Kenya County Climate Risk Profile: Kitui County

Highlights

- Agriculture is the main economic activity in Kitui County (Figure 1), contributing to food security and generating 87% of rural household income.
- Local chicken, goats, mangoes, and green gram (mung beans) were selected as priority value chains under NARIGP because of their economic value, resilience to weather variability and climate change, contributions to household food security, and their position in county frameworks and programs.
- Food insecurity is on the rise in the county due to low productivity associated with factors that include pests, weather variability, and prohibitive input prices. An estimated 39.4% of the population is considered food poor. Among children under five, 38.2% are stunted and 4.2% are wasted.
- High temperatures and increased risk of floods are experienced during the long rains season, (March-May) while in the short rains season (October-December) the climate is more stable and can potentially be exploited with adaptations such as early maturing crop varieties.
- On-farm adaptation options employed by farmers include the use of drought-tolerant crop varieties and animal breeds, conservation agriculture, water harvesting techniques, zai pits for composting, conserving and planting fodder, disease surveillance, breeding programs, health management and improvements in post-harvest handling and storage.
- Off-farm services that assist farmers include early warning systems, weather advisories, value addition and processing, extension and training, formation of farmer groups and cooperatives, and the provision of market information to farmers.

Many institutions in Kitui County, including the government, research institutions, non-governmental organizations, faith-based organizations, community-based organizations, and the private sector, are involved in the promotion of climate-smart agricultural interventions. Limited finance and human capital and lack of adequate infrastructure are their main constraints.

- The county has adopted several national policies geared toward adapting to climate change and its associated risks. These policies provide information to farmers, enabling them to plan, make viable economic decisions, and adapt to anticipated climatic risks.
- The adaptive capacity of farmers to engage in climate-smart agricultural practices and the ability of institutions to identify climate risks and take advantage of climate opportunities should be promoted and be expanded in Kitui County.

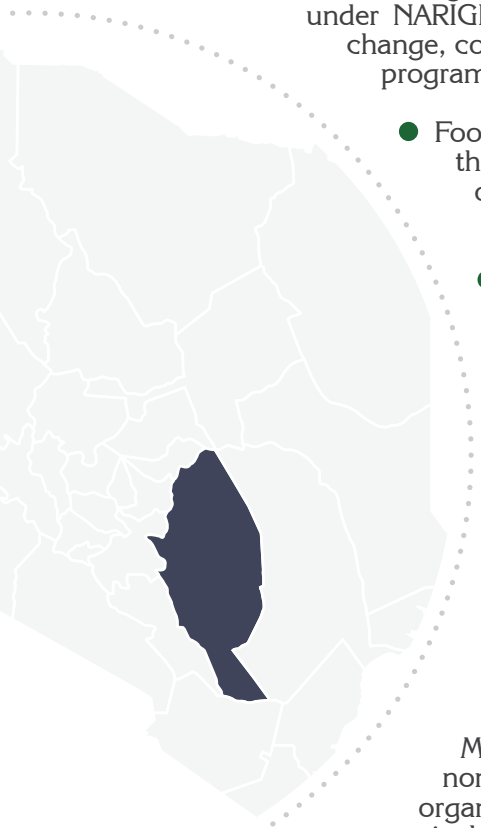

Figure 1: Map of Kitui County

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CONTENTS

List of Figures

List of Tables

List of Acronyms

AEZ: Agroecological zones

ASDSP: Agriculture Sector Development Support Programme

CDD: Consecutive Dry Days

CIAT: International Center for Tropical Agriculture

CIDP: County Integrated Development Plan

DRSRS: Department of Resource Surveys and Remote Sensing

GoK: Government of Kenya

ICIPE: International Centre of Insect Physiology and Ecology

KALRO: Kenya Agricultural and Livestock Research Organization

KMD: Kenya Meteorological Department

KNBS: Kenya National Bureau of Statistics

LGP: Length of the Growing Season

MoALFC: Ministry of Agriculture, Livestock, Fisheries, and Cooperatives

NARIGP: National Agricultural and Rural Inclusive Growth Project

NCCAP: National Climate Change Response Strategy

NCCRS: National Climate Change Response Strategy

NT35: Number of days with maximum temperatures greater or equal to 35°C

P5D: Maximum 5-day running average of rainfall in mm

RCP: Representative Concentration Pathway

VCC: Value Chain Commodities

Kitui

Foreword

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

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

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

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

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Principal Secretary

State Department for Crops Development and Agricultural Research

1. Introduction

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

The 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 clean and secure environment to all its citizens by 2030. The agricultural sector has been identified as a key contributor 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, and, most significantly, climate change.

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

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

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

The Alliance implemented the assessment through a set of interrelated stages (Figure 2). It first initiated a desk review of the conceptual and analytical context of climate change risks at national and county levels. Efforts were made to involve a wide range of institutions that have past and ongoing work on climate change at national and regional levels. The team used globally available data sources as well as collected data from relevant government departments (e.g., Department of Resource Surveys and Remote Sensing (DRSRS), the Kenya Meteorological Department, 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-long, sub-national stakeholder workshops. The final reports were then presented to and validated by national- and county-level stakeholders.

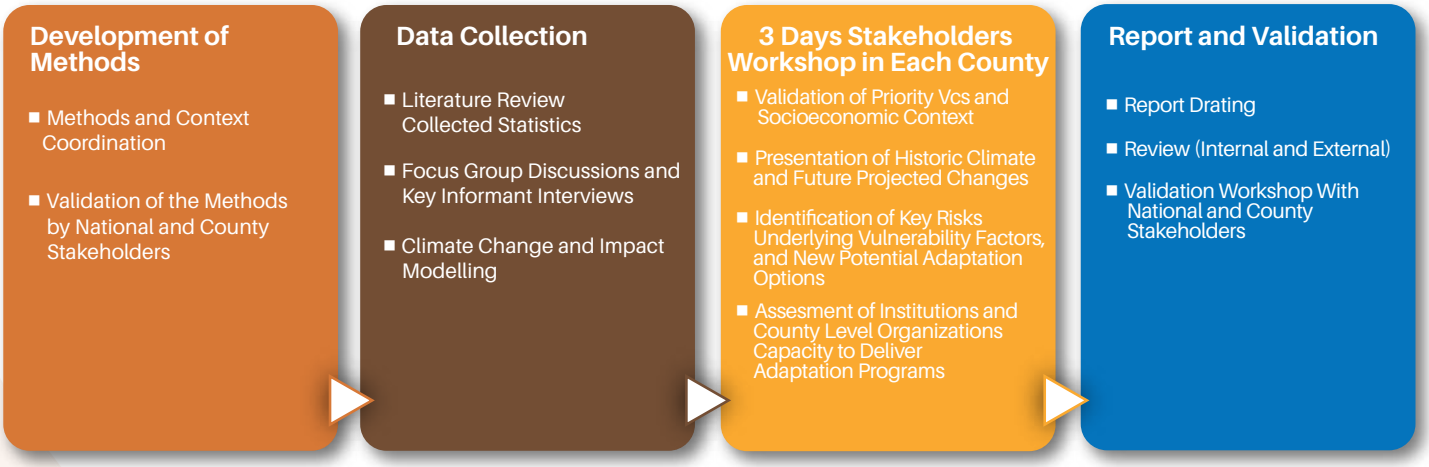

Figure 2: Climate Risk Profile (CRP) development process

This document presents the Climate Risk Profile for Kitui County. It is organized into six main sections, each reflecting an essential analytical step towards understanding current and potential adaptation options in key local agricultural value chain commodities. The first section offers an overview of the agricultural commodities that are key to food security and livelihoods in the county, and then lists major challenges to agricultural sector development in Kitui. In the second section, it identifies the main climate hazards, based on an analysis of historical climate data and climate projections. These include scientific assessments of climate indicators for dry spells, extreme rainfall, moisture stress, and heat stress, among others. Third, the report continues with an analysis of vulnerabilities and risks posed by these climatic hazards to the identified value chains. Based on these vulnerabilities, the fourth section discusses current and potential on-farm adaptation options and off-farm services. In the fifth section, the report provides snapshots of the enabling policy, institutional, and governance contexts for the adoption of resilience-building strategies. Finally, the sixth section presents pathways for strengthening institutional capacity to address climate risks.

2. County Context

Kitui County is in the eastern part of Kenya, bordering Tharaka-Nithi and Meru Counties to the north, Embu to the northwest, Machakos and Makueni to the west, Tana River to the east and southeast, and Taita Taveta to the south. The county has an altitude that ranges between 400-1800 meters above sea level (County Government of Kitui, 2018).

Due to its semi-arid climate, the county is among the most drought-vulnerable regions in Kenya. The average annual precipitation range is 400-1000 mm, with an annual average annual of 750 mm. The eastern part of the county is the driest, receiving less than 500 mm of rainfall, on average, every year. Precipitation in the long rainy season, from March to May, is erratic and unreliable; precipitation in the short rainy season, October to December, is more reliable in terms of its amount and distribution. Most farmers in Kitui County depend on the short rainy season for agricultural productivity: it contributes 60% of the county's crop production, compared to 40% during the long rainy season. The annual average temperature for Kitui is 21-31°C. The western part of the county is nearly 10°C cooler than the eastern part.

The county has eight sub-counties: Mwingi Central, Mwingi North, Mwingi West, Kitui South, Kitui East, Kitui Rural, Kitui West, and Kitui Central.

2.1 Economic Relevance of Agriculture

Agriculture contributes about 87% of the income earned by the rural population and directly employs 355,825 persons, or more than 35% of the population (ASDSP, 2014). Out of the 262,942 households in the county, 82% are engaged in farming activities (KNBS, 2019d).

At 93%, most of the households involved in agricultural activities are engaged in the production of crop such as cereals, industrial, and horticultural crops (KNBS, 2019d). The total annual average of cereal production in the county is 80,680 metric tonnes (Mt), valued at KSh 4.24 billion;[1] industrial crops (cotton, sisal, and sunflowers) are valued at KSh 29.04 million for an average production of 771 Mt; and the average production of horticultural crops stands at 36,950 Mt, valued at KSh 990 million (County Government of Kitui, 2018).

Livestock production is also a main economic activity in the county, with 82% of the county households involved in farming producing livestock (KNBS, 2019d). Households depend on livestock as a food source and for income generation. The main types of livestock in the county are indigenous cattle, goats, local chicken, and donkeys. County farmers prefer these animals, as they are resilient to the hot and dry climatic conditions and can cushion them against adverse conditions such as drought. Of the total farming households, 41% rear indigenous cattle, 69% raise goats, and 68% keep local chickens (KNBS, 2019d). The county's annual average production levels for various livestock enterprise products are as follows: 3,077 tonnes of beef, 1466.6 tonnes of goat meat, 70 million eggs, and 4.2 million liters of milk. Donkeys are primarily used as a means of transport; for this they are kept by 48% of households. They come in handy to help families fetch water across long distances during dry spells. They are sometimes included in dowry negotiations. Also, indigenous chickens are a fundamental source of income for immediate household needs (County Government of Kitui, 2018).

The county's annual production of honey is 960 tonnes (County Government of Kitui, 2018), with 14% of households engaged in the enterprise (KNBS, 2019d). There is huge growth potential for this sector, although it requires concerned stakeholders (including the government, international organizations, the private sector, and farmers) to ensure that the value chain is managed appropriately. Expanding beekeeping would help to increase the GDP of the county, provide food security, and conserve the environment.

2.2 People and Livelihoods

Kitui county hosts 1,136,187 persons, or 2.4% of Kenya's population, of which 48% is male and 52% is female (KNBS, 2019b) (Figure 3). The majority (95%) of the population lives in rural areas, with only 5% living in urban areas. The total number of males residing in the rural areas is 522,943, while females constitute 559,193 (KNBS, 2019c). The number of households in the county is 262,942 with an average household

[1] As at 3/12/2020, 1 KSh is equivalent to 0.009 USD

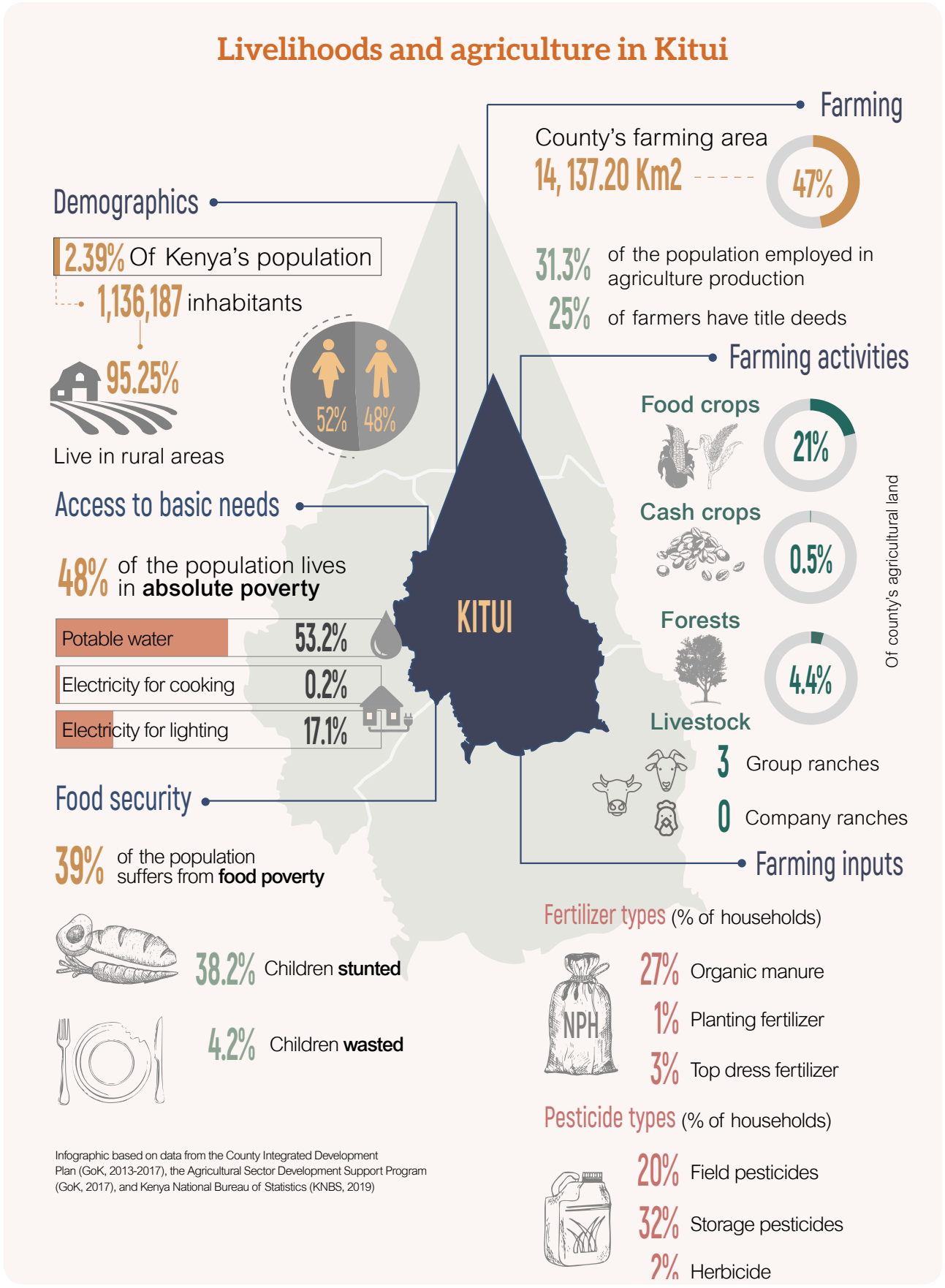

Figure 3: Agriculture and livelihoods in Kitui County

size of 4.3, higher than the national household size of 3.9 (KNBS, 2019a).

