedlings; technical knowledge; high use of farmyard manure; reduced acreage under tomatoes; minimal and staggered chemical application; enterprise withdrawal; overreliance on agro-dealers for information; farmer-to-farmer information exchange	Reduced acreage under tomatoes; enterprise withdrawal; enhanced technical knowledge; staggered application of chemicals like pesticides; use of low-cost effective pesticides, IPM, farmyard manure, foliar fertilizers, high-powered pumps that draw water from distant sources, and drought-tolerant varieties	Use of low-cost means of transportation such as draught power, tuk tuk, and boda boda; increased farm-gate selling; reliance on middlemen to buy produce	Reliance on middlemen to promote produce; market sourcing by telephone; selling tomatoes at local open-air markets; overreliance on middlemen to set market prices, so that farmers become price takers as opposed to price negotiators
Potential Adaption Options	Enhanced use of IPM in nursery management; improved soil fertility management through the utilization of farmyard manure; creation of revolving funds to finance enterprises; establishment of additional irrigation schemes; investment in water harvesting and water saving technologies; implementation of additional exhibition and field days; establishment of GAP digital platforms; heightened FFS methodology to disseminate GAP information	Increased use of irrigation technologies like open-field drip irrigation; use of drought-tolerant varieties; enhanced IPM; use of low-cost, effective pesticides; creation of funds to finance input procurement; subsidization of agro-inputs; enhanced use of mulching; improved water harvesting and conservation techniques and greenhouse technology	Improved aggregation centers managed by farmer marketing organizations; formation of marketing organizations and common interest groups; use of additional market surveys	Market organization for product promotion; capacity building in digital marketing; establishment of digital marketing platforms for information sourcing; creation of market organizations and common interest groups; enhancement of market surveys; establishment of digital market information platforms; improvement of contract farming and negotiations; formation of marketing
Underlying Factors	High cost of irrigation equipment; suboptimal technical knowledge about water saving technologies among low- and mid-level farmers; inadequate enforcement of water harvesting guidelines for on-farm production by relevant institutions	High cost of irrigation equipment and pesticides; preference for young males to take care of irrigation	Low economies of scale; dearth of county agro-processing policy to support value addition and extended shelf; norm that tomatoes can only be eaten raw, which precludes the development of value-added tomato products	Inadequate market accessibility and promotion for poor farmers

