Kenya County Climate Risk Profile: Bungoma County

Highlights

- Agriculture is the main economic activity in Bungoma County, with 78% of households directly involved in farming. It is the main source of food and provides raw materials to agro-industries.
- Bungoma County is in the former Western Province of Kenya. It has two growing seasons that follow the long rains and short rains periods, with a start to the growing season that has usually been in late February or early March.
- Agricultural production has declined over time due to the impacts of climatic change. This has posed a threat to food security: 42% of the population is faced with food poverty.
- Most farmers in the county are reliant on rainfall, which can be unreliable and erratic. Rainfall and temperature fluctuations have led to increased incidents of pests and diseases, which in turn contribute to low crop yields and post-harvest losses.
- Moisture stress, variations in planting seasons, excess and unpredictable rainfall, and high temperatures are the key climatic hazards affecting agricultural production in the county.
- In response to the changing climate, farmers have taken up adaptation strategies for both crops and livestock production. Several organizations support farmers through off-farm interventions and services.
- There is no clear policy framework addressing climate change in Bungoma County, which currently relies on national government policies. In addition, county government departments lack budget allocation for climate change challenges, making it difficult to bridge the gap between adaptation ideas implementation.
- Extensive research on climate change, the formation of more producer organizations, proper and coordinated extension services, subsidies to farmers, insurance schemes, and targeted financing of climate change activities will cushion the population of Bungoma County against climate risks.

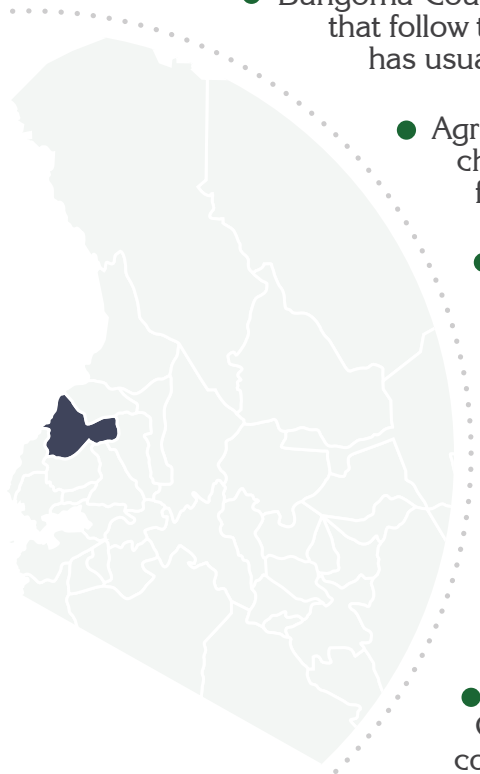

Figure 1: Map of Bungoma County

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List of Acronyms

AI- Artificial Insemination

ASDSP- Agricultural Sector Development Support Programme

CDD- Consecutive Dry Days

CIAT- International Centre for Tropical Agriculture

CIDP- County Integrated Development Plan

CIG- Community Interest Groups

CREADIS- Community Research in Environmental and Development Initiatives

EU- European Union

FAO- Food and Agriculture Organization of the United Nations

GIZ- Deutsche Gesellschaft für Internationale Zusammenarbeit

GoK- Government of Kenya

IPCC- Intergovernmental Panel on Climate Change

KDHS- Kenya Demographic and Health Survey

KFS- Kenya Forestry

KIBHS- Kenya Integrated Household Budget Survey

KIPPRA- Kenya Institute for Public Policy Research and Analysis

KMD- Kenya Meteorological Department

KNBS- Kenya National Bureau of Statistics

LGP- Length of Growing Period

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

NARIGP- National Agriculture Rural Inclusive Growth Project

NCCRS- National Climate Change Response Strategy

NCPB- National Cereals and Produce Board

RCPs- Representative Concentration Pathways

SID- Society for International Development

UNDP- United Nations Development Programme

VCCs- Value Chain Commodities

Bungoma

Foreword

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

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

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

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

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Principal Secretary

State Department for Crops Development and Agricultural Research

1. Introduction

Climate change is becoming one of the most serious challenges to Kenya. The country is currently susceptible to climate-related events, and projections indicate that climate impacts will continue to affect it in the future. In many areas, extreme and variable weather is now the norm. Rainfall has become 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.

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 agriculture 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, 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 in county-level policies, programs, and development plans. Locally relevant, integrated adaptation responses with active involvement of local stakeholders are necessary to achieve this goal.

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

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

The Alliance undertook the assessment in a set of interrelated stages (Figure 2). It first initiated a desk review of the conceptual and analytical contexts of climate change risks at the national and county levels. It made efforts to involve a wide range of institutions that have worked on climate change at the national and regional levels. The team used globally available data sources like the Kenya Open Data Portal and county development plans, and collected information from relevant government departments, such as the Department of Resource Surveys and Remote Sensing, the Kenya Meteorological Department, and the Drought Monitoring Centre. The team also collected data through focus group discussions, key informant interviews with carefully selected experts, climate modeling, and three days of sub-national stakeholder workshops. The final reports were then presented and validated by national- and county-level stakeholders.