Kitui County is one of the 10 largest counties in Kenya by land area. It has a total land area of 30,429 km^2 and a population density of 37 people per km^2; for comparison, the national average is 82 people per km^2.

Despite huge agricultural potential in the county, poverty remains high. A total of 48% of the population is considered poor; this is higher than the national rate of 36%. The poor in Kitui County account for 3.2% of the poor in Kenya. The households and individuals considered to live under absolute poverty are those whose monthly adult equivalent total consumption expenditure per person is less than KSh 3,252 in rural and peri-urban areas and less than KSh 5,995 in core-urban areas (KNBS, 2016). Percentage of people living below the poverty line (US$ 1.90 a day) is 60.4% while people experiencing food poverty is estimated at 39%, compared to the national average of 32%. The monthly adult equivalent food consumption expenditure per person is less than KSh 1,954 among food-poor households and individuals in rural and peri-urban areas and less than KSh 2,551 in core-urban areas. Relatedly, there are high rates of nutritional deficit. Stunting occurs in 38.2% of children below five, while wasting occurs in 4.2% of children below five (KNBS, 2016). These high rates can be explained in part by the long period of food scarcity between June and September as a result of dry spells (less than 20 mm rainfall) in the county.

The land tenure system is divided between family and individual (private) land tenure. The family system grants access to land based on one's qualification as a family member. This land is inherited from family lineage. Under individual tenure, an individual owns the land permanently, free from any third-party claims. Most of the inhabitants in Kitui county lack title deeds: only about 25% of landowners in the county have them (County Government of Kitui, 2018).

Access to water is a limiting factor in the county. The main sources of drinking water include ponds, lakes, streams, protected springs, protected wells, boreholes, water piped into plots or dwellings, bottled water, harvested rainwater, purchase from water vendors, and public taps (KNBS, 2019d). Only 53% of residents use improved sources of water (County Government of Kitui, 2018). There are no significant gender differences in the use of improved water sources. 27% of male-headed households and 25% of female-headed households use improved water sources (KNBS, 2017). The average distance to the nearest water point is 7 km, but walking distance to water increases during dry spells, during which 58% of households spend thirty minutes or more to fetch drinking water (County Government of Kitui, 2018).

People primarily rely on firewood (81%) and charcoal (9%) for cooking (KNBS, 2019d). Firewood is slightly more common in female-headed households than in male-headed households, at 91% and 87%, respectively (KNBS, 2017). Reliance on firewood for cooking derives from factors including a highly rural population, high poverty rates, and the consideration of forest land as a public good. Only 0.2% of people in the county use electricity for cooking, while 0.3% use biogas, and 0.2% use solar energy (KNBS, 2019d).

2.3 Agricultural Activities

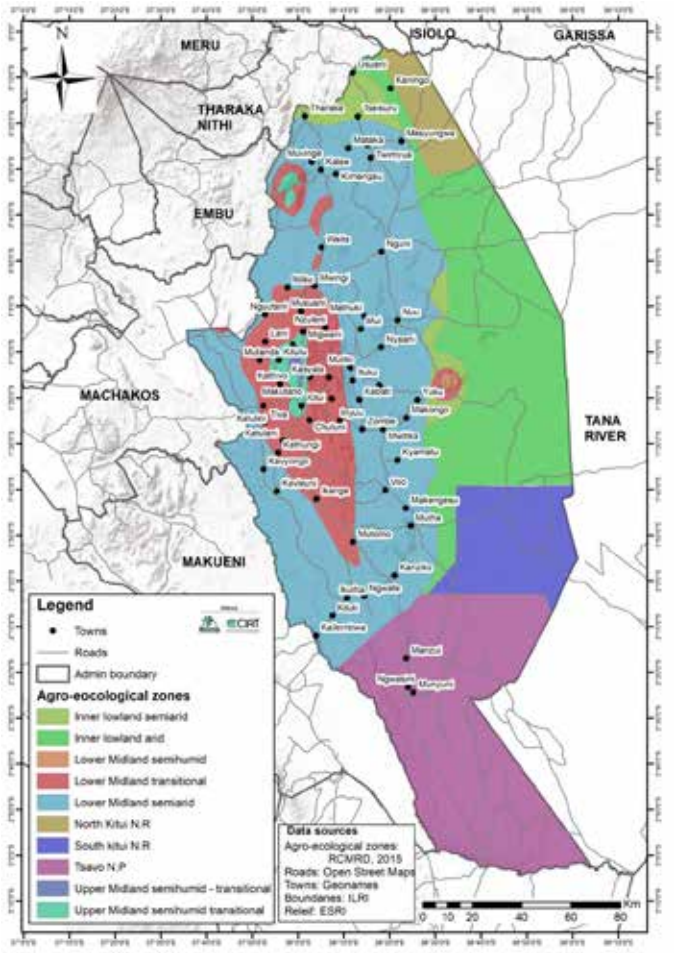

Figure 4: Map of agroecological zones in Kitui County

The main food crops grown in Kitui County include cereals (sorghum, millet, maize); pulses (beans, green grams, pigeon peas, cowpeas); root crops (arrowroot, cassava, sweet potatoes); industrial crops (cotton, sisal, and sunflowers), and horticultural crops such as mangoes, pawpaw, watermelons, tomatoes, kale, onions, and bullet chilies (County Government of Kitui, 2018). Sunflowers, in addition to their role as an industrial crop, are important food sources for apiculture and the indigenous chicken value chain. Out of the 93% of the farmers involved in crop production, 83% (178,365 households) are involved in maize production, 62% (133,390 households) produce green grams, 49% (105,815 households) are engaged in bean production, and 46% (98,030 households) are involved in sorghum production (KNBS, 2019d). The main permanent crops in the county are mangoes, avocado, and citrus. Out of the farming households, 16% are involved in mango production, followed by avocado (6%) and citrus (3.5%).

Livestock rearing is practiced in most parts of the county. The indigenous breeds reared in the county are resilient to its arid and semi-arid climatic conditions. The Zebu breed accounts for 97% of cattle, while Boran and Sahiwal account for 3%. Poultry includes domestic fowl, ducks, quails, turkeys, Guinea fowl, and geese. The most common poultry is indigenous chicken, which is kept by over 90% of households in the county.

The major farm inputs used on crops include planting fertilizers, top-dressing fertilizers, foliar feeds, and manure. The number of households in the county using these inputs for annual crops is variable: 27% use organic manure; 1% and 3% use planting and top-dressing fertilizers, respectively; 20% use field pesticides; 32% use storage pesticides; and 2% use herbicides. Half of the male-headed households use improved seeds and planting materials, compared to 11% of female- and youth-headed households. Likewise, male-headed households dominate the usage of field pesticides at 15%, compared to 2% of female- and youth-headed households. Storage pesticides are employed by 24% of male-headed households, compared to 4% of female-headed and 3% of youth-headed households. These disparities can be explained in part by men having more access to resources and training, being more socialized by their peers to use these products, and having higher levels of education compared to their female and youth counterparts (ASDSP, 2014).

The topography of Kitui County is suitable for irrigation; its irrigation potential is estimated to be 11,095 ha, of which only 1,850 ha have been utilized. Irrigation is practiced along major rivers such as Mui, Thua, Kithyoko, Tana, Athi, Nzeeu, Thunguthu, Katse, Kauwi, and Kalundu. It is coupled with ongoing county projects for water harvesting, including kitchen gardening, on-farm ponds, and cluster irrigation schemes (Kitui County Government, 2017). Underutilization can be driven by inadequate supplies since water resources are not fully recharged when rainfall amounts are low; by high startup capital requirements; and by high operational costs. Proper water harvesting and storage during periods of excess rain is therefore necessary. Farmers can be supported by entities subsidizing the costs of irrigation infrastructure.

2.4 Agricultural Value Chain Commodities

Among the diverse range of commodities grown in Kitui County, several are prioritized by the County Integrated Development Plan (CIDP), development programs NARIGP and 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 agriculture value chain commodities (VCCs) in the county was compiled using the following prioritization indicators: productivity characteristics, including harvested area, production, and production variations over the past five years; economic value; and nutrition characteristics, including dietary energy consumption (Kcal/capita/day), protein content, iron content, zinc content, and vitamin A content. This list was presented to stakeholders for in-depth analysis and selection during a 3-day-long workshop. The list was further honed using a set of criteria agreed upon by the stakeholders, including resilience to current and future climate change impacts (low to high), the percentage of population involved in the value chain (%), and the involvement of economically and socially vulnerable groups (poor, women, and youth) in the VCC (low to high). Each value chain was assessed against all criteria, and the value chains with the highest percentage of the population involved—with special attention on women and the youth—were selected. The four VCCs chosen by this method are mango, green grams, indigenous chicken, and goats. Beekeeping is another important value chain in the county; the selection matrix results yielded a tie between two value chains and the workshop participants agreed to drop beekeeping, while unanimously agreeing that it is an important value chain in the county (Figure 4).

2.4.1 Mango

Mango (*Mangifera indica*) is one of the main cash crops in the county, with 81-100% of farmers engaged in this value chain. It is a perennial crop that is cultivated in most parts of the county. Mango trees are culturally important for providing storytelling spots and shade and for their aesthetic value; they are frequently passed from generation to generation. Mangos, rich in dietary fiber, minerals, polyphenolic flavonoid antioxidant compounds, and vitamins A, E, and K, provide nutrition to nearly all households in the county. They also contain protein, fats, sugar, and other nutrients (Hamdard, et al., 2004). In Kitui, mangoes are mostly eaten fresh, although some farmers practice value addition by processing the fruits into juice, jellies, powder (mixed with sorghum), jams, dry flakes, and chips. Mango byproducts are used by farmers in the county to feed animals. The young leaves, for instance, are suitable for cattle feed (Biovision, 2019b). Mangoes also play an ecological function since trees prevent soil erosion and minimize greenhouse effects. Most mango farmers are small-scale (67%) with a smaller share (32%) of medium-scale and very few (1%) and large-scale operations.

In the county, mango is normally intercropped with food crops such as sorghum, cassava, sweet potatoes, maize, nitrogen-fixing legumes (beans), and indigenous vegetables. During a tree's first five years, intercropping with annual crops is recommended to maximize income until an economical mango yield is achieved (Biovision, 2019b). However, most farmers in the county continue to intercrop after this point.

Mango production is affected by pests and diseases. Common pests include fruit flies, seed weevils, aphids, thrips, bugs, and mites. Anthracnose, powdery mildew, and rots are common diseases. Some farmers engage in integrated pest management while others prefer the application of chemical pesticides.

The main inputs in the mango value chain are seedlings, organic fertilizer, and inorganic fertilizer. Farmers in Kitui County procure these from agro-dealers, who are mainly concentrated in urban areas. The main export varieties in the county include Apple, Tommy Atkins, Kent, Ngowe, Van Dyke, and local varieties like Sikio Punda and Dodo.

Agricultural Training Centers, RTI International (through the Feed the Future initiative), farmer cooperatives, the International Centre of Insect Physiology and Ecology (ICIPE), the county government of Kitui, and processors are key actors in the mango value chain. Kitui Agricultural Training Center provides training to farmers through on-farm demonstrations. RTI International has supported some private-sector mango growers and marketers in Kitui County as they undertake viable agri-business investments to sustainably grow their businesses, create community employment, and provide reliable markets for agricultural producers in the county. The county government and developmental partners like ICIPE support farmers through the distribution of free inputs.

Some varieties of mangoes are exported whole and there are cottage industries in the county drying mango into flakes for export. Mango flakes can fetch up to KSh 500 in the export market. Mango processing plants in the county, including Kitui Enterprise Promotion Company, Rise Kenya, Mwingi Horticultural, and Sun Sweet Fruit Farm, are accessible to all mango farmers.

Marketing involves activities such as linking farmers to buyers, promotion, and pricing. It is coordinated by cooperatives and farmer groups. Promotion in the mango value chain is accomplished through online digital platforms, field days, barazas, radio, and TV. These activities are aimed at creating product awareness and enhancing market access.

2.4.2 Green Grams

Green grams (*Vigna radiata)* are produced by 62% (133,390 households) of farmers in the county (KNBS, 2019d). They provide food security and are key to improving household income. The area under green gram production in the county ranges between 1-10 acres per household (Wageningen Environmental Research, 2019).

With dry spells projected to intensify in the future, green grams are an increasingly important food crop in arid and semi-arid regions because they can withstand harsh climatic conditions. Eighty-nine percent of the county's land is highly suitable for green gram production (Mugo & Musembi, 2016). The total production of green gram is valued at KSh 1796 million (ASDSP, 2014).

Input supply is a key stage in this value chain. Households headed by adult males use more inputs than those headed by adult females and the youth. On average, adult male-headed households use 11 kg of seed material, while adult female-headed households use 6 kg; households headed by male and female youths use 7 kg and 9 kg, respectively. Similarly, adult male- and female youth-female households each use 3 kg of herbicides on average, followed by male youth- and adult female-headed households, each using 1 kg of herbicides on average. Neither adult female or male youth households use basal or top-dressing fertilizers, but adult male and female youth households use 41 kg and 10 kg, respectively. The average male youth-headed household's use of manure is high (2,430 kg) followed by female youth-headed households at 857 kg; adult male and adult female households use 730 kg and 857 kg, respectively. These disparities may be attributed in part to the involvement of male youth in livestock rearing, rendering organic manure readily available to them.

The main varieties of green grams in the county include KS20, commonly known as *Uncle Makueni,* and N26 (*nylon*). Others include *biashara*, *karembo*, and other local varieties. KALRO Katumani is a key provider of certified green gram seeds in Kitui County. They are also involved in the dissemination of improved varieties; the establishment and operationalization of innovation platforms in the value chain; the promotion of farmer-to-farmer learning exchange tours; and the dissemination of technologies through on-farm trials, demonstrations, and field days. Some farmers still resort to low-quality seeds due to the limited availability and prohibitive cost of high-quality varieties, farmers' distance from input suppliers, and insufficient knowledge of crop management options.

Farmers in the county harvest green gram when the pods have turned black. Post-harvest activities include drying, threshing, and cleaning. Proper drying is important for preventing the growth of fungi and aflatoxin contamination (Biovision, 2019a).