Banana

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Excess Rainfall Consequences	Leaching of organic and inorganic fertilizers; reduced workability; loss of value; poor attendance and timelines for the uptake of extension messages; leaching of nutrients	Hard soil pans; increased costs; leaching; loss of value; ineffective uptake of extension information and services; delayed harvests; low crop productivity; post-harvest infections	Inaccessible roads; spoilage; reduced quality; delayed delivery; delayed processing; high costs due to drying; delayed ripening due to high humidity and deteriorated quality; reduced consumption as other competitive products gain an advantage	Reduced opportunity due to attenuated audience; delayed market linkages; low access to markets; depressed sales; spoilage of excess product; advantages accruing to other competitive produce in the market
Magnitude of Impact	Moderate-Major	Moderate-Severe	Moderate	Minor-Severe
Farmers' Current Coping Strategies	Improving drainage to reduce leaching; composting; nursery harvesting; use of fodder strips comprised of Bracharia grass; careful and appropriate timing of field operations	Timely farm preparation before the onset of rain; use of zero tillage to reduce hard pans; use of herbicides and mulching; establishment of appropriate cultivators; good crop husbandry practices	Use of motorbikes and oxcarts, plant packaging materials, and solar driers; utilization of hygienic harvest practices; ripening of fully matured bananas; use of ripening chambers	Enhancing the value-addition process; exploring other market linkages; lobbying for additional market outlets; promotion of banana produce; contractual marketing; diversification of the consumption forum; enactment of policy against waste
Potential Adaption Options	Favoring deep-rooted plants to enable recycling of lost nutrients; incorporating nitrogen fixing plants; collective input procurement; use of soil testing kits; use of mass media and information communication technology; increased mechanization of field operations to promote workability; use of weather forecasts to predetermine activities	Increased mechanization; chemical weeding; timely use of weather forecast; promotion of tissue culture bananas; use of appropriate, disease-resistant cultivars	Lobbying for better roads by producer associations; promotion of post-harvest practices for healthy produce; fiber extraction; synchronization of product demand and processing capacity; diversification of value-added products; use of ethylene to enhance ripening	Contractual engagements for producers and buyers; use of information communication technology and media to disseminate market information; increased large-scale, industrial value addition; additional policies to support marketing; exploration of external markets; mobilization of producers into groups and cooperatives
Underlying Factors	Physical terrain; poverty among farmers; knowledge about inputs; farmers' use of information communication technology such as the internet or social media	Poor and less empowered farmers; low capacity building of producers	Poor roads that make it difficult to transport produce to markets; inadequate skills, capacity, and equipment for value addition; the high cost of ripening chambers; challenges in determining who is able to undertake certain activities; traditional use of cultivars for dowry events	Poverty among farmers; opinion that bananas are a traditional food, which poses challenges for promotion and acceptability; market-oriented policies on bananas that provide an enabling environment for banana sales
Dry Spell Consequences	Delayed ordering and application of inputs; low demand	Effective operation capacity readily available; delayed fertilizer application and poor uptake; soil caking; soil dehydration; delayed maturation; low production; poor-quality bananas	Transportation made easier; timelier ripening, processing, and delivery; sun scorching; favorable weather; reduced cost for drying; reduced access to produce for ripening; lower quality produce	Timely promotion; increased market linkages; unmet quality requirements; low sales volumes; elevated prices due to high demand; produce shortages; diminished quality
Magnitude of Impact	Minor-Major	Minor-Severe	Minor	Minor-Severe
Farmers' Current Coping Strategies	Synchronization of stocking levels with demand; use of alternative products like foliar fertilizer; use of irrigation to cope with plants' needs; use of hardening nurseries; agro-dealers associations	Effective farm operation; use of irrigation from water harvesting sources, as well as of manure and fertilizer; mulching	Bagging; use of plant-based packaging materials; controlling temperatures through ripening rooms with adjustable ventilators; forming and mobilizing	Market agreements to protect produce procurers; agreements and linkages with suppliers; linkages to best offers despite the low volumes sought
Potential Adaption Options	Promotional pricing; use of weather forecasts by agro-dealers before stocking for a season; establishment of hardening nurseries in every sub-county; mobilization of agro-dealers to work with producers and jointly use weather	Establishment of wind cover trees around crop fields; use of fertigation and drip irrigation for effective fertilizer uptake; solar irrigation and drip irrigation	Establishment of shaded collection centers in marketing; introduction of reusable packing material; creation of investment policies; innovation assisted by the Kenya Industrial Research and Development Institute (KIRDI) to design a controlled ripening chamber; proper timing of the harvest regime to meet the transport and market threshold	Marketing models to synchronize the quality and quantity of produce demanded; market fixed terms; market benefits for the producer export market
Underlying Factors	Inability of poor farmers to maintain seedlings before field planting – even though tissue culture laboratories enable those with funds to access seedlings	Inability of poor farmers to implement irrigation strategies that sustain crop production	Inability of poor farmers to access adequate storage facilities, processing, value addition equipment, and facilities and collection centers; inadequate availability of farmers' groups and associations to strategize and lobby for better markets	Low access to cooperative movements and self-help groups; poor market access; a lack of policies to protect the produce market during dry spells by