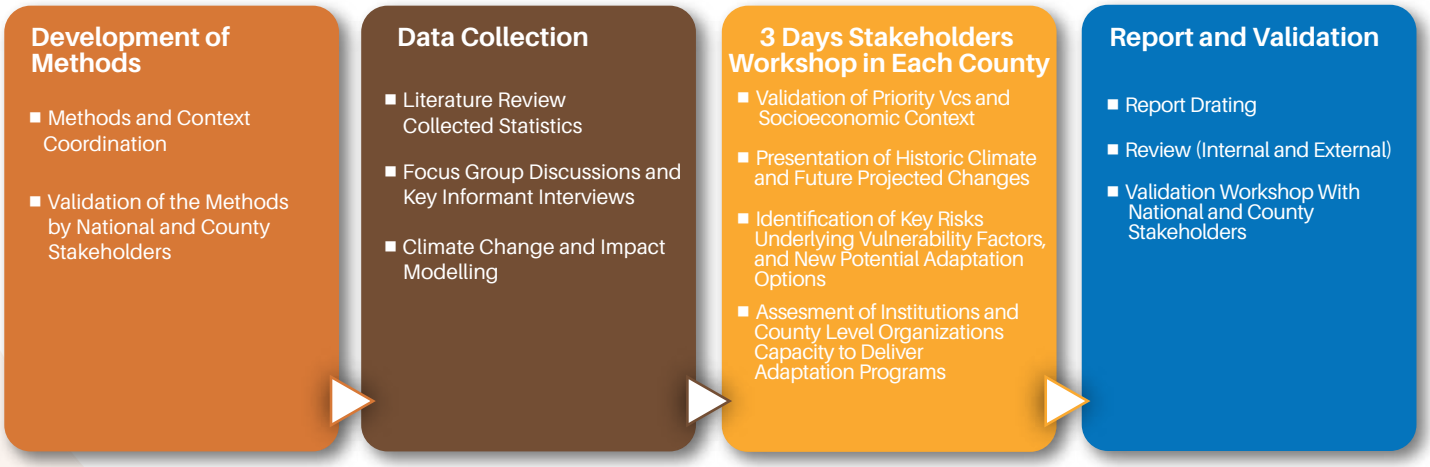

Figure 2: Climate Risk Profile (CRP) development process

This document presents the Climate Risk Profile for Bungoma 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 document's first section offers an overview of the agricultural commodities that are key to food security and livelihoods in the county in the context of major challenges to agricultural sector development in Bungoma. In the second section, it identifies the main climate hazards, based on an analysis of historical climate data and climate projections. This includes 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 local vulnerabilities to the risks posed by these climatic hazards on 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

Bungoma County is located in the former Western Province of Kenya. It borders the Republic of Uganda to the northwest, Trans-Nzoia County to the northeast, Kakamega County to the east and southeast, and Busia County to the west and southwest.

The county covers a land area of 3032.4 km^2, of which 618 km^2 is gazetted forest reserve, 61 km^2 is non-gazetted forest, and 50.7 km^2 is Mt. Elgon National Park. The County's major physical features include Mt. Elgon; Chetambe, Sang'alo, and Kabuchai hills; the Nzoia, Kuywa, Sosio, Kibisi and Sio-Malaba/Malakisi rivers; and waterfalls like Nabuyole and Teremi. The altitude of the county ranges from 1,200 m above sea level to 4,321 m above sea level at the summit of Mt. Elgon (County Government of Bungoma, 2018).

2.1 Economic Relevance of Farming

Agriculture is the backbone of Bungoma County, with 78% of households engaged in crop and livestock farming (KNBS, 2019b). About 50% of people living in the county earn their income directly from the agricultural sector, compared to 44% of the national population in Kenya (KNBS & KIPPRA 2013). Likewise, there is 48% of the employed labor force in small-scale agriculture (Mwendia & Notenbaert, 2018). Agricultural activities serve both subsistence and commercial purposes.

The major food crops in Bungoma County are maize, beans, finger millet, sweet potatoes, bananas, Irish potatoes, and assorted vegetables. Sugar cane, cotton, palm oil, coffee, sunflowers, and tobacco are grown as cash crops. The main livestock include cattle, sheep, goats, donkeys, pigs, poultry, and bees. The average land carrying capacity is 3 Tropical Livestock Units (where one unit is the equivalent of 250 kg) per acre. Indigenous chicken and cattle are the livestock most commonly kept by families. The average on-farm income is Kenyan Shilling (KSh) 48,635. The mean annual on-farm income for male-headed households is KSh 49,881 and that of female-headed households is KSh 33,486 (ASDSP, 2014). Compared to a national average of 35%, in Bungoma County the share of household income spent on food stands at 38%.

2.2 People and Livelihoods

Bungoma County has a population of 1,670,570 people, of which 49% are males and 51% are females (KNBS, 2019a) (Figure 3). The population density is 454 people/km^2, making the county the fifth most populated in Kenya. This already sizeable population is projected to grow by 22% by the year 2022 (KNBS, 2016). There are a total of 358,796 households, the average size of which is five individuals (KNBS, 2019a). Approximately 90% of the population live in rural areas. However, urban population is projected to grow to above 15% in the medium term, due to sustained rural-urban migration (County Government of Bungoma, 2018). Children (0-14 years old) constitute 49% of the total population, while the 15-34 age cohort represents 33% (KNBS, 2016). The percentage of residents with no formal education stands at 14% while 10% have attained primary education and 19% have a secondary or higher-level education (County Government of Bungoma, 2018). The literacy level stands at 88% in the county for people aged 15 years and above.

Absolute poverty is widespread in Bungoma, standing at 52%; the rural poor accounts for 53% and 42% of the population is food poor (County Government of Bungoma, 2013). Population living below the poverty line (US$ 1.90 a day) in Bungoma is 47% accounting for 0.46% of the national share. 72% of residents in Bungoma County have access to potable water (Mwendia& Notenbaert, 2018, KNBS & SID, 2013). Potable water sources in the county include protected springs, protected wells, boreholes, water piped into dwellings, and rainwater collection. The portion of the population without access to these sources relies on ponds, dams, lakes, streams/rivers, unprotected springs, unprotected wells, and water vendors. The water service provider in Bungoma County is Nzoia Water and Sanitation Company. Rural water schemes are operated by the County's Department of Water and Irrigation through its field water officers. At 22%, nearly a quarter of residents in Bungoma County use electricity as their main source of lighting, while 36% use solar lighting. Firewood is employed as cooking fuel by 78%, while only 0.4% use electricity as a source of fuel for cooking (KNBS, 2019b).