Green gram produce is transported by road using motorbikes and other vehicles, donkeys, trekking, and trains. Farmers in groups and cooperatives bulk their produce for increased bargaining power in price negotiations. Cooperatives in the county coordinate post-harvest and marketing. One example is the Imani Multipurpose Cooperative Society in Mwingi Central. The Sasol Foundation has also promoted the commercialization of green grams by increasing agricultural productivity, generating farmer-guided value chain analysis, inculcating business attitudes regarding farming, and creating market linkages (Sasol, 2015). Sasol provides a green gram handbook to farmers for capacity building and the dissemination of best farming practices.

The green gram value chain experiences some challenges in the county. These include pests such as bean aphids, bean flies, and bruchid weevils. Bruchid weevils are common in the county, where they are called *ngulu*. They are post-harvest pests that are managed through storage pesticides, hermetic storage technology, or adding neem leaf ash to the produce before storage. Other farmers prefer to store the grains in covered tins, drums, pots, or sealed containers, traditional practices passed through generations and employed when prices prohibit farmers from purchasing pesticides.

There are no off-farm processing services for green grams in the county. Threshing is done manually or mechanically on the farm. This is a major gap in the value chain which should be closed by the establishment of processing plants.

2.4.3 Indigenous Chicken

More than 80% of farmers in the county (147,023 households) are engaged in the local chicken value chain, with an average flock size of 50 birds (KNBS, 2019d). High market demand for chicken products drives high levels of farmer involvement in the value chain.

Indigenous chickens freely roam around homesteads and scavenge for food, requiring little in the way of upfront (for the construction of housing structures) or ongoing (supplementary feeding) costs. Local chickens are kept for meat, eggs, and their supply of manure.

In the indigenous chicken value chain, (adult) female-headed households dominate decision-making, accounting for 56%, followed by (adult) male-headed households at 32%. Female youth-headed households (9%) also are more involved in decision-making than male youth-headed households (3%) (ASDSP, 2014). These disparities can be attributed to several factors, including a cultural affiliation of this value chain with females.

Farmers manage the health of their birds through procuring veterinary services. Vaccination is offered by both the Department of Veterinary Services and private providers. Chicken diseases such as Newcastle Disease and fowl pox reduce the productivity of this value chain.

The main slaughtering areas in the county are in Kitui Town, Mwingi, and Mutumo. The county needs improved slaughterhouses where farmers can aggregate and slaughter their birds in a structured manner according to public health requirements. Currently, slaughterhouses are individual, makeshift, and do not follow public health protocols.

The poultry supply chain is coordinated by cooperatives such as the KICOPO Cooperative Society, which is tasked with linking buyers to sellers, aggregation, value addition, marketing, and market assurance. Their slogan is "Kuku ni pesa," indicating the economic viability of indigenous chicken and encouraging people to join the cooperative, which currently has 3,000 members.

NARIGP and ASDSP promote this value chain through providing capacity building to farmers and financing their infrastructure (provision of incubators, housing, and feeds).

2.4.4 Goat (Meat)

Goat rearing is one of the most important livestock activities in Kitui County. The 2019 census report by KNBS shows that 69% of farming households keep goats, with an average holding around five animals. The main goat meat breeds are Gala, Small East African, and crossbreeds of these two; the main dairy goat breeds are the Toggenburg (95%), followed by German Alpine (5%). Goat-keeping is practiced in all the agroecological zones in the county (Figure 4). Goats tolerate the county's climatic conditions because they accept low-value feed, have versatile habits, and have high production relative to their size.

Goat grazing management systems can be categorized as continuous or controlled grazing. Continuous grazing allows the goats to decide when and where to graze, resulting in high plant selectivity. Conversely, controlled grazing involves strategic movement of goats through multiple grazing paddocks based on their nutritional needs.

Goat is produced mainly for meat purposes in the county, as dairy goats are less tolerant and less resilient to climatic shocks. Goats are also used for dowry payment and act as collateral in financial matters.

Key decision-makers in the goat value chains are adult males and females, who account for 50.7% and 37.7%, respectively. Youth, both male and female, are less involved, and each constitutes 5.9%.

Breeding influences the genetic composition of the herd and can thus improve the profitability of the goat value chain. There is a breeding department that spearheads this activity in the county. However, farmers' adoption of crossbreeds is low due to the prohibitive costs. Veterinary services are offered by both public and private service providers, but the costs associated with vector control are often quite high.

Household labor is used in services such as dehorning, branding, and tagging. However, these practices should be done under the supervision of a veterinarian to control excessive bleeding and monitor for infections that otherwise would lead to premature deaths of the goats.

Limits on input use are a major challenge in the goat value chain. The major contributing factors are high prices, distances to the market, ineffective inputs (such as artificial insemination), and lack of timely access.

There are 71 slaughterhouses in the county accessible to farmers rearing goats. Some farmers transport their goats in motor bikes while others trek to the slaughterhouses and market centers. The main markets for goats are Tseikuru, Katse, Nguni, Muthaa, Ukasi, Kamuwongo, Zombe, Mutomo, Kisasi, Kabati, Mwingi, Kavisuni, Kalundu, and Ngomeni. Poor road networks can hamper access to markets and slaughterhouses, thereby increasing transaction costs. The major gap in this value chain is a lack of cooperatives that could coordinate output supply.

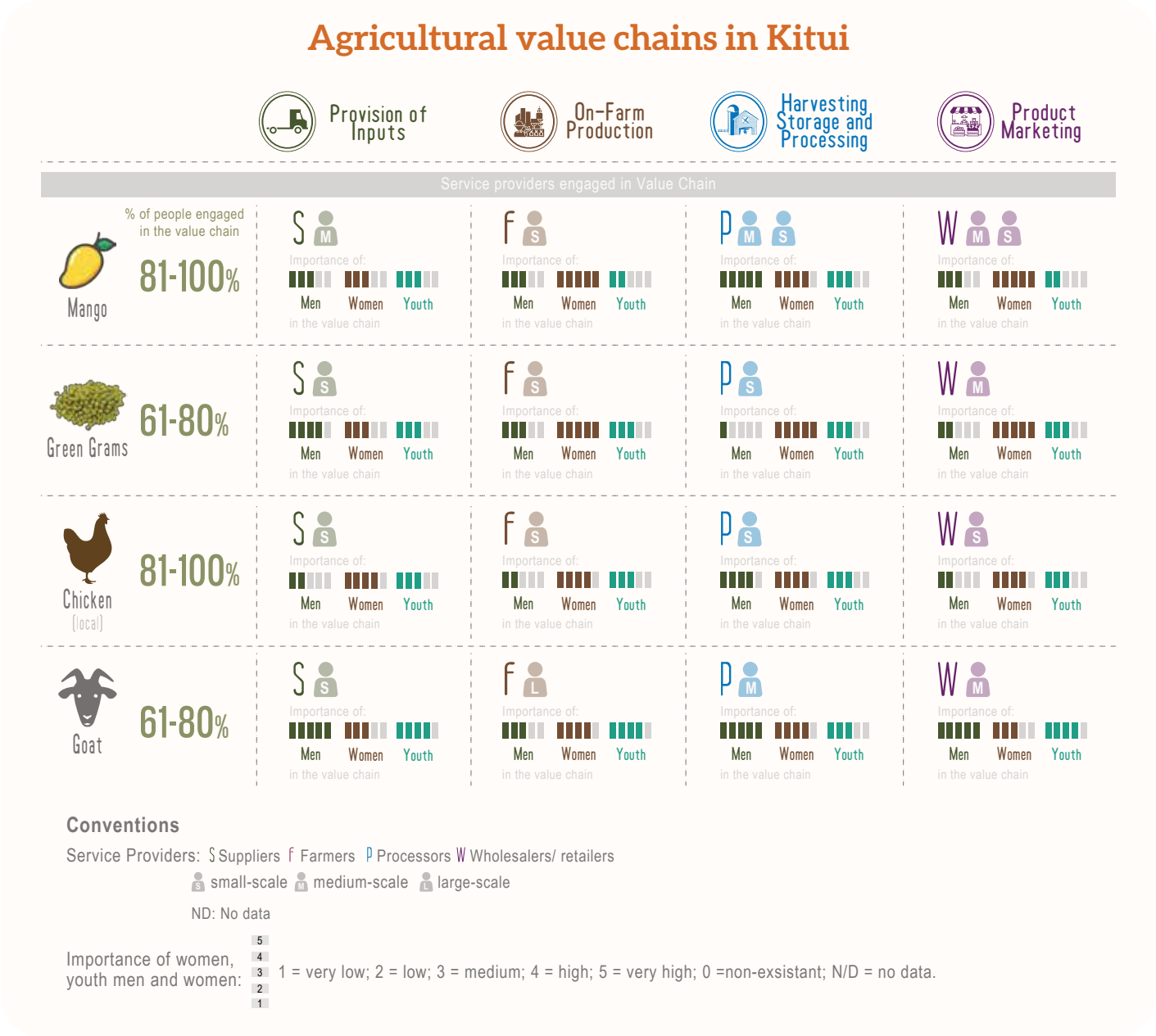

Figure 5: Characterization of the selected agricultural value chains in Kitui County

2.5 Agricultural Sector Challenges

Kitui County has the potential to feed its population and sell surplus products to other counties and beyond. However, recurring challenges hinder the prosperity of agriculture, including difficulty in accessing inputs, climatic risks, inadequate infrastructure, and high poverty levels. As a result, the level of food self-sufficiency in the county is only 51%.

There is low adoption of input use in crop production (fertilizers and pesticides) and livestock rearing (vaccines, de-wormers, semen, mineral supplements).

High prices, long distances to input markets, lack of timely access, ineffectiveness, adulteration, and unavailability all reduce input use among farmers in Kitui.

Deforestation and land degradation are high in the county, due to the number of people who derive their livelihoods from declining forest resources. Ultimately, deforestation negatively impacts agriculture since forests are key components of the rain cycle and act as carbon sinks. The Kitui County Assembly created an act to regulate and manage the production, use, and trade of charcoal. However, this legislation needs more widespread adoption and more stringent enforcement (GoK, 2010).

Climatic risks pose a serious challenge to the agricultural sector in the county. Floods can drown livestock and wash away food crops; they destroy farm structures like poultry sheds, cow pens, irrigation infrastructure, and greenhouses. Conversely, drought significantly reduces yields for both rain-fed and irrigated crops, as water resources are not fully recharged during dry periods. Insufficient water affects livestock water and pasture requirements, leading to premature death.

Like any other business, agriculture incurs financial expenses and is thus limited by high poverty levels in the county. This makes it difficult for agribusiness to thrive in Kitui. Agricultural financial obligations include procuring inputs (fertilizers, extension services, vaccination, health management, housing), establishing irrigation infrastructure, maintaining on-farm activities (labor expenses), post-harvest processing and transportation, and marketing activities.

A lack of improved infrastructure affects service deliveries (at the input supply stage) and the transportation of produce to markets (at the output market stage). Poor secondary and tertiary roads in the county reduce rural farmers' access to markets. Road networks are further endangered by flood risks, as flooding can render them impassable, leading to increased overhead costs. Conversely, during the dry spells, dust from dry roads can contaminate produce.

3. Climate Change and Agriculture: Risks and Vulnerabilities

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

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

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

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

To assess the degree to which rainfall and soil moisture levels 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.

3.1 Climate Change and Variability: Historic and Future Trends

Kitui County has two rainy seasons (Figures 5 and 6). The long rainy season, experienced between late February or early March and May, is drier than the short season, which runs from October to December.

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

Dry spells (characterized by less than 20 mm rainfall) are experienced from June to September. November receives the highest amount of rainfall (around 200 mm per month). In the long rainy season, the main risks are related to extreme weather variability. Climate projections indicate that temperature and precipitation are expected to increase along with their attendant risks of heat stress and flooding.

Though the annual total rainfall trends showed a decrease in the past (1985-2015) for both seasons (Figure 8), an increase of rainfall is projected for both seasons for the periods 2020-2040 and 2041-2060. Annual mean temperatures increased in the past (1985-2015) and are expected to continue to increase in the future for both seasons (Figure 9). Climate projections indicate an increase of risks of heat stress and flooding.

The number of CDD serves as an effective measure of extremely low precipitation and seasonal droughts. In the long rainy season, most of the county historically experiences fewer than 50 CDD, while in the short rainy season, the number CDD was lower than 60 days. However, in the future, the county could experience an overall increase of CDD of up to 15 days. Increasing CDD suggests a high risk of droughts in long rainy season throughout the county. In the short rainy season, the future climate could experience an overall decrease of CDD of up to 25 days, suggesting a far less incidence of drought throughout the county (Figure 10).

Flood risk is indicated by P5D. The consequences of higher precipitation over 5 days are more severe than excessive precipitation on a single day and will lead to more frequent flooding events in the future. In the long rainy season, P5D has historically remained low (below 25 mm), with some scattered large values. However, future climate projections indicate that P5D will increase across the county (by 5-25 mm), with the northern and central regions experiencing more extreme rainfalls than the south. Overall increases in P5D suggest increased flood risk by approximately 10 mm throughout the county. Climate projections indicate that the short rainy season will experience P5D increases as well, but at a lower magnitude than the long rainy season. Flood-prone areas in the county often lie along rivers, including the Tiva River in Kitui Rural, the Enziu River in Mwingi Central, and areas around the Thua River in Kitui East (Figure 11).

The 95th percentile intensity serves as an indicator of heavy rainfall (very wet days) and is linked with erosion risks. In the long rainy season, the 95th percentile intensity has historically been high in the northern regions, with some scattered large values in the central regions. Future climate projections indicate that 95th percentile intensity will concentrate in the northern and central regions, suggesting increasing localized erosion risk. The spatial variation in 95th percentile intensity for future years matches closely with P5D index. Areas that are particularly prone to erosion risk include parts of Kitui Rural and Mwingi Central.

The total number of days with a maximum temperature greater or equal to 35°C (NT35) within a season serves as an indicator of heat stress. In Kitui, the NT35 has historically remained low during the long rainy season in the western regions, with no incidence of days above 35°C. However, in the same season, the eastern regions can have 75 or more days. Future climate projections indicate higher values in the eastern regions than the western, but NT35 will also increase drastically in the western regions, suggesting extreme heat events that could last 3-4 weeks.

Moisture stress is estimated as the number of days with ratio of actual to potential evapotranspiration below 0.5. It serves as an indicator of available soil moisture for plants. Higher values of moisture stress reduce the growth of crops in the growing season. Areas in the county that are prone to this climatic hazard include Kyusyani and Ukatse Nguni wards. A comparison of historical and projected trends in Kitui county indicates that moisture stress is expected to change across the county, with our projections indicating that the eastern part of the county will have reduced incidences of moisture stress of up to 7 days or more.

The start of the growing season is estimated based on when the climatic conditions become suitable for crop growth. Historically, the start of the long rainy season's grown season has varied widely between March and May in Kitui County. The second season starts between late September and November. However, future climate projections suggest that the start of the growing season in the eastern regions of the county will move early by a month or more, while some western regions will experience up to a month of delay in the short rainy season. Our future climate projections indicate an overall change of 10-30 days earlier for the start of the growing season in the county.