Chicken

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Heat Stress Consequences	Low production and growth rate due to poor housing design and materials; deteriorated quality of feeds; veterinary drugs and vaccines liable to deteriorate faster	Diminished production and growth rate due to reduced uptake of feeds; declining workmanship due to uncomfortable conditions; deterioration of farm hygiene leading to a high accumulation of ammonia; lessened hatchability	Deterioration of egg quality; stress on live birds that can lead to low production and death; depressed meat quality	Reduced sales due to mortality; depressed sales of eggs due to low quality; diminished quality of manure
Magnitude of Impact	Minor-Major	Moderate-Severe	Minor-Severe	Minor-Major
Farmers' Current Coping Strategies	Use of locally available materials to construct chicken houses; feeding chickens on farm produce such as cereals and kitchen leftovers; use of technical knowledge such as certain applications of use of aloe vera and pepper	Use of free-range chicken rearing system; selection of capable brooding chickens	Storage of eggs in locally available containers with soft cloth material or grass; use of locally made clips; slaughtering when the sun is not out; storage by hanging in kitchens	Transportation of chickens to markets using locally made, aerated clips; proper storage of eggs in available containers with soft cloth or fibers; hipping of chicken manure in the shade
Potential Adaption Options	Use of well-designed, well-ventilated poultry houses; training farmers about homemade chicken feeds and good storage; utilizing veterinary services; procurement of the correct vaccines and drugs from reliable sources	Use of boosters like multivitamins; implementation of hygienic measure like foot baths, good sighting of poultry houses, and use of washable materials like plastic; use of incubators to regulate temperatures for good hatchery and brooding	Use of modern technology for storage like trays and fridges to safeguard the eggs; transport with modern vans and carriers featuring good nutrition and cooling systems; construction of slaughterhouses with refrigeration; maintenance of hygiene and cleanliness during slaughtering	Transport using modern facilities with aeration and cooling facilities; value-addition strategies at home such as on-farm slaughter; establishment of chicken processing plants; use of modern technologies to store the eggs in trays and crates; establishment of modern egg storage with a cooling facility; training in composting and the use of digesters
Underlying Factors	Poverty among farmers; insufficient access to proper chicken house designs	Difficult working conditions under high heat stress; high costs to moderate temperatures and improve hatchability and feed intake	A lack of guidelines about the conditions of transportation for live birds; a lack of slaughterhouses equipped with necessary facilities	Insufficient access to good transportation facilities; a lack of guidelines for market institutions; inadequate access to cooperatives
Heavy Rainfall Consequences	Flooding and destruction of chicken houses; delayed supply of equipment due to poor accessibility; delayed veterinary services; reduced availability of drugs and vaccines	Spoilage of feed due to aflatoxins; reduced hygiene in chicken houses due to flooding and muddy conditions; low hatchability of eggs	Delayed collection and transportation of eggs due to poor accessibility; delayed collection and transportation of birds due to poor accessibility; reduced slaughter	Reduced sales of live birds and eggs due to poor market accessibility; diminished sales of manure due to poor quality
Magnitude of Impact	Minor-Severe	Moderate-Major	Minor-Severe	Minor-Major
Farmers' Current Coping Strategies	Construction of high, raised housing; homemade equipment using available and unused containers; use technical knowledge, e.g., about herb trees	Feeding chicken with kitchen leftovers and animal produce direct from store or farms; free-range rearing; use of available litters and ash; installation of wooden shelves; establishment of incubation sites in kitchens where it is warm, or on soft clothing that increases warmth	Use of alternative means of transport, e.g., walking, donkeys, and oxen	Use of alternative means of transporting live birds to market; hipping the manure under shade, e.g., covered with banana leaves
Potential Adaption Options	Construction of well-designed, flood-proof chicken houses with high floors; procuring equipment in good time; planning vaccination and drug administration before the rainy season	Construction of modern storage facilities to ensure feeds are kept in good condition; construction of well-designed chicken houses with sighting to avoid the occurrence of flooding; construction of incubators to regulate temperatures and ensure good hatchery during low temperatures	Establishment of accessible aggregation centers for the collection of eggs; establishment of accessible cool rooms to store slaughtered birds; use of weather forecasts to plan the slaughter	Establishment of cooling facilities for the storage of meat; value addition through slaughtering on the farm, followed by storage in refrigerators; establishment of an egg aggregation center for storage; using participatory scenario planning in order to store manure
Underlying Factors	Inability of poor farmers to afford good chicken housing; differential impacts, worse for people living in lower zones than in upper zones; a lack of access to good road networks	Disadvantages especially for people living in lower zones; high costs of specialized equipment to regulate temperatures and construct adequate feed storage facilities	A lack of access to good road networks and to markets; a lack of cooperatives and other organized marketing groups	Far-flung locations of small-scale farmers; negative impacts for buyers and traders purchasing from farmers at high prices