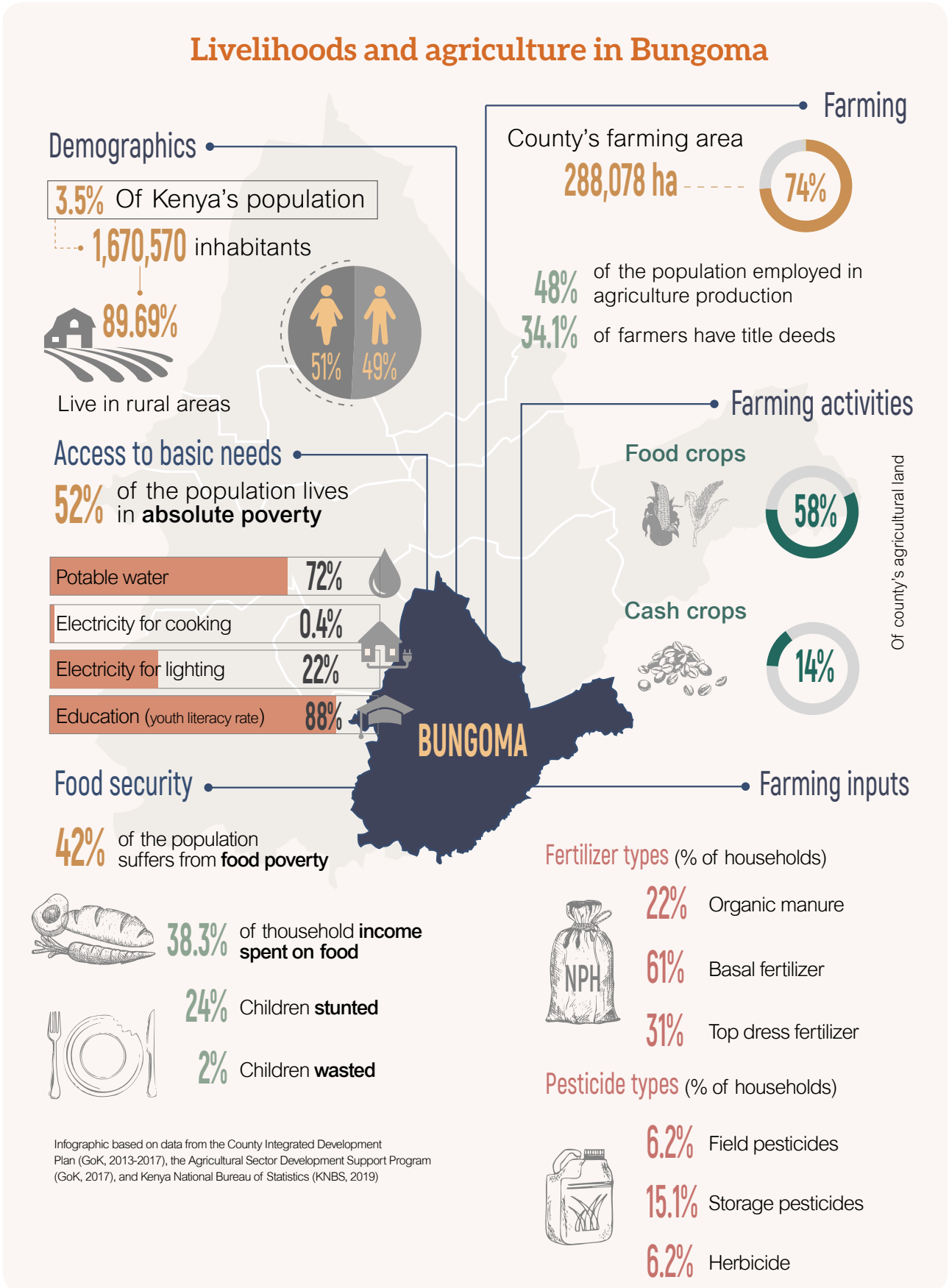

Figure 3: Agriculture and livelihoods in Bungoma County

The level of food insecurity in the county stands at 42%. Around 24% of children under five years are moderately or severely stunted, compared to a national average of 26%. The population of children under five years who are wasted (moderate or severe) stands at 2%, compared to a national average of 4%, Children under five years who are underweight stand at 9% against 11% at the national level. Moreover, children who are overweight or obese stand at 3%, compared to the national average of 4% (County Government of Bungoma, 2018, KNBS, 2014). Malnutrition is attributed to poor diversification of food sources, including an overdependence on crops such as maize. The county, however, produces enough food for both consumption and sale to other parts of the country.

2.3 Agricultural Activities

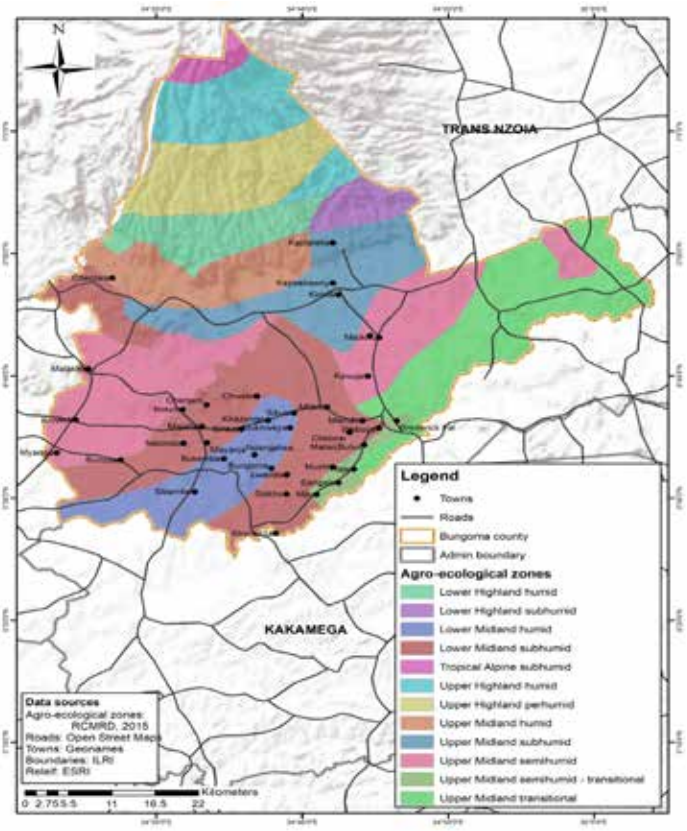

Figure 4: Agroecological zones of Bungoma County

Bungoma County has a total land area of 303,240 ha, accounting for approximately 0.5% of the total land area in Kenya. Of this, 223,269 ha (73.6%) is arable land (KNBS, 2019b). About 58% of arable land is under food crops while 14% is under cash crops; pastures take 15% and fodder take about 5% of land (Mwendia& Notenbaert, 2018). Most of the agricultural activities are rain-fed, meaning that farmers only plant during the rainy season. 280,445 households, or 78% of all households in the county, are involved in farming (KNBS, 2019b). Good soils and favorable climatic conditions play key roles in making the county a leading producer of some of the most important crops in Kenya, such as maize. The county has four main agroecological zones (Figure 4), namely: Upper Highlands (UH1- UH3), Lower Highlands (LH1-LH3), Upper Midlands (UM1-UM4) and Lower Midlands (LM1-LM2) (County Government of Bungoma, 2013).