The length of the growing season is estimated based on the period when the climatic conditions are suitable for crop growth. Historically, the length of the growing season in the county during the first season has always been short. Our future climate projections indicate that the length of the growing season will slightly increase in the eastern and southern regions and decrease in the western regions of Kitui County. In the short rainy season, the length of the growing season is projected to increase from 25 to 30 days. Additionally, it will increase in the western, central, and parts of the northern regions of the county by about 10 days.

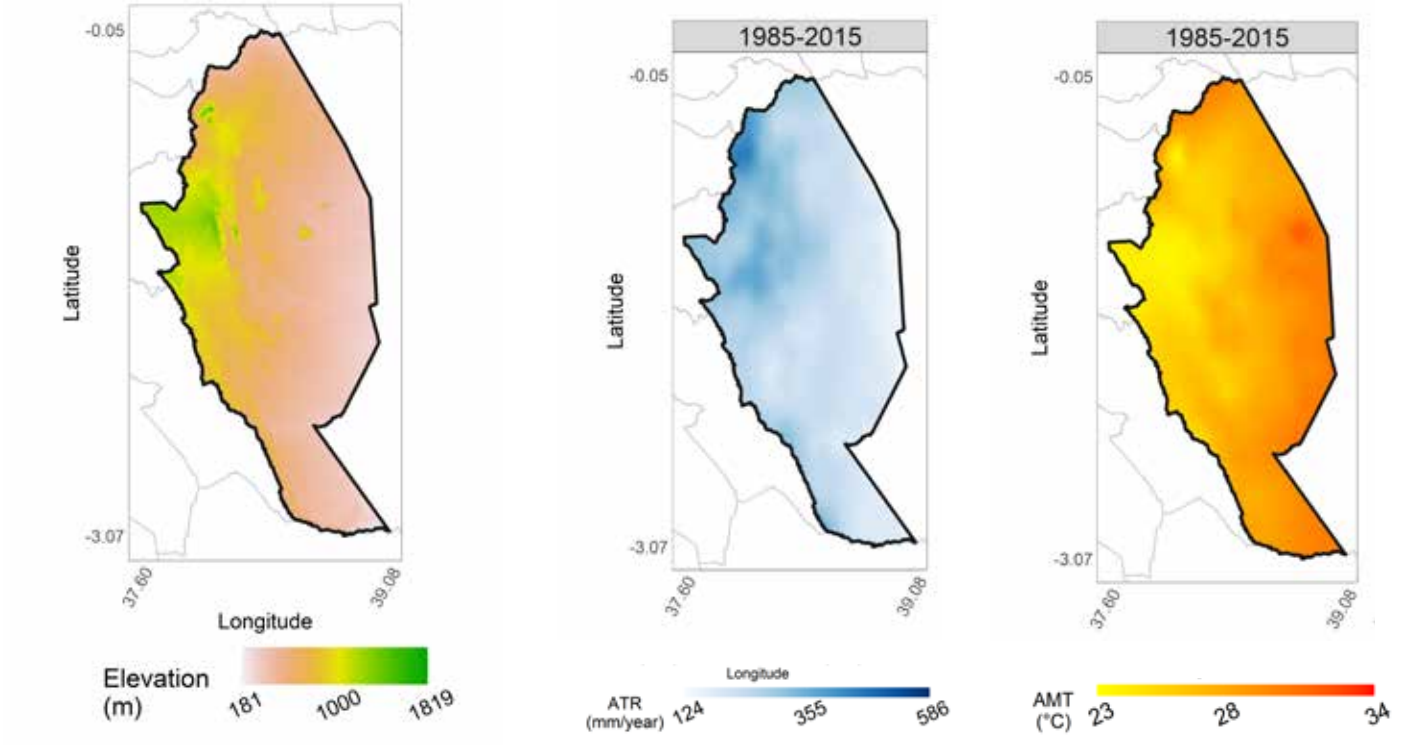

Figure 6: Elevation (left), historical (1985-2015) annual mean precipitation in mm (center) and historical (1985-2015) annual mean temperature in °C (right) for Kitui County for the long rainy season

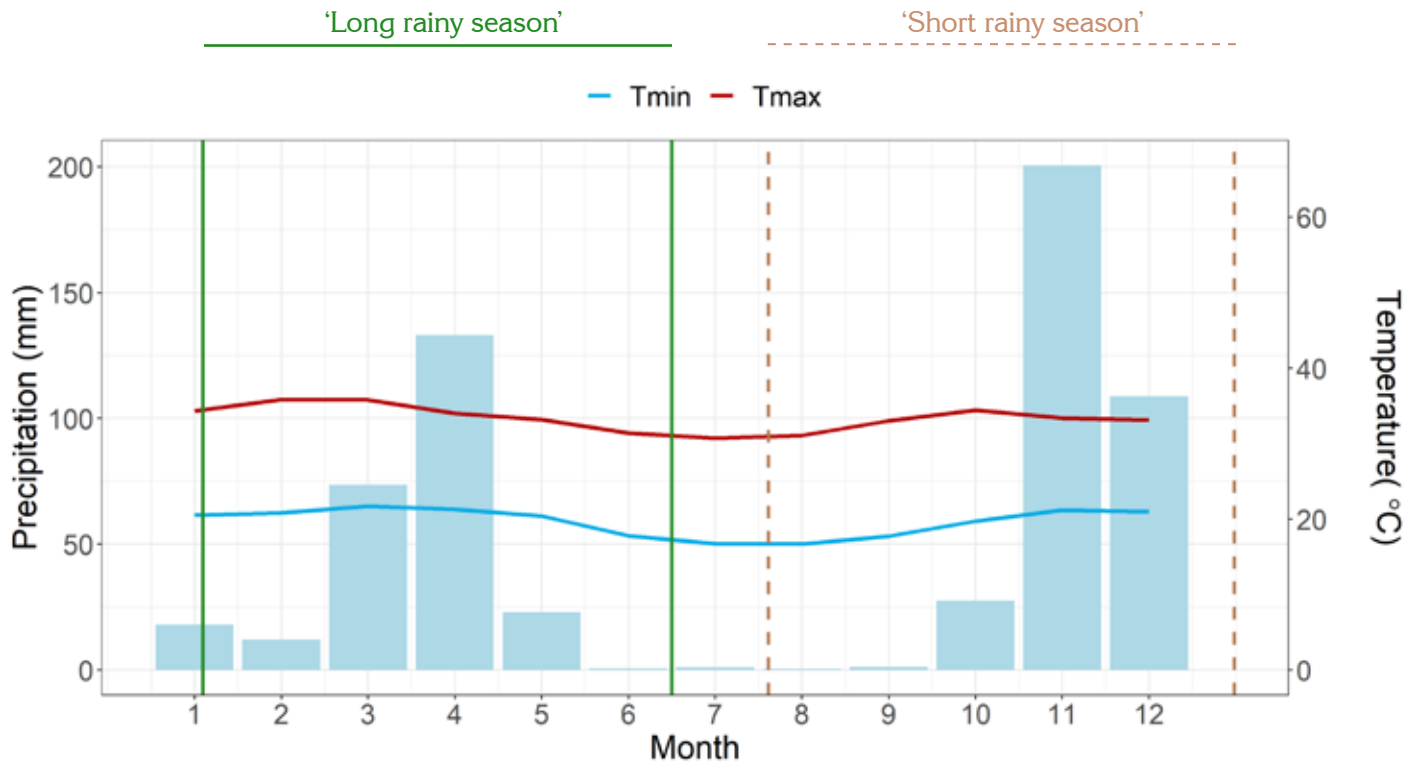

Figure 7: Historical monthly mean temperature and precipitation (average 1985-2015) for Kitui County. The first long rainy season is the 100-day wettest period from January to June, while the second, the short rainy season is the 100-day wettest period from July to December. Bars represent total monthly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

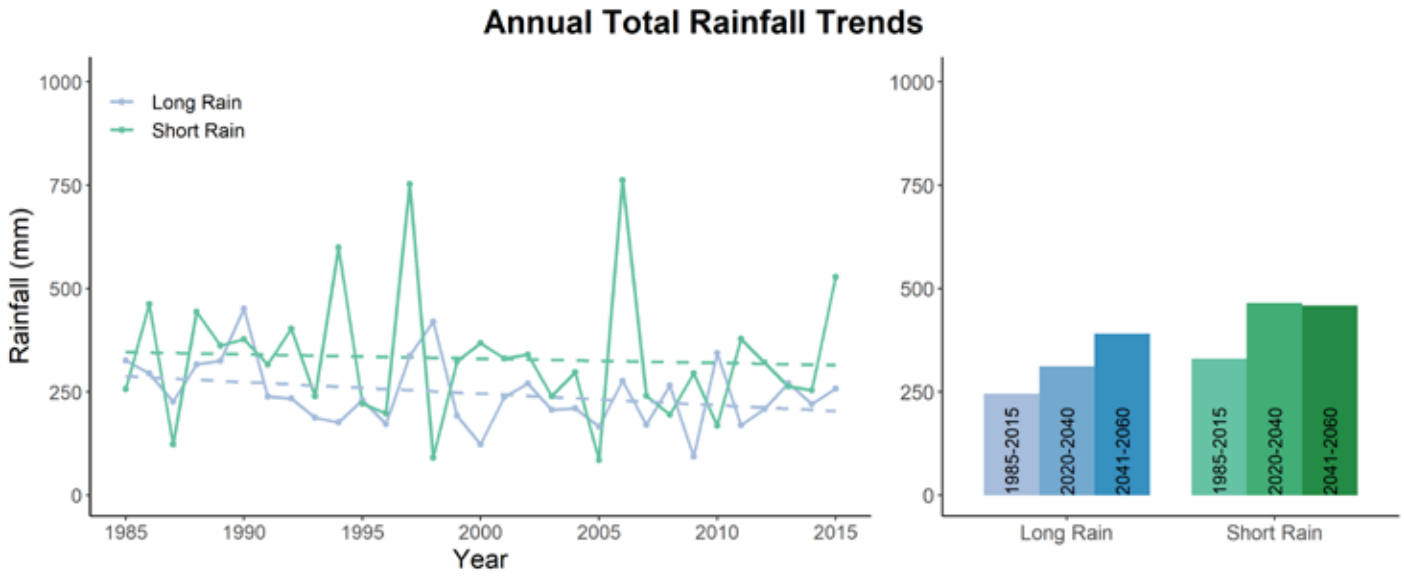

Figure 8: Annual total rainfall trends for the long rainy and short rainy seasons in the past (1985-2015) and in the future (2020-2040 and 2041-2060)

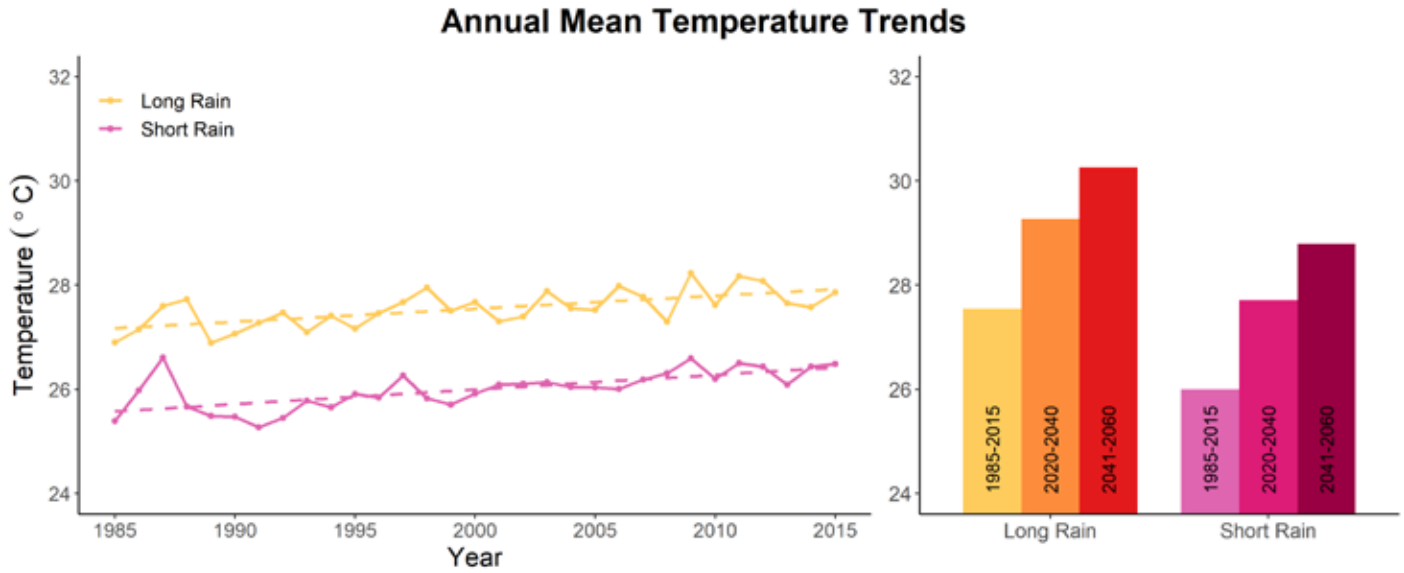

Figure 9: Annual mean temperature trends for the long rainy and short rainy seasons in the past (1985-2015) and in the future (2020-2040 and 2041-2060)