Avocado	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Heavy Rainfall Consequences	Poor accessibility of information; damage to road infrastructure, affecting the flow of required agronomical information; low accessibility of the centralized nursery system; poor accessibility of organic and inorganic fertilizers due to impassable road networks; obstacles to transportation and technical support services	Poor workability on farms; delayed or displaced harvesting heavily affected by heavy rainfall	Inaccessible farms due to damaged road infrastructure; low volumes of produce, leading to loss of business; delayed delivery due to adversely affected infrastructure	Emergence of middlemen due to poor farmer-buyer linkages; depressed prices as uncertain market result in desperate disposal of perishable avocadoes; hindered promotion services as trade relations suffer strain from unmet contractual obligations
Magnitude of Impact	Severe	Major-Severe	Major-Severe	Severe
Farmers' Current Coping Strategies	Use of broadcast, print, and digital media, such as radio shows and WhatsApp; use of smaller transport options like motorcycles and tuk tuk; mixed farming, such as avocado production and animal rearing, to produce organic manure on site	Sustainable land management; use of drainage to improve soil workability; crude timing to plant before rains; crude timing to harvest when not raining	Use of local non-motorized transport like animal carts; Formation of farmers' cooperatives to aggregate produce; exploration of the local market	Selling to licensed exporters; partnering with the licensed exporters for stable prices or reliable markets; partnering with the licensed exporters for consistent market access
Potential Adaption Options	Consultation with the cooperative's in-house agronomist for advice about recommended seedlings, fertilizers, and agrochemicals; empowerment of the cooperative society and its members to own certified avocado nurseries; bulk procurement of fertilizer by cooperative societies to distribute to farmers	Use of mechanization, e.g., handheld soil augers, to enable farmers to plant even during harsh weather; mechanization of harvesting activities; use of protective clothing to guard against harsh weather	Mechanization to access farms ; scaling up the area under avocado production; use of all-weather means of transport such as rail or air transport	The avocado cooperative society to have their own pack house and direct market channel to the international market; Value addition of avocado e.g processing extraction of avocado oil; digitalization of promotion of services
Underlying Factors	Uneven infrastructure availability in different areas	Biophysical factors, with drainage and flood-proneness varying across different areas; economic differentials, such that not everyone can afford expensive management practices like drainage systems	Uneven access to good road networks in different areas	Economic inequalities, such that middlemen exploit small-scale, less well-off farmers; a lack of policy or poor implementation of policy to cushion farmers
Dry Spell Consequences	Greater access to information by farmers; diminished quality and inadequate supply of seedlings; Low volumes of business due to unwillingness of farmers to plant during dry spells	Decreased land preparation operations declines due to uncertain rains; lack of planting; low volumes of avocados produced	Low volume of fruit collected; low productivity; poor quality; business losses due to low volumes	Market losses due to low quality and quantity; loss of business trust and confidence; low supply, leading to high prices; inability to meet market expectations
Magnitude of Impact	Minor-Major	Major-Severe	Minor-Severe	Moderate-Major
Farmers' Current Coping Strategies	Use of farmers' barazas to avoid overcrowding; partnering with or sourcing seedlings from certified nurseries; use of crude irrigation methods like watering cans	Rotational farming; drought-resistant crops; diversification of crops to bridge the gap during dry season	Use of low-capacity transportation means, e.g., lorries or pickups; exploration of local market due to low volume, quality, and quantity; diversification of crops to cover harsh conditions	Selling produce as animals feeds such as for pig farming; contractual farming for stable pricing; focus on the local market which has less stringent marketing requirements
Potential Adaption Options	Digitization of extension services; training farmers in the production of certified high-quality seedlings of recommended varieties; installation of irrigation systems at avocado nurseries; installation of drip irrigation systems on farms to provide supplementary water during dry seasons	Installation of water harvesting and irrigation techniques to optimize land preparation and planting and to increase the volumes of harvested fruits; expansion of the area under avocado production	Expansion of the area under avocado production and implementation of water harvesting and irrigation techniques to increase the fruit volumes collected and actualize avocado planting even during the dry season, so that transport business will continue	Capacity building of the cooperative society to enhance quality control and value addition and reduce losses from poor-quality fruits; expansion of the area under avocado production by implementing water harvesting and irrigation techniques so as to enhance the supply of fruits during the dry season; research and development into suitable avocado varieties for the growing area and market tastes and preferences
Underlying Factors	Uneven ability to afford quality seedlings due to low supply and high demand; differential access to water infrastructure for better quality seedlings	Uneven ability to afford expensive irrigations systems	Differential ability to manage Integrated Pest Management (IPM) operators and achieve better quality and quantity	Uneven institutional and business relationships with the market and consumers that enable farmers to keep their business

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

5. Policies and Strategies on Climate Change

The government of Kirinyaga County is working with the national government, international actors, and non-governmental organizations, in an effort to provide interventions and strategies that mitigate the climatic challenges facing the agricultural sector in the county. The county government aligns all its activities with national government policies. It is in the process of developing a climate change framework that will form the basis of climate change interventions and improvement plans within county government departments. Table 1 shows the national policies that have been adopted by the county, the activities at the county that are aligned with these policies, and the challenges affecting their implementation.