- Upper Highlands 1 (UH1) are mainly moorlands, Upper Highlands 2 (UH2) are heath lands, and Upper Highlands 3 (UH3) are mainly forest lands. These zones have moderately deep, dark reddish-brown, stony clay loam and friable clay loam soils.

- Lower Highlands 1 (LH1) in Bungoma County are areas where tea, dairy, maize, wheat, and pyrethrum thrive. On the other hand, LH2 and LH3 are coffee and tea zones. The entire Lower Highlands of Bungoma County have brown to dark-brown acrisol soils

- Upper Midlands 1 (UM1) are marginal sugarcane zones; UM2 are coffee and maize zones; UM3 are sunflower and maize zones; and UM4 are cotton and sugarcane zones. The entire Upper Midlands have dark red to red nitosol, ferrasol, and brown to dark brown acrisol soils.

- Lower Midlands 1 (LM1) is a cotton zone, while LM2 comprises marginal sugarcane areas. The entire Lower Midlands have brown, friable, sandy clay loams and dark yellowish- brown sandy soils.

The annual rainfall in the county ranges between 400-1800 mm, while annual temperatures vary between 0 and 32 °C. The average farm holding size in Bungoma County is 2.5 acres for small-scale farms and 10 acres for large-scale farms. However, variations do exist in Mt. Elgon and Tongareni sub-counties, with large farms of between 10-50 acres. Only 34.1% of land parcels in the county have title deeds, whereas 65.9% of households reside on ancestral lands with no official documents of ownership (KNBS, 2007). The major inputs used by farming households in the county are certified seeds (90%), planting fertilizer (61%), top-dressing fertilizer (39%), and manure (22%). Only about 1% of the farmers use irrigation water. A high number of households (62%) use farm machinery and equipment in their agricultural activities. Of these, 49% use oxen ploughs while 19% use tractors (ASDSP, 2014). The percentage of all farming households in the county using pesticides is 6.2% for field pesticides, 6.2% for herbicides, and 15.1% for storage pesticides. Adult females provide the largest share of family labor in crop production, while adult males provided the most for livestock production. Hired labor for livestock production is dominated by youth (ASDSP, 2014). In terms of population, Bungoma county has 62,009 exotic dairy cows; 9,822 exotic beef cattle; 279,428 indigenous cattle; 78,494 sheep; 109,693 goats; and 1,191,092 Indigenous chickens (KNBS, 2019b).

2.4 Agricultural Value Chain Commodities

There is a broad diversity of agricultural production systems in Bungoma County. Various value chains have been prioritized for development interventions by different government organizations and programs, such as the County Integrated Development Plan (CIDP), the Agricultural Sector Development Support Program (ASDSP), the Kenya Agricultural and Livestock Research Organization, the University of Nairobi survey, and the Kenya Agricultural Productivity Program. For the development of this profile, four major value chain commodities (VCCs) were selected for in-depth analysis, based on their contribution to food security, their productivity characteristics, and their importance to the economy. A provisional list was presented to stakeholders during a 3-day workshop for in-depth analysis and selection. The selection was further honed using a set of criteria agreed upon by 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 in the VCC of economically and socially vulnerable groups (poor, women, and youth) (low to high). Each value chain was assessed against all criteria, then the VCCs with the highest percentage of population involved and highest involvement of the poor, women, and youth were selected. The VCCs selected by this process for this report are maize, beans, indigenous chickens, and dairy cattle.

2.4.1 Maize

Bungoma County is the fourth largest producer of maize in Kenya, after Trans-Nzoia, Uasin Gishu, and Nakuru counties; it thus contributes a large percentage of the country's annual maize production. Maize and beans account for about 90% of the estimated household income from crops in the county. Total production is approximately 258,000 tons per year, with a value of about KSh 6.7billion (ASDSP, 2014). An estimated 81-100% of the county's population is involved in the maize value chain, with a total of 262,063 households engaged in maize production. This constitutes 93% of the total farming households in the county (KNBS, 2019b).

At the input acquisition stage, the key activities are the purchase of clean and certified seeds, fertilizers, and pesticides. Suppliers of these inputs are mainly small- and medium-scale agro-dealer shops. Kenya Seed and Western Seed companies are among the large-scale seed companies which distribute certified maize seeds to the agro-dealers. The government of Kenya contributes to the supply of fertilizers at subsidized prices through the National Cereals and Produce Board (NCPB).

Most farmers prefer to grow maize during the long rains and on lands where production thrives—mainly in the Lower Highlands and Upper Midlands of the county. Most maize-producing farmers are small- or medium-scale, with 0.5-10 acres of land under maize. The few large-scale farmers who practice maize farming (on holdings over 10 acres of land) are found in areas of Tongaren sub-county. Maximizing maize yields requires good agricultural practices, including soil testing, proper land preparation, proper weeding, pest control, and harvesting at the right maturity index. Women and youth are the main actors in providing labor at the farm level.

Post-harvest losses can be minimized through proper post-harvest management activities such as threshing, drying, grading, and storage. Maize grains require drying to 13% moisture content levels (KCEP, 2016). Storage of maize in hermetic bags, which increase the shelf life of the grain by protecting it against storage pests such as weevils, is a growing practice in the county. Maize is processed into flour for home consumption primarily by local posho mills, although the county has some large-scale maize millers such as Webuye and Tongareni Millers.

Maize markets in Bungoma County are dominated by exploitative middlemen. Other buyers include millers, institutions (schools, hospitals, etc.), and the NCPB. Maize prices are highly volatile year to year. Most buyers revolve around the prices set by the NCPB. Middlemen buy at lower prices, but small-scale farmers prefer to sell to them because they buy at the farm gate and thereby reduce farmers' transport costs. Additionally, pressing household needs can lead to urgency in selling the produce to brokers. Household finances are mainly controlled by men; their engagement at the input and output stage is very high.