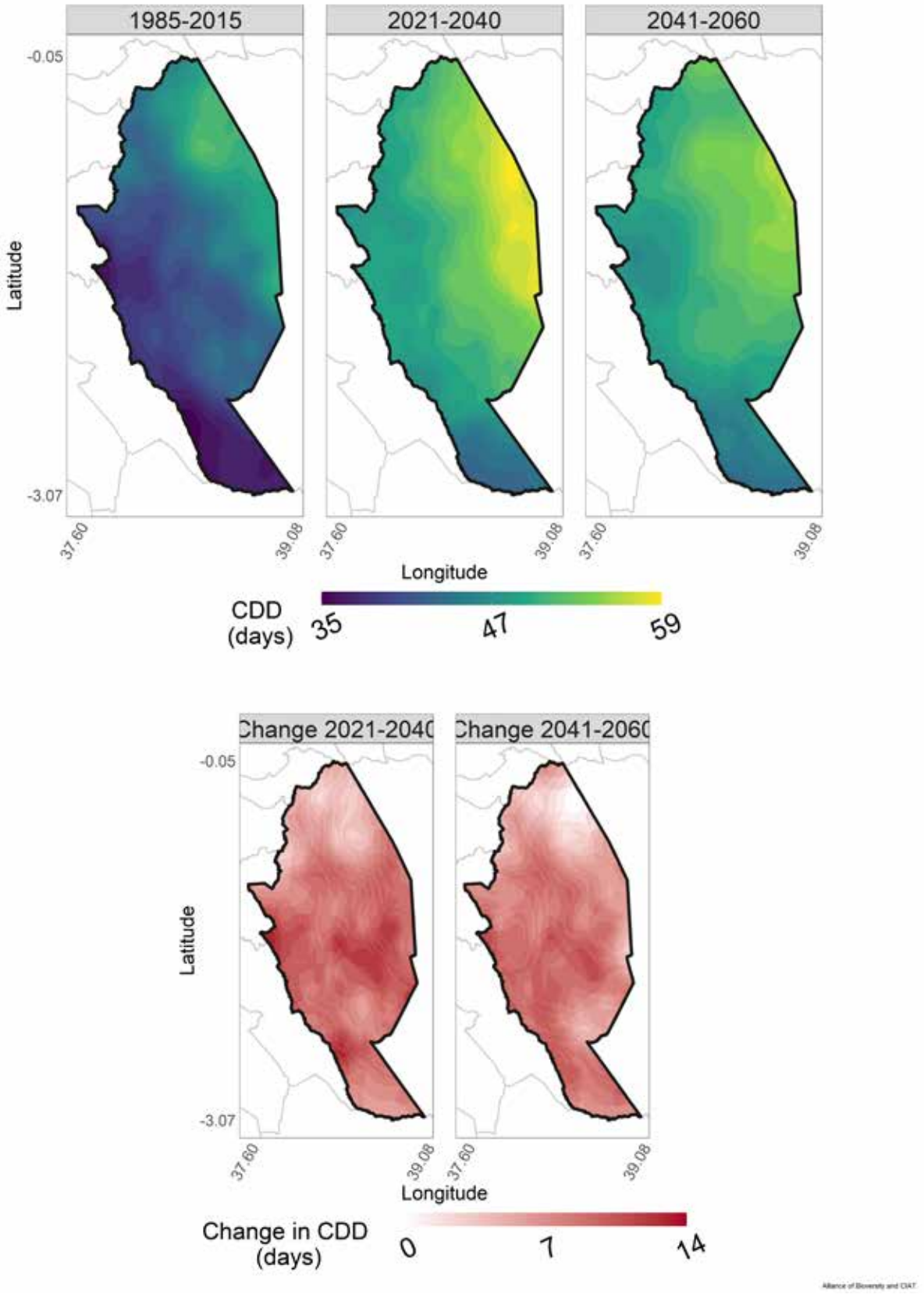

Figure 10: Historical (left, average 1985-2015), future projected (center), and projected change (right) for the number of consecutive dry days for the long rainy season

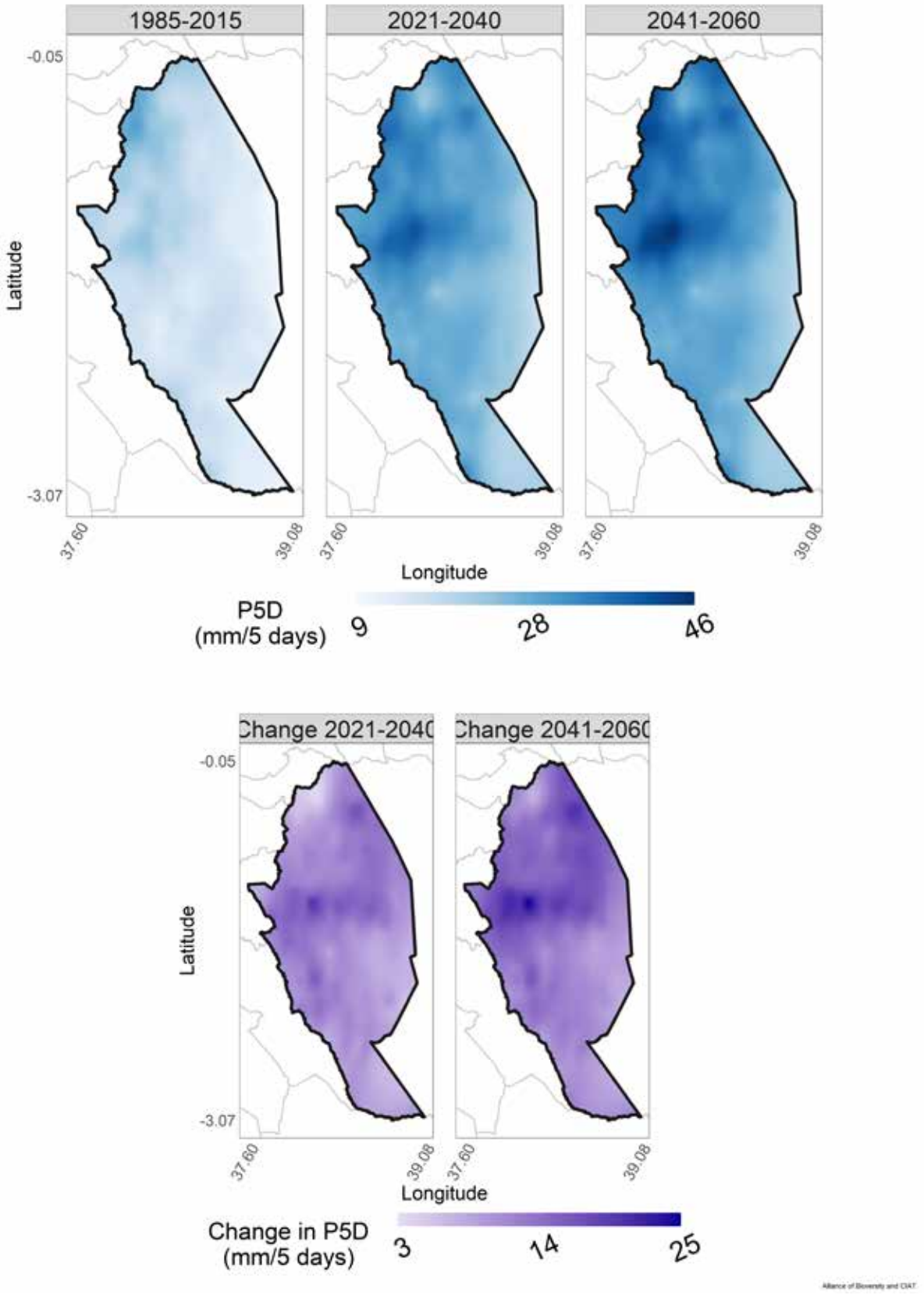

Figure 11: Historical (left, average 1985-2015), future projected (center), and projected change (right) for maximum 5 days running average precipitation in mm for the long rainy season

3.2 Climate Change from Farmers' Perspectives

Focus group discussions were carried out for each value chain in Kitui County. Farmers perceive climate change as a "monster" that has impacted their agricultural activities adversely. They report that the rains have been more erratic over the years. They particularly note severely reduced rainfall that has led to low yields and crop failure, insufficient livestock water requirements, depletion of surface and groundwater irrigation water supply, and depletion of domestic water supplies.

Variations in the onset of rains and the LGP have affected planting calendars. Farmers have noted the shift in rainfall, with the onset moving from the third week of October to the second week of November. The short rains are more reliable than the long rains, so that farmers depend more heavily on the short rains (October-December). This explains the higher food security rate in the county between January and April. Moreover, the length of the growing season has reduced over the years, leading to crop failure.

Water scarcity is another limiting factor in the county. The distance to water sources has increased over the years. County residents in some communities may leave their homesteads at 6 am and spend up to six hours in search of water. Animals can walk 3-12 km for water access—and in extreme cases, up to 20 km. The areas most affected by water scarcity are Kyusyani ward in Kitui Rural and Ukatse and Nguni wards in Mwingi Central. Prolonged dry spells have also led to the drying of rivers and loss of pasture, in turn affecting livestock production. Farmers attest that the impact of water scarcity has been the continuous, premature loss of their livestock, affecting their household income. The depletion of pasture leads to conflicts among the pastoralist communities within the county.

Floods are another serious climatic hazard in the county. Farmers, especially in the lowlands, experience high-intensity rainfall and occasional flash floods.

There is a direct relationship between the increase in temperatures and the occurrence of forest fires, as explained by the farmers during the focus group discussions. Hot and dry conditions exacerbate the likelihood of forest fires igniting and spreading.

Farmers also reported the emergence and high prevalence of pests and diseases in the county, associated with the impacts of dry spells and increased rainfall. For instance, bruchid weevils affect green grams during post-harvest. In the livestock sector, the loss of pasture leads to trans-boundary diseases, highly contagious epidemic diseases that advance swiftly and without regard for jurisdictions. They lead to a high prevalence of livestock illness and an increased number of premature deaths in animals, thus having multiple effects on society, the economy, and public health. Diseases and pests are a continuous threat to the livelihoods of livestock keepers. High-impact animal diseases, such as hoof-and-mouth disease, are common in the county due to livestock migration in search of pasture. This is an acute problem in parts of Mwingi North, Mwingi Central, and Mwingi East.

Farmers attest to diminishing vegetation cover over the years, due in part to drought. Farmers in Kitui South mentioned that their forefathers used to have a lot of beehives with high production, which is currently not the case. Additionally, farmers in Kitui Rural attest to the reduced tree cover on the Mbitini Hills. They associate the reduced vegetative cover with the effects of climate change. Climate change has led to an increase of the degraded land locally referred to as "*Mang'alata*," a situation affecting both biodiversity and the aesthetic value of nature.

The youth are particularly affected by beehive reductions. Honey is a commercialized product in the county and beehives are normally inherited from fathers for sustainable livelihoods. Farmers argue that the reduction of the beehives is a result of climate change impacts and that it has compromised their income levels. Affected areas include Kitui South. Relatedly, climate change affects labor costs, driving them upwards. When households accordingly prefer to engage in family labor, the youths who are reliant on farm labor for income are adversely affected.

3.3 Climate Vulnerabilities across Agricultural Value Chain Commodities

With its reliance on rain-fed agriculture, Kitui County is rendered more vulnerable to climate change and its consequences.

In addition, in the recent past, the locust crisis has had a devastating effect in all sub-counties with Mwingi North and Mwingi Central bearing the brunt of the invasion. These destructive locusts have compounded the challenges of food and nutritional security to the rural households who are dependent on agriculture for their livelihood (Kenya News Agency, 2021; FAO, 2020)

Specific climatic hazards affect Kitui's prioritized value chains in different ways, as detailed below.

3.3.1 Mango

Drought is a limiting factor in the production, processing, and marketing of mangoes. Drought increases the prevalence of pests that attack the leaves, branches, and root systems. The most common pests in the county are fruit flies, including the African invader fly (*Bactrocera dorsalis*), the Mediterranean fruit fly (*Ceratitis capitata*), and the mango fruit fly (*Ceratitis cosyra*). Farmers in the county use pesticides for control, but pesticides can have negative impacts

including health impacts on farmers and consumers from chemical residues. Pesticides also indiscriminately kill beneficial bees and affect the ecosystem (Gill & Garg, 2013). This reduces bees' production, an important commercialized enterprise in the county.

Even though mango trees are drought tolerant, prolonged dry spells cause rapid stomatal closure on the leaves, reducing photosynthesis and affecting the production of the fruits. This has a corresponding negative effect on fruit set, retention, and overall fruit size (Normand et al., 2015). Specific areas in the county, due to their hot and dry characteristics, are more likely to be affected. These include areas in Kitui Rural, Mwingi Central, and Kitui South.

Heavy rainfall is another climatic hazard that affects mango production in the county. Excessive rainfall leads to flooding and waterlogged soils; the vegetative development of mango trees can be so impacted that they perish within a few days (Normand et al., 2015). Mango trees in waterlogged areas are affected by soil-borne fungus (*Phytophthora*) and anthracnose (*Colletotrichum gloeosporiodes*), which reduces their productivity. Additionally, the farmers' costs associated with controlling these pests are usually high.

Heavy rainfall renders the road network impassable, reducing the accessibility of inputs. It further impedes the aggregation, bulking, and transportation of produce to processing facilities and the market.

The mango value chain has also been a casualty of the locust crisis invasion. More than attacking the mango trees so much so that they lose their boughs, the spraying of the locusts with pesticide has also led the disapearance of bees that are key pollinators of mangoes. Therefore, it is expected that the mango production in Kitui County will take a hit as a result of the invasion (National Geographic, 2021).

3.3.2 Green Grams

Moisture stress is a key hazard for green gram production. The best climatic conditions for green gram cultivation are temperatures of 28-30° and moderate rains of 350-650 mm. Areas within Kitui County that lie outside of these ranges are severely affected by low productivity.

The efficacy of many herbicides and pesticides depends on soil moisture. Plants experiencing moisture stress may not respond to foliar-applied chemicals or fertilizer; they may even be damaged by chemical burns. Nutrient utilization and fertilization practices are also influenced by soil moisture status (Wright, 2018). Insufficient moisture can thus lead to wilting, which affects green gram productivity in the county.

Extreme temperature variations are another hazard posed by climate change to this value chain. Extreme atmospheric temperatures in turn affect the soil temperature, which affect the breakdown of parent material into compost and the rate at which micro-organisms work. Soil microorganisms will slow down when it is too hot (above 35°C) or too cold, affecting soil fertility and green gram productivity (Greenlife, 2020).

Extreme temperatures also affect crop growth and development (Greenlife, 2020). If the soil gets too hot or too cold, then the uptake of water and the growth of roots will slow down. High temperatures increase evaporation and lead to reduced produce quality, shedding of leaves, and shattering.

Like most pulses, the moisture content of green grams in storage should not be above 13%. Green grams are very susceptible to bruchid attacks and are best stored immediately after sun-drying, in airtight drums, tins, or gunny bags in a clean, ventilated place. Mixing seed with ash is effective against storage pests, as is treatment with sunflower oil or mixing with neem leaves (Biovision, 2019).

The green grams value chain in Kitui County has been hugely affected by the locust crisis. In 2020, the invasion came at the time of harvest when farmers expected . The insects pulverized the farms turning the lush crops into leafless strands thereby leaving the rural farmers in Mwingi North and Mwingi Central counting losses and impoverished (Standard, 2020).

3.3.3 Indigenous Chicken

Indigenous chickens are adversely affected by drought, which renders them vulnerable to inadequate food and water supplies. Most farmers in the county practice free choice feeding for chickens, in which feed is always available in an unlimited supply. However, droughts cause farmers to ration feed, leading to declines in production and/or stock loss. Drought affects farmers unequally: wealthier farmers are better able to procure or harvest water and to purchase and store supplementary feed.

In the post-harvest stage, drought reduces the shelf life and thus the quality of chicken eggs, consequently affecting household incomes.

Indigenous chicken is also vulnerable to heat stress. Increased temperatures trigger increased infestation of parasites and predatory activity, leading to declines in production and/or stock loss. This increases the financial burden of farmers, who need to construct housing to protect their birds. Additionally, heat reduces the efficiency of vaccination, leading to rising incidences of diseases.

The reduced availability of feed due to heat affects the birds' performance and their overall live weight. Brooding is also impacted by reduced hatchability and survival rates. Post-harvest activities also experience effects like reduced collection of eggs due to spoilage, high predation, and chicken theft. During transportation, mortality rates rise due to the reduced

live weight of the birds. Together, these various impacts lead to reduced prices and low-volume sales at market due to the reduced quality of the birds.