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

Policy	Year	Policy Objective(s) at the County Level	Climate Change Adaptation and Mitigation Interventions	Challenges and Policy Gaps
National Climate Change Framework Policy	2016	The county is in the process of formulating a framework for mainstreaming its climate change response.	Establishing an environmental and social safeguard office to coordinate environmental matters Forming a climate change unit and training its officers	Limited funds to carry out climate change adaptation initiatives Some beneficiaries do not practice what they are taught during extension and training session Low adoption rates of proposed adaptations due to financial challenges Inadequate strategies and structures to domesticate the national policies to fit the county context
National Climate Change Action Plan	2013-2017	Increasing forest cover Rehabilitating degraded lands	Conservation and management of riparian areas Forest rehabilitation Riverine and stream protection Construction of dams and water pans in the lowlands	
National Climate Change Response Strategy	2010	Assessing the evidence for and impacts of climate change Recommending research and technology	Early warning systems	
Kenya Climate Smart Agriculture Strategy	2017-2026	Enhancing the adaptive capacity and resilience of farmers	Soil and water conservation Conservation agriculture Introduction of drought-tolerant crops	
Kenya Climate Smart Agriculture Implementation Framework	2018-2027	Reducing the vulnerability of agricultural systems to climate change Reducing greenhouse gas emissions	Use of renewable energy sources Cushioning farmers' adaptive capacity	
Agriculture Sector Development Strategy	2010-2020	Developing sustainable value chains for improved income, employment, food, and nutrition security	Participatory Scenario Planning Extension services Provision of agricultural inputs such as seeds.	
The Agricultural Sector Transformation Growth and Strategy	2019-2029	Launching three knowledge and skills building programs focused on technical and management skills	Increasing the opportunities for small-scale farmers, pastoralists, and fisher folk by boosting household food resilience and increasing agricultural output	
Kenya Vision 2030	2008	Transforming smallholder agriculture from subsistence farming to a more commercially-oriented agricultural sector	The Kirinyaga CIDP 2018- 2022 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. In Kirinyaga County, there are many governmental, private, non-governmental, and community-based institutions 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, and disease surveillance. Table 2 provides a sample of institutions that are currently supporting and implementing agricultural interventions in Kirinyaga.

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

Off-Farm Services	Institutions	Specific Interventions in Kirinyaga	Challenges
Agricultural Research and Extension Services	Department of Agriculture, Livestock, Veterinary and Fisheries Kenya Agricultural Livestock Research Organization-Mwea Center.	On-farm demonstrations of the new crop and livestock technologies, innovations, and management practices Increasing the productivity, commercialization, and competitiveness of the rice and cotton sectors through knowledge and technology promotion	Poor coordination among the organizations leads to duplication and overlap of roles and efforts In many cases, climate adaptation planning is reactive rather than proactive.
	Kamweti Agricultural Training Centre Kenya Plant Inspectorate Service	Training on good agriculture practices Farmer Field Day trainings Provision of improved crop seed	
	Department Environment and Natural Resources	Rehabilitation of community water schemes Connecting households to piped water Drilling boreholes Constructing additional water harvesting structures (tanks)	
	Kenya Forestry Service Kenya Forest Research Institute Upper Tana Natural Resource Management Project Water Resources Management Authority National Irrigation Authority Mwea Irrigation Development Authority Anglican Development Services of Mount Kenya East	Promoting conservation and protection of water catchment areas Promoting farm and dry land management	
	National Environment Management Authority	Promotes sustainable environmental management through integrating environmental considerations into development policies, plans, programs and projects	
	Directorate of Livestock County veterinary services Private Veterinary Officers	AI services Animal selection per agroecological zone Training extension staff and farmers on climate risk management Vaccination services	
	Pest Control Products Board	Pest and disease management	
	Kenya Agricultural and Livestock Research Organization Jomo Kenyatta University of Agriculture and Technology	Varietal and breed development On farm research trials Production, extension, and technology transfer	
Climate Information Services and Agro-weather Advisories	Kenya Meteorological Department CARE Kenya	Provides weekly bulletins and seasonal weather forecasts in the local language Empowers communities to work with stakeholders to formulate and implement adaptation programs and policies	