2.4.2 Beans

Most maize producers in Bungoma county also grow beans. Together, beans and maize account for 90% of the estimated household income from crops in the county. The total production of beans is approximately 35,000 tons per year while the value of production is about KSh 1.8billion (ASDSP, 2014). About 61-80% of the county's population is engaged in the bean value chain, the majority of which are those who intercrop beans with maize. However, a few farmers grow beans in pure stands, and a small minority intercrop them with perennial crops like coffee. In Bungoma County, 222,747 households, or 79% of the total farming population, grow beans (KNBS, 2019b).

The main activities at the input acquisition stage include extension services and obtaining seeds, fertilizer, and pesticide. Medium- and small-scale agro-dealer shops are one-stop points selling these inputs. Most farmers still use reserved seed from previous crops, especially for beans; therefore, seed suppliers are mainly small-scale farmers who either sell to other farmers or use the seed in their own farms. Thanks to

capacity building initiatives, bean farmers are gradually shifting to planting certified seeds. Women are the key players across all the stages of the bean value chain, particularly as the suppliers of seed from the previous crop.

Beans are primarily grown by small-scale farmers. Soil testing, analysis, and land preparation are necessary to facilitate a suitable environment for bean planting and growth; good agricultural practices promote optimal growth and development to maximize production. Most bean varieties in the county are harvested three months after planting.

Industrial processing of beans does not take place in the county. However, post-harvest activities like drying, cleaning, grading, and proper storage are conducted by producers in preparation for the market. As with maize, farmers are increasingly adopting the use of hermetic bags for storage to prevent pests.

Farmers in Bungoma County mostly grow beans for subsistence, but a few (especially those who grow in pure stands) do it for commercial purposes. Markets are unstructured and are mainly controlled by middlemen. Bean production is still far below its potential in the county. More research on high-yielding varieties and better support of farmers through capacity building is therefore necessary. NARIGP is promoting beans as a one of its value chains in Bungoma County.

2.4.3 Indigenous Chicken

There are a total of 197,318 households who keep livestock in Bungoma County. Out of these, 161,433 households, or 82%, rear indigenous chickens (KNBS, 2019b). About 81-100% of the county's population is involved in this value chain, most at a small-scale level. There are a total of 1.2 million local chickens in the county (KNBS, 2019b), with a total value of about KSh 596 million (ASDSP, 2014). Poultry is kept so widely because it is easy to manage through free range production, its feeds are readily available, and it is a key product with a huge market across the county.

Good housing structures are a prerequisite for raising chickens. The key activities during input acquisition include the purchase of chicks, feeds, and vaccines. Suppliers of feeds and vaccines are mainly small-scale agro-dealer shops. Day-old chicks are supplied by individual farmers and Community Interest Groups (CIGs). A few producers source their chicks from other counties. Men are the active participants at this stage, as they mainly control the household budgets.

Most chicken farmers are small-scale, although there are exceptions. Women are the main contributors to on-farm activities (brooding, cleaning housing structures, feeding, and vaccinations in cooperation with vet officers). Chickens are susceptible to Newcastle disease, *gumboro*, fowl pox, and chronic respiratory disease, most of which can be prevented through vaccination. Post-production activities include slaughtering, packaging chicken products (eggs, meat), and transportation to the market. The main markets are neighboring households, shops, supermarkets, hotels, and other institutions. Producer organizations, such as Sirisia Poultry Cooperative, have been formed to draw resources and strengthen the value chain.

2.4.4 Dairy Cows

The dairy cattle value chain is one of the most vibrant sectors in Bungoma County. Between 41-60% of the county population is involved in the production of dairy cattle. 32,344 households own a total of 62,009 exotic dairy cattle; 113,733 households own 279,428 indigenous cows (KNBS, 2019), with a total value of KSh 6.7 billion (ASDSP, 2014).

Some of the important activities to initiate dairy farming include the acquisition of breeding stock and the acquisition or lease of land for planting fodder and sourcing planting material—although not all farmers plant their own fodder. Men are actively engaged in input acquisition. Small- and medium-scale agro-dealer shops supply feed supplements, acaricides, and fodder seeds. Adoption of artificial insemination (AI) methods is rising dramatically, driven both by the need to improve breeds and by expanded capacity facilitated by different stakeholders.

Dairy farmers are mainly small- and medium-scale, with herds of 20 cows or fewer; the scale is the same for both indigenous and exotic breeds. The bulk of dairy cattle's feed intake is fodder like Napier grass, hay, and Brachiaria. Fodder cultivation, management, and silage making are key components of dairy production in the county; women and youth play the biggest roles at the farm level with their involvement in activities like planting fodder, fodder storage, feeding the cows, spraying against ticks, and transportation of milk.

Milk processing is well structured, from on-farm processing activities up to organized dairy cooperatives. Big processors like Brookside and New Kenya Cooperative Creameries have set up milk collection centers in most areas of the county. These processors, who make products such as yogurt, cheese, and butter, are instrumental in dairy value addition.

Farmers and cooperative societies are both involved in selling milk. Marketing raw milk through formal channels has led to increased incomes for smallholder farmers in Bungoma County. In contrast to the past, when most farmers sold their milk to the hawkers who dominated the informal market in the county, partnerships with large milk processors have guaranteed farmers' income from milk sales. Milk processors participate in growing campaigns to train farmers on methods to increase milk production, such as investment in fodder crops and pasture grasses.

The dairy cooperatives in the county include Bumula Dairy Cooperative and Namwela Dairy Cooperative. These have been instrumental in helping farmers to acquire inputs at lower prices, coordinating the marketing of milk, building the capacity of their members, and adding value to milk products. The county government has also come up with a strategic dairy plan instrumental to developing dairy enterprise in Bungoma.