3.3.4. Goat (Meat)

Drought affects goat rearing and production. The hot and dry climate leads to inadequate water reserves and dry pastures, affecting goats' food supply and leading to starvation and premature death. Farmers resort to walking long distances to look for pasture.

In the event of drought, farmers opt to sell the goats to raise cash for their household's food security needs and living expenses like school fees and medical expenses. Other farmers engage in feed conservation and building stores to use when the browse is depleted or practice paddocking.

Value addition in livestock is rudimentary in Kitui County. Farmers with the required knowledge and technology are less susceptible to drought consequences. Farmers are involved in differentiation of goat meat parts (ASDSP, 2014). Others are incorporating traditional knowledge in preservation techniques like smoking and drying with ash.

Conversely, during floods, impassable roads bottleneck the delivery of inputs like vaccines and prophylactic materials. Vaccination is a prerequisite for the survival and the maintenance of goats since traditional herbs are less effective against worms and other pests. At the same time, excessive rainfall also increases goats' susceptibility to death due to drowning, and increased rates of pneumonia, Rift Valley Fever (RVF), foot rot, and other diseases. Wet periods also lead to the thriving of *tsetse* flies. Trypanosomiasis diseases transmitted by *tsetse* flies are common in Kitui County due to its proximity to parks which are breeding grounds for insects. Trypanosomiasis leads to debilitating chronic illness that weakens livestock and reduces their fertility, meat, and milk production.

Floods can destroy housing units for goats, increasing mortality rates of the animals; land degradation through soil erosion reduces feed supply and availability.

4. Adaptation to Climate Change and Variability

4.1 Factors Determining Future Vulnerability to the Impacts of Climate Change

Farmers in Kitui County are vulnerable to climate change. There are underlying factors that increase the sensitivity and exposure of the individual farmers to climate change while at the same time undermining their adaptive capacity. These factors are economic, social, infrastructural, policy-, market-, and education-related, among others.

The poor and the rich suffer the burden of climate change unequally. The poor are unable to procure infrastructure with high operational costs, such as irrigation facilities; pest and disease-management inputs can also have prohibitive prices. Furthermore, because extension services are demand-driven, they are likely to favor the rich, who can afford to seek help from both public and private service providers.

Additionally, education levels help to determine vulnerability. Some farmers' lack of knowledge pushes them to use low-quality crop varieties and practice poor crop management options.

Lowland farmers are more exposed to the risk of floods, drought, moisture stress, and heat stress due to the hot and dry characteristics of their agroecological zones, topography, and soil characteristics. They thus suffer the worst of the consequences that arise because of these climatic hazards.

4.2 Climate Change Adaptation Options

Farmers in the county practice adaptation strategies to address climate risks (Figure 11). These strategies are aimed at using resources efficiently and sustainably towards longer-term livelihood security. The overall cost of taking prompt measures is lower than reacting to climate change impacts as they happen (Shalaby & Aboelnaga, 2017). Some of these practices include adopting drought-tolerant and early maturing crop varieties; adopting drought-tolerant livestock breeds; conserving fodder; soil and water conservation; engaging in conservation agriculture; using zai pits or planting pits; and using water harvesting techniques like dams and water pans.

4.2.1 Ongoing Adaptation Practices

Dry spells lead to feed shortages; farmers have adapted by conserving bumper crops of fodder as hay for use when the stock is depleted. Crops such as maize, sorghum, and Napier grass are used to make hay. Farmers are planting drought-tolerant fodder grass and fodder trees, which require less water to grow. Acacia trees are the primary fodder tree in the area; their bark is mixed with dry grass to feed livestock.

Drought and heat stress lead to feed shortage in the indigenous chicken value chain. Farmers in the county formulate feed using locally available materials like sunflower and *omena*. They are adapting to heat stress and heavy rainfall by constructing improved housing structures and reducing stock to avoid loss. An adequate shelter improves the welfare of the livestock by protecting them from the effects of extreme weather conditions.

The Department of Veterinary Services in Kitui County oversees disease surveillance, health management, breeding, and endemic disease control to ensure high-quality livestock products in the county. Climate change, specifically drought, heat stress, and excessive rainfall, increases the incidence of pests and diseases. Some farmers in the county monitor and evaluate the weight and condition scores of their goats to make nutrition adjustments as needed. Farmers also manage goat and chicken health through vaccination. The overall impact is improved health and increased livestock productivity.

Artificial insemination is an important adaptation strategy in the county. Services are administered by both public and private service providers. Screening done after semen collection prohibits the transfer of venereal disease as compared to the natural mating.

The County Government, with the help of NARIGP and organizations like Dorcas Aid, is promoting the beekeeping value chain. This enterprise has a high potential in the county. Farmers' cooperatives, such as Kamaki Farmers' Cooperative Society in Kitui South, are involved in the processing, packaging, and commercialization of honey. Their adaptation measures include planting sunflowers, encouraging agroforestry and woodlots, the use of modern beehives to reduce heat, and other adaptation options.

In the crops sector, farmers in Kitui County are adopting climate-smart and conservation agriculture practices such as zero or minimum tillage, zai pits or planting pits, sowing cover crops, mulching, and others. The use of minimum or zero tillage increases organic matter retention, encourages nutrient cycling, and increases the amount of water that infiltrates the soil. Farmers are rehabilitating their degraded drylands (*mang'alatas*) using zai pits, farmer-managed natural regeneration, and tree planting in appropriate agroecological zones. Zai pits help to make formerly degraded, hard-pan soils productive; they are filled with organic materials (manure, compost, dry biomass) that increase microbial activities and water infiltration. Traditional vegetables such as cowpeas are used as cover crops for erosion control; to improve soil structure, moisture, and nutrient content; to increase beneficial soil biota; and to suppress weeds.

Given the increase in recurrent, long dry spells in the county, farmers have been planting drought-tolerant or resilient food crops such as cassava, sorghum, millet, and others. Similarly, they are diversifying the crops they plant. Within the same farm, a farmer can have a variety of crops (maize, beans, green grams, sorghum, local vegetables) as security against a single crop's failure due to climatic shocks.

Given unreliable rainfall patterns, farmers are planting early maturing varieties of crops (for example, KAT 00301, KAT 00309, and KAT 00308 in green grams). This practice is also promoted by the county government and non-governmental organizations working to ensure that improved varieties are available through agro-dealers in the county. KALRO Katumani disseminates early maturing varieties of various crops to farmers and provides capacity building on the best practices.

As a result of the sporadic weather patterns, farmers are increasingly using irrigation to augment rain-fed agriculture. Proper irrigation systems can secure uninterrupted agriculture.

Water harvesting is a key adaptation option in the county. Surface water harvesting includes the construction of earth dams, embankment dams, water pans, and sand dams; groundwater harvesting involves boreholes, shallow wells, and subsurface dams. Farmers practice rooftop rainwater harvesting with water tanks: during excessive rainfall events, water can be collected and stored for use in dry periods. Additionally, farmers have shifted from the traditional, grass-thatched houses to iron sheets to facilitate roof water tank harvesting.

Pests and diseases are prevalent during both dry spells and high rainfall events, affecting crop production at the on-farm and post-harvest stages. Farmers in the county engage in integrated pest management, combining innovative practices with traditional knowledge systems to ensure environmental conservation and management. These include the use of biological controls, food bait-based sprays or traps, farm sanitation (deep burying), and the use of ash. Hermetic storage technology is used to prevent post-harvest losses because of storage pests like insects, rodents, birds, and fungi; it also helps produce to maintain quality over longer periods of time. This explains the low adoption of storage pesticides in the county.

The county government is involved in the mechanization of farms on behalf of farmers, for example, subsidized ploughing costs at a rate of KSh 1000, rather than the market price of KSh 2500. This kind of subsidy enables more farmers to engage in agriculture that is limited by the prohibitive cost of mechanization. Subsidized mechanization costs are particularly beneficial for the youth.

4.2.2 Potential Adaptation Options

Climate change is complex; future scenarios predict high temperatures, dry spells, and flood risks in Kitui. Current adaptation options are not sufficient to tackle the complexity of future climate hazards. Potential adaptation strategies that could be implemented in the county include the adoption of early maturing varieties, research and development on seeds varieties and livestock breeds, water technologies at the farm level, crop and livestock insurance to safeguard farmers, and the construction of cold storage facilities (Figure 11). Solutions to marketing challenges

include strengthening farmers' cooperatives, value addition, improving market infrastructure, and radical partnerships and collaborations among key stakeholders.

Early warning systems are important off-farm services that reduce the impact of climatic hazards. However, to be effective, weather advisories need to be localized and downscaled to the level of wards and villages. This can be achieved with additional human resources and a fully equipped RANET studio where weather, climate, and related information can be made accessible to communities in remote areas. One such studio is currently in place but not equipped. Kitui County is large; a properly-equipped radio studio is a feasible pathway towards transmitting weather information to weather stations, rural radio stations, and community centers in remote areas.

The goat value chain—specifically for goat meat—has a huge, currently underutilized potential. County-wide programs and policies can support this value chain with research and training on breed improvement, animal husbandry, health management, disease control, aggregation, and output marketing. Additionally, enhanced record-keeping is necessary for the economic viability of this value chain; farmers should be able to track how their goats have performed to gain insights for improving stock productivity and prudent decision making. The goat value chain also needs affordable, accessible services for veterinary care and artificial insemination.

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 Kitui County

Mango	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Heavy Rainfall Consequences	Heavy rains affect resource mobilization; destruction of infrastructure (e.g. roads) delays training	Flooding and waterlogging impede land preparation; delayed crop establishment; increased difficulty of controlling pest and diseases	Destruction of infrastructure like roads reduces quantity and quality of mango collected; infestation of pests e.g. fruit fly and mango blight	Poor linkage of farmers to buyers; poor mango quality leads to low sales hence low income; high prices at the market due to low supply
Magnitude of Impact	Minor-Severe	Severe	Severe	Severe
Farmers' Current Coping Strategies	Community table banking; organizing funds drives; disaster management response; government procurement and distribution of farm inputs; taking advantage of free training, demonstration, and technical support	Opening drainages; avoiding cultivation in flood-prone areas; training on crop establishment; pest and disease management	Formation of cooperative societies; reliance on donor support; reliance on private enterprise (e.g., motorbikes) for transport; manual collection and carrying; value addition (e.g., processing into flakes)	Farmer-buyer linkages through online platforms; direct sales by farmers; individual price fixing; buyer price fixing; market price fixing
Potential Adaption Options	Upscaling community table banking; encouraging self-reliance; crop insurance; upscaling government provision of free farm inputs e.g. ; hybrid seeds; research and development of better seeds; upscaling training and technical support; cost sharing for extension services; embedding extension services in the private sector	Adherence to weather advisories; upscaling of opening drainage; training farmers to establish crops during low rainy season; enhanced training on and upscaling of technical pest and disease management	Formation of more cooperatives; upscaling and coordinating donor support; upgrading roads and other transport infrastructure; building bridges and drifts; government provision of modern transport facilities; upscaling mango processing technologies	Upscaling online mango marketing and improving farmers' online marketing skills; forming marketing cooperatives for price setting; encouraging farmers to coordinate selling
Underlying Factors	Farmers are unwilling to work together; corruption and petty theft; lack of relevant trainers and training institutions; distance of some farmers from urban centers	Farms on flat lowlands are more vulnerable; soils with poor drainage tend towards waterlogging; lack of knowledge/skills of some farmers	Lack of good road infrastructure; not all farmers aggregate produce or form cooperatives due to social issues; farmers who lack processing skills are more impacted	Compliance with market requirements, specifications, and standards; marketing strategies
Drought Consequences	Lack of sufficient funds for investment; difficulty procuring inputs; resources diverted to other food interventions	Delays land preparation activities; delays flowering and fruiting; increases vulnerability to fruit fall, pests, and diseases; reduces spraying, weeding, and pest/disease control; increases production costs	Very low yields and reduced aggregation; poor quality mangoes which are unsuitable for value addition	Low quantity of mango produced reduces sales and promotion; poor farmer-buyer linkages
Magnitude of Impact	Moderate-Severe	Moderate-Severe	Severe	Severe
Farmers' Current Coping Strategies	Use of community table banking; organizing fund drives and sourcing funds from donors; reliance on county funding; reliance on distribution of free inputs from the county government and development partners; use of free extension services and farmer training centers; holding barazas, workshops, and field days	Use of free or subsidized tractor ploughing provided by county government; contributions from farmers and private enterprises; demonstrations on crop establishment and management; trainings, field days, demonstrations, and research trials on crop management	Formation of cooperative societies; donor and government support for cooperatives; improving community feeder roads; provision of transport services to farmers; promotion of mango value addition and micro-processing technologies	Linking mango farmers to buyers with online platforms/marketing; individual marketing; form cooperative marketing societies; individual price fixing; buyer price fixing
Potential Adaption Options	Promotion of existing microfinance institutions; encouragement of private sector investments; increased funding from national government; increased farmer contribution towards projects; subsidies; increasing extension staff; encouraging public-private extension partnerships; encouraging the uptake of new farming practices	Upscaling tractor ploughing programs; training farmers on early land preparation; sensitizing farmers on new farming and land preparation technologies; upscaling research trials on crop establishment; increasing trainings and tours to improve farmers' practices	Upscaling formation of cooperative societies; supporting cooperatives with equipment; construction of modern storage structures; improvement of feeder roads; encouraging private entrepreneurs to become involved in value chain; upscaling processing technologies; formulating mango processing policy; training farmers on safe handling	Upscaling online marketing and improving farmers' marketing skills; encourage cooperative marketing societies to improving price negotiation capacity
Underlying Factors	Poverty levels reduce farmers' purchase and uptake of inputs; lack of knowledge about mango inputs due to low education levels among farmer and inadequate local technical experts; distance from input access points	Some areas (e.g., Muthaa, Nuu, Seikuru) never have rain; lack of education; expensive land ownership and development rights; high poverty levels	Lack of aggregation due to poor infrastructure or poor social connections among farmers; gaps in processing industries have uneven effects among farmers; developing processing skills may pose a challenge to some farmers	Lack of local marketing societies means that brokers take advantage of vulnerable farmers