Off-Farm Services	Institutions	Specific Interventions in Kirinyaga	Challenges
Early Warning Systems and Participatory Scenario Planning	Kenya Meteorological Department Agriculture Sector Development Support Program	Issuing warnings on disasters Supporting planning of farm activities Coordinating participatory scenario planning spring and fall rains Providing advisories and facilitating their dissemination	Farmers' cooperative societies and associations are often weak or disorganized with no clear governance structure Farmers are susceptible to exploitation by intermediaries
Non-Financial Subsidies	Wezesha Flagship Program	Providing seedlings feeds and other important inputs	
	Kirinyaga County Government	Providing subsidized farm inputs	
	East Africa Seeds Co. Ltd. Kenya Seeds Co. Ltd. OSHA Chemicals Murphy Chemicals Ltd. Bayer East Africa Amiran Kenya	Distributing and selling agro-chemicals and other farm inputs Providing training and demonstration on the use of these inputs	
	Jomo Kenyatta University of Agriculture and Technology Aberdare technologies Lab.	Supplying tissue culture banana seedlings	
Financial Services	Agricultural Finance Corporation	Providing credit facilities, managerial and technical assistance to individual and farmer groups	
	National Agricultural and Rural Inclusive Growth Program	Providing financing to support on farm and input supply	
	Savings and Credit Cooperative Organizations	Providing credit solutions	
	Banks	Providing credit solutions	
	Microfinance	Providing credit solutions	
	Water Sector Trust Fund	Providing a common pool of resources to finance water sector initiatives	
Market Services, Infrastructure and Linkages	Kenya Dairy Board New Kenya Cooperative Creameries	Milk Value addition Processing and marketing milk	
	Kenya Meat Commission (KMC)	Meat value addition Providing ready markets Increasing productivity and competitiveness	
	Africa Harvest Twiga foods Meru Greens ICOSEED	Promoting banana ripening facilities Linking farmers to high-value markets in the city Processing banana byproducts into marketable goods	

7. Synthesis and Outlook

This Kirinyaga County Climate Risk Profile focuses on five major value chains based on their contribution to food security, their productivity characteristics, and their importance to the county economy. These five value chains are dairy, bananas, avocadoes, tomatoes, and chickens. This risk profile also identifies the two climatic hazards that most threaten each value chain. Low temperatures and dry spells affect dairy production; heat stress and heavy rainfall have a significant impact on chickens; excessive rainfall and dry spells are a risk for bananas; heavy rainfall and dry spells may reduce avocado production; and high temperatures and drought can cause issues for the tomato value chain. These climatic hazards can compromise the food security and livelihoods of farmers.

Kirinyaga County is in the process of formulating policies within county government departments to address climate change and climate risk management. These will form the basis for new interventions and improve on existing ones. Kirinyaga County is also in the process of developing a 15-year visionary agenda which will be its first sub-national paper, titled the *Mountain Cities Blueprint*. It encompasses ways to employ modern agricultural practices in crop farming, poultry rearing, livestock keeping, and fish farming to improve production. Another aspect is sourcing better markets locally and abroad for tea, coffee, horticultural products, and rice, as Kirinyaga County seeks to turn agriculture into a lucrative venture. The

county government is also working with the national government in the construction of the Thiba Dam, to put more land under irrigation.

Farmers in Kirinyaga County have been successful in implementing some adaptation options with the backing of the county government and other relevant institutions, though the adoption rates of certain interventions are still low. For instance, about 38% of household are adapting to climate change through soil and water conservation, 19% are engaged in water harvesting, 19% in feed conservation, and 29% use irrigation. Low adoption rates of some interventions to address climate change impacts may be attributable to the fact that most farmers are more inclined towards the use of short-term coping strategies rather than long-term adaptation strategies; therefore, they remain exposed to climate shocks.

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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, 2015).

Climate change: refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings 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).

Female-headed household: a household whose main decision-maker on matters of agricultural production, marketing, and consumption is a female person aged 36 years or older (ASDSP, 2014).

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, 2015).

Male-headed household: a household whose main decision-maker on matters of agricultural production, marketing, and consumption is a male person aged 36 years or older (ASDSP, 2014).

Stunted growth: Shows % of children over six months and under five years of age 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 website, 2019).

Undernourished: the 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 and 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.

Wasted: showing % of children over six months and under five years of age 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." (WHO website, 2019).

Youth-headed household: a household whose main decision maker on matters of agricultural production, marketing, and consumption is a male or female person aged between 18 and 35 years, irrespective of sex or marital status (ASDSP, 2014).

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