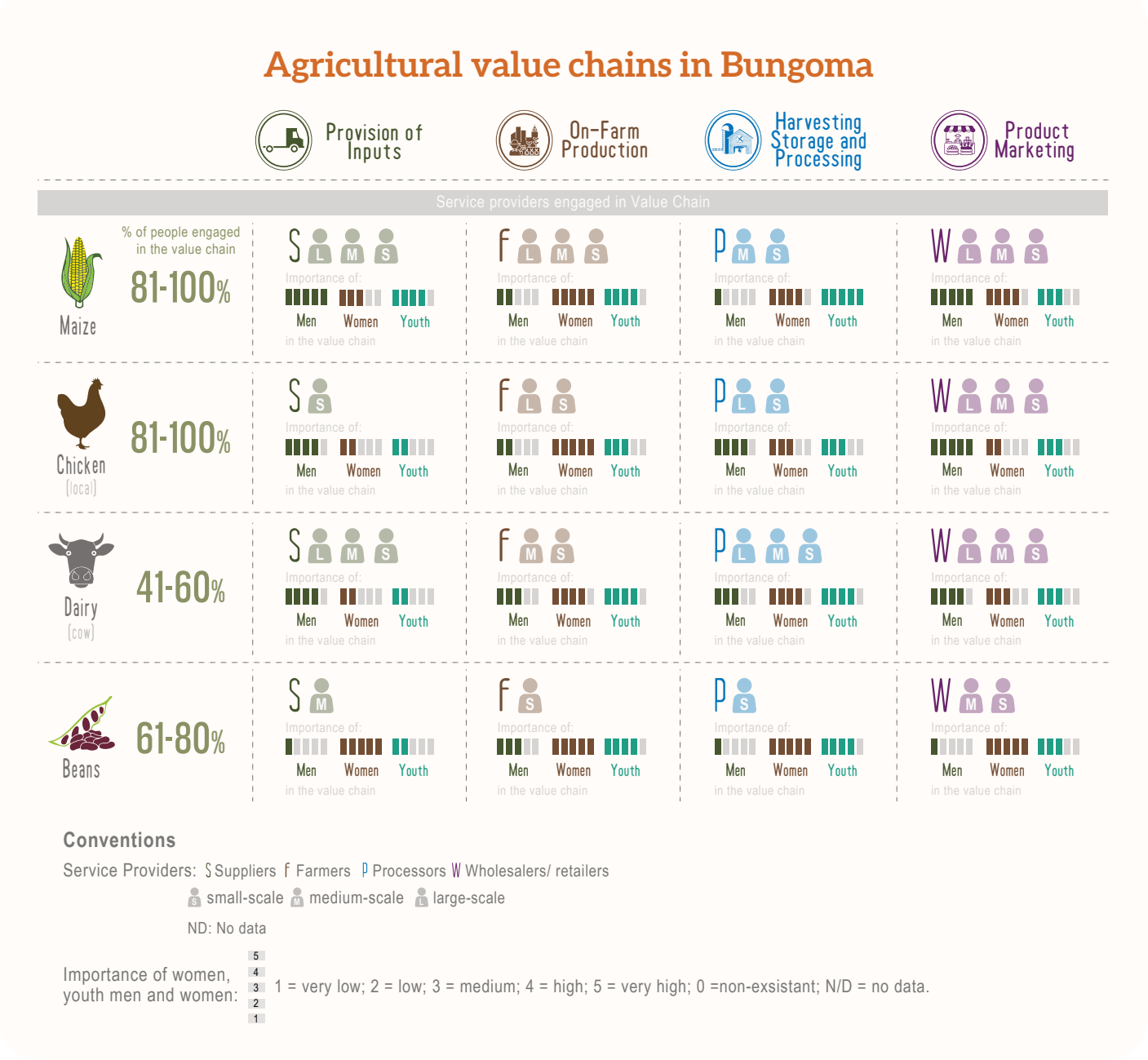

Figure 5 : Characterization of selected value chains in Bungoma County

2.5 Agriculture Sector Challenges

Production, economic, and social factors challenge agriculture in Bungoma County. Population pressure has been a major constraint, contributing to a decline in agricultural productivity due to the fragmentation of land into small units. National land use policy provides a framework to address this issue, but in Bungoma County, there is insufficient control over land fragmentation and enforcement of agrarian zone policies. Some parts of the county also have unutilized arable land.

Most farmers are over-reliant on rainfall, which can be unreliable and erratic. Rainfall and temperature fluctuations have led to the emergence and increased

incidence of pests and diseases, such as fall armyworms and locusts, which in turn contribute to low crop yields and post-harvest losses.

Most farming technologies are expensive; due to resource constraints, most farmers in the county cannot afford to adopt them. Low levels of modern technology application and innovation also contribute to low productivity. Inadequate capital and demand-driven research have also been major setbacks to the agricultural sector.

Poor farming methods and continuous cultivation are among the major drivers of declining soil fertility in Bungoma County. Moreover, weak enforcement of regulations regarding cultivation on steep slopes and encroachment into forests, especially in Mt. Elgon sub-county, has contributed to catchment degradation and soil erosion. Most parts of the county have inadequate storage facilities and improper handling of farm produce is rife, contributing to increased losses during pre- and post-harvest stages.

Market access and marketing infrastructure in Bungoma County are poorly organized, further disadvantaging the agricultural sector. Poor infrastructure and distribution networks reduce access to farm inputs and increase costs. Poor road infrastructure networks in the rural areas increase the costs of transportation, reducing farmers' profit margins. Resources access, ownership, and control are inequitably distributed at the household level and across the agricultural value chains in the county.

Weak implementation of policies, strategies, standards, and regulations in the agricultural sector is a key challenge in Bungoma County. Data availability has been insufficient to support policy planning and weak monitoring and evaluation systems have contributed to slow growth in the agricultural sector. In addition, inadequate extension services, due to a high farmer-to-staff ratio, has contributed to weakened support systems for smallholder farmers. Available extension personnel, furthermore, often lack access to emerging knowledge on modern farming practices.

The livestock sector shares most of these challenges. Its specific, additional, challenges include poor livestock nutrition, the prevalence of animal diseases, and low-quality herd or flock genetics. These are often the result of inappropriate production systems and poor management by farmers, who prefer the traditional, extensive free-range production system because it is cheaper. However, this system depends on rainfall patterns and is therefore vulnerable to climate risks that affect both water and fodder supplies for the animals.