Green Grams

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Moisture Stress Consequences	Unproductive land; low yields and poor crop performance; delayed or deferred planting; reduced or skipped spraying	Difficulty in land preparation; pesticide performance is affected, leading to crop injuries and wilting; poor yields	Low volume for bulking; high storage costs; food insecurity due to reliance on crop for household consumption	High commodity prices; reduced linkages due to low harvesting quantity; low sale volumes
Magnitude of Impact	Minor-Severe	Minor-Severe	Moderate-Major	Moderate-Major
Farmers' Current Coping Strategies	Manure application; water harvesting; ripping; attending to traditional and national seasonal weather forecasts; diversifying income-generating activities	Waiting for rains; foliar feed	Traditional processing; storing in new farm stores	Farmers sell everything; consumers look for cheaper alternatives; selling to brokers and local traders; aggregation
Potential Adaption Options	Intensify water harvesting; implement conservation agriculture; integrate traditional and modern forecasts; use of certified and early-maturing seeds; diversifying income sources	Mechanization in land preparation; irrigation where possible; intensifying use of foliar feed; conservation agriculture; use of certified, early maturing and/or drought-tolerant seed	Use of machinery; construc-tion of modern storage facilities; intensifying aggregation	Contract farming; government subsidies; market outsourcing in advance; intensified aggregation
Underlying Factors	Soil type and topography affect moisture retention capacity; impoverished farmers cannot afford to improve the soil; inadequate knowledge on water and soil conservation; high taxation on inputs; lack of incentives for the value chain	Farmers cannot afford to construct water harvesting structures or soil conservation features; inadequate knowledge on water harvesting; beliefs on seed types, fertilizer application, and spraying programs; ineffective and unclear policy on production in the value chain	Inadequate resources for and knowledge about processing and bulking; inadequate machinery for processing and value addition; poor road networks	High poverty levels result from farmers selling at lower prices to gain quick funds; poor access to market information; exploitation by brokers; lack of marketing policy (including for exports); poor road networks; distance to markets and aggregation centers
Extreme Temperature Variations Consequences	High costs due to increase in pesticide use; Beneficial micro-organisms die; salinity increase; produce quality deteriorates; increased pesticide use	Low germination rate; impacted efficiency of chemical inputs; crop scorching; shedding of leaves; ponds dry and shutter	Delay in drying of crops, shattering of pods/seeds; Low volume and poor quality of yields	Low pricing; may not get the ideal market; not easy to get buyers
Magnitude of Impact	Minor	Major-Severe	Moderate-Major	Major
Farmers' Current Coping Strategies	Use of conservation agriculture; agroforestry; use of indigenous technology such as pots for storage	Replanting; repeated spraying with pesticides; early-morning harvest before the green grams completely dries; selective harvesting	Selective harvesting; harvesting and drying outside; Use of ash, guards, and pots for storage; aggregation and sorting	Famers sell at throw-away prices in local markets; selling to brokers and local traders
Potential Adaption Options	Intensify conservation agriculture and agroforestry; improved seed storage; use of integrated pest management	Mulching; conservation agriculture; agroforestry; integrated pest management; proper timing of spraying; improved varieties that mature uniformly; mechanized harvesting	Planting seeds for uniform maturation; mechanical harvesting; improved storage facilities; bulking; mechanization of cleaning; value addition; aggregation	Aggregation; outsourcing markets; contract farming; capacity building; market information research; increased government policy
Underlying Factors	Types of soil and topography; poverty levels prevent farmers from buying excess certified seeds and pesticides; inadequate knowledge for purchase and use of pesticides and inorganic fertilizers; failure test soil; insufficient policy to cushion farmers against input costs	Lack of crop insurance; lack of policy to guide production of value chain; topography types of soil; planting using indigenous ineffective methods	Poorly ventilated aggregation centers and stores; poor road networks; lack of machines for processing; low economic status of farmers; inadequate resources for labor; lack of cereal boards; lack of policy on value addition and insurance against losses; poor coordination between farmers for aggregation or collective bargaining power	Poor farmers are more likely to accept low prices and are not equipped to deal with brokers; farmers have limited access to market information; poor road networks; lack of clear guidelines and marketing policy

Chicken (Local)

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Drought Consequences	Increase in predation; draws down resources intended for chicken housing repair and construction; reduced capital for breeding stock; malnutrition; high cost of production	Reduced production and productivity; increased incidence of disease; high production costs; reduced hatchability and brooding stock	Reduced egg production; increased transportation costs; increased disposing of stock	Increased supply in the market due to increased slaughtering reduces quality; prices are lower hence low income
Magnitude of Impact	Minor-Severe	Minor-Severe	Moderate-Major	Moderate-Major
Farmers' Current Coping Strategies	Housing birds overnight in structures or the home; borrowing amongst individuals; use of NGO support; de-stocking; purchase of feed; domestic consumption	Diversification of poultry (e.g., adding geese); de-stocking; use of traditional herbs; vaccination; reducing the number of eggs for brooding; selecting the best brooders	Improvised laying boxes; daily egg collections; scouting for laying points; increased feed rations; farm-gate selling; trekking to markets; slaughtering proximate to point of sale; selling live birds; slaughtering when temperatures are low	Withholding selling; barter; home consumption; improving the quality of chickens; use of market survey for better prices; selection of good chickens before slaughter
Potential Adaption Options	Proper housing and fencing; increasing the availability of credit services; establishing a breeding unit; feed formulation; breed improvement	Guided diversification of poultry species; enhance feed sources and encourage farmers to do their own feed production; train farmers on vaccination and drug administration; increasing drug/vaccine outlets; supporting extension services; establishing group hatcheries; supporting public-private partnership in breeding programs; supporting extension services to farmers	Improved housing with proper facilities; adoption of controlled free-range farming; establishing egg aggregation centers; formation of farmer groups; improving road networks; contract farming; establishing mobile cold rooms and storage facilities; establish modern meat processing units/facilities	Value addition; enhanced market linkages; enhancing farmers' skills and knowledge on market driven production; focusing on by-products; establishing cold rooms for collection and processing; market scouting and export promotion; establishing collection and fattening units; use of poor quality meat as raw materials for products like sausages and feeds
Underlying Factors	Because chickens are culturally considered to be women's work; funds for construction of structures and provision of inputs are limited	Women are the primary actors in this chain; hazards affect poor/vulnerable groups disproportionately; distance to urban centers affects access to inputs	Women are more engaged in these activities than men; the poor suffer more hazard-related consequences than the rich; proximity to slaughtering points and access to improved roads for transportation of chicken; animal welfare issues	Slaughterhouses are not available in rural areas; low adaptation of strategies; poor market linkages lead to spoilage
Heat Stress Consequences	High cost of construction materials; increased predation and parasite invasion; reduced performance; increased water intake; reduced feed efficiency; reduced general productivity	Reduce vaccine efficiency; increased incidence of disease; reduced hatchability; reduced chicken survival; reduced feed intake; reduced performance	Increased losses; spoilage; increased predation; increased mortality during transportation; reduction in live weight	Losses due to spoilage; reduced slaughtering; reduced incomes; reduced quality; low prices hence reduced income; low demand due to poor quality
Magnitude of Impact	Moderate-Major	Moderate	Moderate-Severe	Moderate
Farmers' Current Coping Strategies	Use of locally available construction materials; farmer-to-farmer cockerel exchange; breed selection and improvement; combination of free-range and backyard systems	Mass intake of poultry; use of locally available herbs; controlled movement; caging chicks; use of drugs; breed improvement	Selling live chickens; slaughter at consumption point; household consumption of eggs; farm-gate selling; transportation at night	Slaughter on demand; slaughter and transport at night; poultry selection; withholding selling until conditions improve
Potential Adaption Options	Linkage to credit facilities; training local artisans; establish breeding units; enhancing knowledge on breed selection and management; creating micro-environments in poultry houses; introduction of heat stress-adaptive breeds	Introduction of thermostable vaccines; improving extension services; establish model farms for training; improving breeds to adapt to heat stress	Improved slaughter points with cold storage; improved egg storage facilities; egg aggregation when weather is conducive; appropriate transportation facilities	Construction of meat processing plants; market-driven production; extension services for husbandry; introduction of heat stress-adaptive breeds; aggregation
Underlying Factors	Farmers are unable to afford better structures; poor access to credit services; inadequate knowledge on feed formulation; high cost of feeds; inadequate extension and support services	Poultry is a driven by women, who have little knowledge of animal husbandry practices; traditional practices on diseases; inadequate knowledge on feed formulation; free-range system exposes poultry to higher risks	Due to poor roads, farmers are affected; limited innovation and technological development; the Covid-19 pandemic further reduced market access	Poultry is the province of women who have restricted access in markets thus hindering marketing; price is determined by brokers (gate keepers) due to surplus

Goat	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Heavy Rainfall Consequences	Topsoil erosion; increased incidence of diseases and drowning; inadequate and expensive labor	Decreased leasing time due to biting flies; poor farm accessibility; disinterested farmers engaged in planting activities; downscaling of husbandry practices	Goats loose condition; increased likelihood of disease transmission; poor road networks	Increased costs; poor market access; Inaccessibility of the slaughterhouses; losses to traders
Magnitude of Impact	Moderate-Major	Moderate	Moderate-Major	Minor- Major
Farmers' Current Coping Strategies	Terracing; planting trees and grass; fencing; vaccination, surveillance, and treatment of diseases; controlled livestock movements; farmers and family providing labor	Utilization of conserved fodder and pellets; use of pour-ons; provision of advice through SMS and calls or Google; use of traditional practices	Supplementary feeding with post-harvest crop residues; livestock isolation and inspection before aggregation; use of vehicles like bicycles, motor bikes, donkeys, ox-carts; spot improvement	Farm-gate sales; backyard slaughter; small-scale slaughter; use of transportation facilities
Potential Adaption Options	Mechanized and ox-plough subsoiling; planting trees; manure application; disease surveillance and vaccination; mechanization of operations e.g. fencing	Stocking fodder by preservation and storage; use of commercial feeds; establishing farmer field schools; early construction of housing structures prior to rainfall	Use of supplementary feeds, concentrates, and mineral licks; livestock inspection; routine vaccination; isolation before aggregation; road improvement and maintenance	Improved market facilities; improved slaughterhouse facilities; accessible slaughter-houses; linking farmers to bulk buyers
Underlying Factors	The high economic status of goat cushions farmers against land degradation; low literacy levels affect farmers' understanding of diseases; aged women and men are more affected in terms of treating animals; farmers with poor health will be more affected in terms of labor provision, treating animals, and digging	Aged women and children are more affected in terms of scaled down husbandry and their inability to handle decreased feeding time; the poor are more vulnerable due to poor infrastructure, catering to feeding time, and scaling down husbandry; the ability of the terrain to absorb water after raining	The poor cannot afford to maintain goats with high body score, increasing the likelihood of disease transmission; low-literacy farmers lack knowledge and have increased likelihood of disease transmis-sion in their flocks; poorly developed roads affect the transportation of goats to market places	Poor mechanisms of awareness creation lead to poor interventions; farmers are exploited due to poor access; limited linkages between farmers and buyers; cartels and brokers act as middlemen; weak or absent cooperative societies
Drought Consequences	Overgrazing; bushfires; low fertility; health deterioration; increased costs of production	Lack of nutritional balance; reduced extension services; inability to cater for expenses	Forced destocking to cater for finances; high costs of living; dusty roads	Price fluctuations; low consumer buying power; increased overhead costs for processing and preservation
Magnitude of Impact	Major	Minor-Severe	Moderate	Moderate-Major
Farmers' Current Coping Strategies	Controlled grazing (paddocking, rotational and communal grazing); supplementation; culling non-producing animals; introduction of novel breeding stock	Feed supplementation; leasing fertile land; using traditional herbs and other cultural practices; self-medication; use of Internet research	Supplementing feeding; targeted selling; brokerage; travelling at night or in early mornings	Decreased sales; immediate disposal of the goats to consumers
Potential Adaption Options	Mechanization; fencing; improved pastures; subsoiling; improved feeding programs; use of modern breeding methods and cross breeding; paddocking; stocking animal feeds in advance	Feed supplementation; government subsidies on agro-products	Planned, seasonally-based culling; formation of cooperatives; enhancing value chain linkages; regular road maintenance; water to control road dust	Improved market linkages; loans from financial institutions and cooperatives; Installation of solar freezers
Underlying Factors	Constraints on farm size and the ability to cater to animals' health affects the poor disproportionately; low literacy levels expose farmers to the effects of low goat fertility; overgrazing leads to increased costs of production; the status of goats as a wealth stature prevents some residents from selling the flocks	Poor cannot afford to pay for extension services; lack of sufficient land size; less literate farmers lack knowledge of required nutritional balance; land practices lock some farmers into specific products; likewise, deforestation limits livestock choice; women and the aged cannot afford to cater for expenses due to the nature to their income sources	The poor are forced to destock due to high cost of living; insufficient policies on road networks and animal handling adversely affects those connected by poor roads disproportionately	Low consumer buying power reduces traders' prices, leading to market price fluctuation; high overhead costs of processing and preservation

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

5. Policies and strategies on Climate Change

Given the far-reaching consequences of climate change, effective policies are essential to achieve deep, long-term reductions in the drivers and effects of climate change and to increase the adaptive capacity of communities by strengthening their climate resilience. Kitui County is adopting several national policies that are geared toward tackling climate change and its associated risks. These policies provide information to help farmers plan, make viable economic decisions, and adapt to anticipated climatic risks (Table 1).

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

Policy	Year	Policy Objective(s) at the County Level	Climate Change Adaptation and Mitigation Interventions	Challenges and Policy Gaps
National Climate Finance Policy	2016	Establishing mechanisms to mobilize climate finance	The Kitui Climate Change Fund seeks to finance climate change resilience Providing funding to mainstream climate change programming and investment	Funding is limited to implementing institutions Inadequate personnel Farmers lack resources to implement adaptation options Farmers lack awareness of mitigation strategies and adaptation options
National Climate Change Action Plan	2013-2017	Increasing forest cover Rehabilitating degraded lands	Construction of dams and water pans in the lowlands Promotion of indigenous species plantations Tree planting Forest Conservation Rehabilitating degraded sites	
National Climate Change Framework Policy	2016	Integrated planning, budgeting, decision-making and implementation Public awareness of climate change responses Research in sustainable management of resources	Currently being finalized Will provide a framework for the development, implementation, management, monitoring, and budgeting of climate change projects, plans, and programs The Department of Environment and Climate Change spearheads the County Environmental Committee	
National Climate Change Response Strategy	2010	Assessing the evidence 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	The use of renewable energy sources Increasing farmers' adaptive capacity Promoting access to affordable and clean energy Promoting the use of solar chicken incubators	
National Forest Policy	2014	Managing forest resources for soil conservation, water biodiversity, and environmental stability Increasing forest cover Rehabilitating degraded sites	The Kitui County Charcoal Management Act of 2014, whose objective is to sustainably use, conserve, and manage forests and trees while promoting community and private participation in forest management Supporting forestry research, education, training, information generation, and technology transfer for sustainable development	
Agriculture Sector Development Strategy	2010-2020	Value-chain oriented approaches Helping agricultural enterprises to become highly productive, commercial, and competitive at all levels	Supporting the development of the chicken value chain through feed formulation Supporting the development of the green gram value chain through post-harvest handling and processing interventions Supporting post-harvest handling development in the sorghum value chain	

6. Institutional Capacity on Climate Change

Having effective institutions with the capacity to withstand and adapt to climatic shocks is a major strength in any county. There are many institutions operating in Kitui County on climate change issues, including the government, research institutions, non-governmental organizations, faith-based organizations, community-based organizations, and the private sector. Institutional arrangements include, financial support, extension services, soil and water management, the availability of weather and climate information, natural resource governance, and others (Table 2).