3. Climate Change and Agriculture: Risks and Vulnerabilities

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

We used Representative Concentration Pathway (RCP) 8.5, one of the four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth Assessment Report (AR5) in 2014. Future climate projections were generated based on an ensemble of multiple CMIP5 models (Taylor et al., 2012), using RCP 8.5 for two future periods: 2030 and 2050.[1]

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, indicative of floods, and 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 adequacy of rainfall and soil moisture to meet the potential water requirements for agriculture, focus was placed on drought stress, represented by the number of consecutive days in each season where the ratio of actual to potential evapotranspiration (ETa/ETp) is below 0.5. This was calculated for each pixel per season per year by evaluating soil's water capacity and evapotranspiration in order to define the number of days that could undergo this level of stress.

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

3.1 Climate Change and Variability: Historic and Future Trends

Historically (defined as 1985-2015), Bungoma County has had monthly temperatures of 15-29°C. The long rains season, which runs between February and June, is wetter than the second rainy season, experienced between late July and December. A dry season (characterized by fewer than 80 mm rainfall) is experienced from December to February. April and May receive the highest rainfall (more than 200 mm per month). The annual average precipitation in the county is 1100-1700 mm. Most of Bungoma County receives an annual average precipitation of more than 1400 mm. The annual average temperature range for Bungoma is between 10-25°C, although elevation affects temperatures and most of the land area experiences an annual average temperature of more than 20°C. The eastern part of the county, primarily Tongaren and Webuye sub-counties, is the driest, receiving less than 1000 mm of average rainfall every year. The northern part of the county, covering the Mt. Elgon region, is significantly cooler than the southern parts (Mainly covering Bumula and Kanduyi sub-counties), with temperature differences on the order of 10°C or more (Figure 6 and 7).

The total annual rainfall has remained stable since 1985 and is expected to decrease slightly until 2040. A slight increase is expecting from 2041 to 2060 for the long rainy season. For the short rainy season, the trends show an increase since 1985 which will continue (Figure 8). The mean annual temperatures trends show an increase since 1985 for both seasons and these will continue in the future (Figure 9).

Bungoma County has two growing seasons that follow the long rains and short rains periods. Between 1985-2015, the start of the first, long rains growing season was between early February and late March. This pattern is expected to continue. The growing seasons in the western regions (mainly covering Sirisia sub-county) have historically begun earlier when compared to the eastern regions (Mainly covering Tongaren and Webuye sub-counties). However, future climate projections suggest that this will equalize somewhat; the first growing season in the east will start sooner, while some parts in the northern regions (Mainly Mt Elgon sub-county) will experience up to 3 weeks of delay. The start of the second, shorter growing season is expected to experience significant delays of 40 to 120 days from its historical period.

Historically, the LGP in the long rains season was more than three months in Bungoma County, with some areas in the center and south reaching up to five months. However, future climate projections indicate that LGP will drastically decrease throughout the county (Figure 10). Some locations will experience the loss of more than two months of suitable growing days in the long rains season. Although the LGP of the first growing season seems to have stabilized, it is not expected to increase from this point. It is projected that there will be significant reductions—up to 100 days—in the length of the second growing season.

The number of days with moisture stress in the county has historically ranged between 20 and 40 (Figure 11). Historical and future trends indicate that the number of days with moisture stress will increase across the county by 11 to 19 days in the first season. The eastern regions (Mainly covering Tongaren and Webuye sub counties), will experience significantly higher moisture stress than the rest of the county. In the future, days with moisture stress will frequently reach 40 or more. In the second season, there is a projected reduction in the number of days with moisture stress in most areas except in the north, where projections indicate a moderate increase of about 4 days.

From 1985-2015, the number of CDD has shown slight overall increases with a few extreme years, leading to variation between 5 and 15 days. The eastern regions (mainly Tongaren and Webuye sub-counties) experienced more than the southern (Mainly covering Bumula and Kanduyi sub-counties) and western regions (mainly covering Sirisia sub-county). The future climatic projections indicate a significant increase in CDD, which will frequently be in excess of 20 days. Increasing length of CDD leads to high risk of droughts in the long rains season during the period of 2020-2040. However, the number of CDD is expected to decrease after the year 2040 due to increase in rainfall. Future climate projections also indicate that the spatial trends in CDD will remain the same. Northern (mainly Mt Elgon sub county) and eastern regions (Tongaren and Webuye sub counties) will experience 15-20 days of CDD. In the short rains season, there will be a slight decrease in CDD in northern (mainly covering Mt Elgon sub county) and western regions (mainly covering Sirisia sub-county) of the county but significant increase in variability in future periods.

The total number of days with maximum temperature greater or equal to 35°C (NT35) for a season is an indicator of heat stress. In the long rainy season, NT35 has historically remained extremely low with no incidence of days above 35°C. Annual risks were also low: historically, most years experienced 5 days or fewer of these extreme temperatures. However, future climate projections indicate that NT35 will increase drastically in the southern regions (Mainly covering Bumula and Kanduyi sub-counties), suggesting extreme heat events that could last up to 3 weeks (see Figure 10). In the second rainy season, it is projected that there will be an increase of about 6 days with temperatures above 35 degrees annually in the southern regions (Mainly covering Bumula and Kanduyi sub-counties).

The P5D measure serves as an indicator of flood risk. In the long rains season, P5D has historically remained low (below 20 mm), with some scattered large values. Future climate projections indicate that P5D will increase significantly across the county (by 3-9 mm), with northern regions (mainly Mt Elgon sub county) experiencing more extreme rainfall events than the southern regions (Mainly covering Bumula and Kanduyi sub-counties). Overall increases in P5D suggests more flood risk throughout the county. The hydrological consequences of higher precipitation over five days are more severe than extreme precipitation on a single day: increased P5D will lead to more frequent flooding events in the future in the first season. In the second season, it is projected that there will be an increase in rains in all the regions of around 8 to 12 mm.