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

Off-Farm Services	Institutions	Specific Interventions in Kitui	Challenges
Agricultural Research and Extension Services	Kitui Directorates of Agriculture, Livestock, and Fisheries	On-farm demonstrations on new crop and livestock technologies, innovations, and management practices Sensitizing farmers and training them on sustainable land management practices, such as intercropping, conservation agriculture, terracing, water harvesting, composting, and general climate-smart agriculture practices Developing capacity through training on good nutrition practices Artificial insemination services Extension services to the farmers Animal selection suitable to agro ecological zone	High extension officer-to-farmer ratio (1:3392) Significant gender disparities (only 21% of extension officers are women) Inadequate funds limits climate change interventions Inadequate infrastructure to enforce logging regulations and tree-planting initiatives
	KALRO Katumani	Disseminating early maturing varieties of various crops Providing capacity building on the best practices Developing and Disseminating certified seed to farmers	
	Water Resource Authority	Managing the Tiva-Teya sub-region Developing sub-catchment water management plans Collecting data such as sediment load, pollution levels, and siltation.	
	Kitui Agricultural Training Center	Providing training to farmers through on-farm demonstrations	
	Water Resource Users Associations	Protecting and conserving sub-catchment areas	
	National Environmental Management Agency	Supervising and coordinating environmental matters in the county Enforcing environmental regulations Developing county environmental action plans and creating state-of-environment reports Conducting environmental impact assessment and auditing	
	National Drought Management Authority	Environmental conservation Enhancing food security Constructing the Kwandaki Dam Using management information systems to track all activities and influence future planning and implementation	
	Kenya Forest Service	Implements activities related to climate change, farm forestry, and forest conservation Increasing tree cover from 7.2% of the county Holding transition implementation plans with the county government designating its forestry functions	
	Kenya Forestry Research Institute	Providing research and extension systems to promote indigenous species plantations in the county Developing drought-tolerant trees	

Off-Farm Services	Institutions	Specific Interventions in Kitui	Challenges
	Directorate of Environment and Climate change	Coordinating the county environmental committee Bringing together key stakeholders in the conservation around the environment and management of climate change	Lack of robust data collection to effectively plan and implement interventions
	ADRA-Kenya	Constructing sand and earth dams Drilling boreholes Fostering climate-smart water capture at the household level	
	Southeastern Kenyatta University	Technology transfer	
Climate Information Services and Agro-Weather Advisories	National Drought Management Authority	Providing a platform to bring together key stakeholders, share climate information, and package weather advisories Generating and disseminating seasonal forecasts	
	Kenya Meteorological Department	Generating and disseminating climate information in the county	Kenya Meteorological Department lacks an adequate supply of volunteers
	Ministry of Agriculture, Livestock, Fisheries, and Cooperatives	Disseminating weather advisories	
Early Warning Systems and Participatory Scenario Planning	Kenya Meteorological Department	Generating seasonal forecasts through data analysis Integrating traditional knowledge through participatory scenario planning activities	
	Kenya Cereal Enhancement Project	Supporting participatory scenario planning under the auspices of the Climate Change Resilience Agriculture Livelihood window	
	Anglican Development Services	Providing climate information services	
Non-Financial Subsidies	Kenya Cereal Enhancement Project	Identifying crops suitable in Kitui County Providing farm inputs using an e-voucher system	
	County Government	Subsidizing mechanization Subsidizing artificial insemination services	
	Anglican Development Services	Supporting vulnerable farmers with inputs Constructing water harvesting structures	
	Farmers' cooperatives	Giving farmers access to economies of scale Reducing the costs of inputs, storage, and transport through collective negotiation Enabling farmers to improve products and service quality while reducing their risks	
	Dorcas Aid	Supporting bee keeping farmers with input supplies	
Financial Services	Financial institutions e.g., banks	Providing credit facilities to farmers for investing in agricultural activities	
Market Services, Infrastructure, and Linkages	Farmer Cooperatives Imani Multipurpose Cooperative in Mwingi Central (green grams) Yangalyu Green Growers in Kitui Rural (mangoes) KICOPO Cooperative in Kitui Central (local chicken) Kamaki Farmers' Cooperative Society in Kitui South (beekeeping)	Offering farmers more bargaining power by aggregating or bulking their produce, establishing prices, and marketing	

Off-Farm Services	Institutions	Specific Interventions in Kitui	Challenges
	Agriculture Sector Development Support Programme	Linking farmers to markets Providing farmers with market information	Delays in releasing funds affects the proper planning and implementation of activities attributed to bureaucracy and protocols Poor road network affects marketing activities and reduces access to input supplies.
	The Small-Scale Irrigation and Value Addition Project Ministry of Agriculture, Livestock, Fisheries and Cooperatives	Linking farmers to markets Providing value addition	
	RTI International The Kenya Crops and Dairy Market Systems Activity	Improving market access of mango, passion fruits, and dryland crops	
	Caritas Kenya	Building farmers' capacity for marketing Linking farmers to the markets in partnership with private organizations	
	Kitui Development Center	Providing value addition and processing in the chicken, mango, and sorghum value chains Focusing on food security by utilizing appropriate knowledge and abilities among the community	
	Kitui Enterprise Promotion Company Rise Kenya Mwingi Horticultural Sun Sweet Fruit Farm	Mango Processing	

7. Synthesis and Outlook

The four value chains (mango, green grams, indigenous chicken, and goat) represent Kitui County's diverse agricultural landscape. The magnitude of the climate risks analyzed in this report varies across value chains. The most significant climatic hazards in the county are drought, flood risk, and heat stress; these have impacts that include livestock death, decreased productivity, the destruction of farm structures and the loss of produce. Policies and programs coordinated by local, national, and international institutions are aimed at climate change adaptation, yet they face financial, institutional, and infrastructural limitations.

This analysis of the vulnerability of agricultural production systems to climate change concludes that value chains work best when their actors collaborate to produce higher-quality products and generate more income for all stakeholders involved. Value chain actors are connected; an enabling environment needs to be established at all stages for the easy transfer of goods. For instance, increased drought risk, forecast and forewarned by advisories from the Kenya Meteorological Department and National Drought Management Authority, necessitates the development and mass dissemination of early maturing varieties by institutions like KALRO and the Department of Agriculture. It is important to improve the infrastructure that facilitates input supply and post-harvesting activities, including road networks and the distribution of processing plants across the county. The capacity of farmers to engage in value addition activities to increase their household income can be expanded.

Important adaptation strategies that increase the resilience of the agricultural sector are ongoing in Kitui County. These include the construction of water pans, shallow wells, and water tanks; the sowing of cover crops; crop rotation; developing agroforestry systems; and the expansion of drought-resilient crop varieties and livestock breeds. Off-farm services and programs enable the uptake of adaptation options. These include the provision of early warning systems, weather advisories, extension services, and training.

Post-harvest losses are a major setback for agricultural productivity in Kitui County. Storage pests and contamination, low technology use in handling and processing, poor road networks, and a lack of ready markets cause most post-harvest losses. Solving these issues requires focused research on the control of pests and diseases, a clear dissemination plan, capacity building on proper processing, improving road networks, and strengthening market access though farmers' cooperatives and farmer groups. Despite the huge potential of the green gram value chain, processing is currently done at the household level and there are no off-farm storage facilities for green grams in the county. Off-farm adaptation

services will stabilize market prices by adjusting supply and demand, increasing income for farmers, and limiting post-harvest loss.

Climate change is an all-encompassing issue and as such requires coordinated solutions by all actors. The education and private sectors should be invited to participate in climate risk management. Climate change issues can be incorporated into students' curriculum from an early age. Awareness of climate change can be generated using simple tools like vernacular radio stations, barazas, field days, and agricultural shows. Private-sector actors can take advantage of climate change opportunities and expand the participation of the youth through their recruitment to agricultural activities. This has the potential to increase local employment opportunities for the youth thus, increasing household incomes.

Establishing an effective legal and institutional framework provides an enabling environment that incentivizes farmers to transform their agricultural production systems and their livelihoods. Kitui County currently has a water policy and climate change fund aimed at financing climate change resilience; it has also drafted a climate change policy. In agricultural development and climate change interventions, formal and informal institutions increase farmers' resilience, support livelihood diversification strategies, and enhance adaptation options. Key institutions are in place in Kitui County for climate risk management, but they experience financial and human resource limitations. Additionally, routine institutional mapping is necessary to allow the county steering group and county steering committee to efficiently bring all actors on board. Data and information sharing is necessary to avoid duplication of roles, to ensure efficient use of resources, and to enhance activity implementation.

Several institutions are at the forefront of researching new technologies and developing means of dissemination to help farmers to adapt to climate change. However, they face financial, institutional, and infrastructural setbacks. The national government and donors should allocate funds for climate risk management research and development. The county government, on the other hand, should integrate climate change into all development projects and implement environmental protection interventions. Public-private financing options are a viable option to allocate more funds for climate change.

8. Works Cited

ASDSP. (2014). *Agricultural Sector Development Support Programme (ASDSP).* Ministry of Agriculture, Livestock, Fisheries, and Cooperatives. Kenya, Nairobi: Government of Kenya.

Biovision. (2019a). *Green Gram.* Retrieved from https://bit.ly/34k3iFT.

Biovision. (2019b). *Mango.* Retrieved from https://bit.ly/3uo9bfU

County Government of Kitui. (2018). *Kitui County Second County Integrated Development Plan 2018-2022.* Republic of Kenya, Nairobi, Kenya.

Gill, H.K & Garg, H. (2013). *Environmental Impacts and Management Strategies.* Retrieved from https://bit.ly/3bVtfzE

GoK. (2010). *National Climate Change Response Strategy.* Nairobi, Kenya.

Green Life. (2020). *Green Gram Production.* Retrieved from https://bit.ly/3bSxNHm

FAO. (2020). Desert Locust Briefs. Rome, Italy. Retrieved on 30, May, 2021 https://bit.ly/3xlmY8Y

Hamdard, M. S., Rafique, M., & Farooq, U. (2004). *Physico-Chemical Characteristics of Various Mango, Mangifera indica L. Varieties.* Journal of Agricultural Research. Pakistan.

IPCC. (2018). Summary for Policymakers. In IPCC, M. Allen, M. Babiker, Y. Chen, H. de Coninck, S. Connors, et al. (Eds.), Global Warming of 1.5° : An IPCC Special Report on the impacts of global Warming of 1.5° above pre-industrial levels and related global green house gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Geneva : World Meteorological Organisation.

KALRO. (2020). *Green Gram: Disseminate the Newly Released High-Yielding and Drought-Tolerant Green Gram Varieties.* Retrieved from https://bit.ly/3fnjJHX

Kenya News Agency. (2021). Desert Locust Extermination Intensified In Kitui. Retrieved from https://bit.ly/2RSh5Rz

Kitui County Government. (2017). *Short Rains Food Assessment Report*

KMD. (2020). State of the Climate in Kenya 2020.

KNBS. (2016). *Kenya Integrated Household Budget Survey (KIHBS), Basic Report on Well-Being in Kenya.*

KNBS. (2017). *Exploring Kenya's Equality: Pulling Apart or Pooling Together, Kitui County.* Retrieved from https://www.knbs.or.ke/?wpdmpro=kitui-county.

KNBS. (2019a). *Kenya Population and Housing Census, Population by County and Sub-County, Volume 1.* Retrieved from https://bit.ly/3bQAysD

KNBS. (2019b). *Kenya Population and Housing Census Volume II: Distribution of Population by Administrative Units.* Retrieved from https://bit.ly/3oZ6z75

KNBS. (2019c). *Kenya Population and Housing Census Volume III: Distribution of Population by Age and Sex.* Retrieved from https://bit.ly/2SvevAG

KNBS. (2019d). *Kenya Population and Housing Census Volume IV: Distribution of Population by Socio-Economic Characteristics.* Retrieved fromhttps://bit.ly/3voeWLL

Mugo, J., & Musembi, P. (2016). Identification of Suitable Land for Green Gram Production using GIS-Based Analytical Hierarchy Process in Kitui County, Kenya. *Journal of Remote Sensing and GIS.* Vol. 5. Retrieved 27 November 2020, from https://bit.ly/2QSsbp4

National Geographic. (2021). Locust plague hit East Africa. The pesticide solution may have dire consequences. Nairobi, Kenya. Retrieved 28 May, 2021, from, https://on.natgeo.com/3zpMeN1

Navarro-Racines C, Tarapues J, Thornton P, Jarvis A, Ramirez-Villegas J (2020) High-resolution and bias-corrected CMIP5 projections for climate change impact assessments. Sci Data 7(1):1–14. https://bit.ly/34gttNQ

Normand, F., Lauri, P., & Legave, J. (2015). *Climate Change and Its Probably Effects on Mango Production and Cultivation.* Retrieved 27 November 2020, from https://bit.ly/3fnNfNz

Sasol Foundation. (2015). *Green Grams Manual.* Retrieved 27 November 2020, from https://bit.ly/3bW0sv4

Shalaby, H., & Aboelnaga, S. (2017). *Climate Change Impacts on Urban Planning in the Cities.* Retrieved 27 November 2020, from https://bit.ly/3uiLw0t

Standard (2020). One week of untold terror as locusts pitch camp in Mwingi. Nairobi, Kenya. Retrieved 28 May 2021 from https://www.standardmedia.co.ke/nairobi/article/2001358969/one-week-of-untold-terror-as-locusts-pitch-camp-in-mwingi

Taylor, K.E., Stouffer, R.J., & Meehl, G.A. (2012). An overview of CMIP5 and the experiment design. *Bulletin of the American Meteorological Society*, 93: 485-498.

Wageningen Environmental Research. (2019). *Green Grams, Kenya, Climate Change Risks and Opportunities.* Retrieved 27 November 2020, from https://bit.ly/3fNeC2H

World Health Organization of the United Nation. (2015, November 19). Stunting in a nutshell. WHO | World Health Organization. https://bit.ly/2RPEYZZ

World Health Organization of the United Nations. (2019, November 14). Malnutrition. WHO | World Health Organization. https://bit.ly/3oVxCAm

Wright, D. (2018). *Water Use and Irrigation Management of Agronomic Crops.* Retrieved 27 November 2020, from https://bit.ly/3yEwchP

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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: 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 factors such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2018).

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

Climate risk: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as the 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: 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).

Greenhouse Gases: Atmospheric gases responsible for causing global warming and climate change. The major greenhouse gasses are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Less prevalent but very powerful greenhouse gases are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6).

Improved water sources: Sources of drinking water such as water piped into dwellings, yards/plots, public taps/stands, tube wells/boreholes with pump, protected wells, rainwater collection, and bottled water (County Government of Kitui, 2018).

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 the percentage of children between six months and 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, 2015).

Representative Concentration Pathways (RCPs): Four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its Fifth Assessment Report (AR5). The four RCPs, RCP2.6, RCP4.5, RCP6.0, and RCP8.5, are named after a possible range of radiative forcing values in the year 2100 (of 2.6, 4.5, 6.0, and 8.5 W/m2, respectively).

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 and measuring inequality in distribution by using household income and expenditure surveys. The minimum requirement for dietary energy is usually between 1750 and 2030 kilocalories per person per day (WHO, 2019).

Wasted: Shows the percentage of children between six months and 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, 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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