The 95th percentile of daily precipitation for a season is an indicator of heavy rainfall and is therefore linked with the erosion risk. In the long rains season, 95th percentile intensity has historically been high in the northern regions (mainly Mt Elgon sub county), with some scattered large values in the central (Mainly Kabuchai sub- county) and southern regions (Mainly covering Bumula and Kanduyi sub-counties). During the period of 1985-2015, the 95th percentile risk trended downward, with most years recording values between 20-25 mm. Future climate projections indicate that 95th percentile intensity will concentrate in the northern regions (mainly Mt Elgon sub county), suggesting increasing localized erosion risk. Future climatic projections indicate a decreasing trend till 2030, followed by a steady increase. In the future, it is expected that the long rains season will become wetter, especially in the northern regions (mainly Mt Elgon sub county). In the short rains season, it is projected that there will be an increase in the 95th percentile of daily precipitation of around 2-7 mm, mainly in the southern regions (Mainly covering Bumula and Kanduyi sub-counties).

Recently insect pests such as locusts have become frequent affecting crop productivity in Bungoma. For instance in 2019 locusts were first spotted in Kimilili, Tongaren, Mt. Elgon and Bumula constituencies. Majority of farmers had just started preparing their land for planting season. However, the emergence of locusts spread panic among farmers, as they feared destruction of the crops (i.e. maize and beans) by the swarms at an early growth stage. The insects seized planted grass reducing feeds meant for dairy cows (FAO,2021).

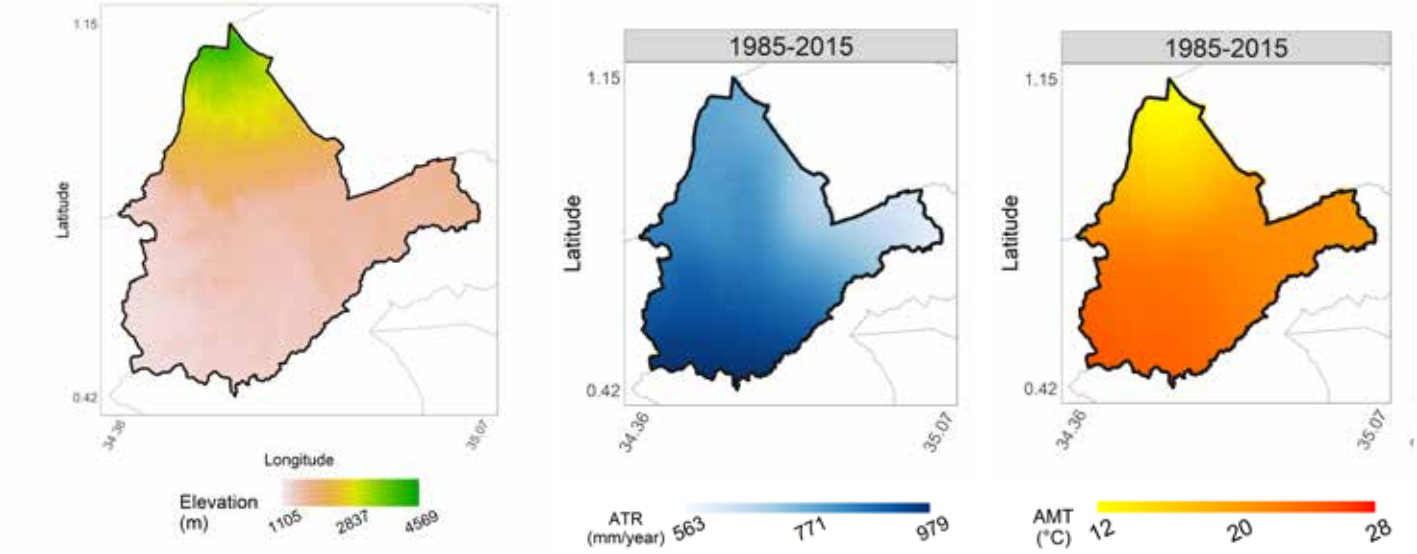

Figure 6: Elevation (left), historical annual mean precipitation in mm (center), and historical annual mean temperature in °C (right) for Bungoma County for the long rainy season

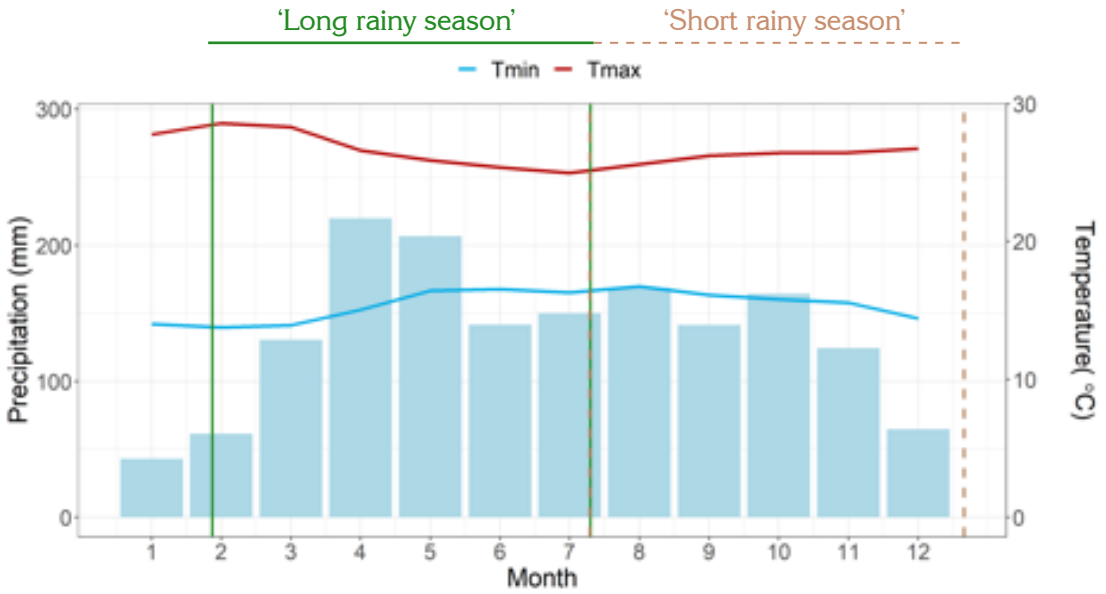

Figure 7: Historical monthly mean temperature and precipitation (average of last 30 years) for Bungoma County. The first long rainy season is the 100-day wettest period from January to June, while the second, the short rainy season is the 100-day wettest period from July to December. Bars represent total monthly precipitation and lines represent maximum (red line) and minimum (blue line) monthly mean temperatures.

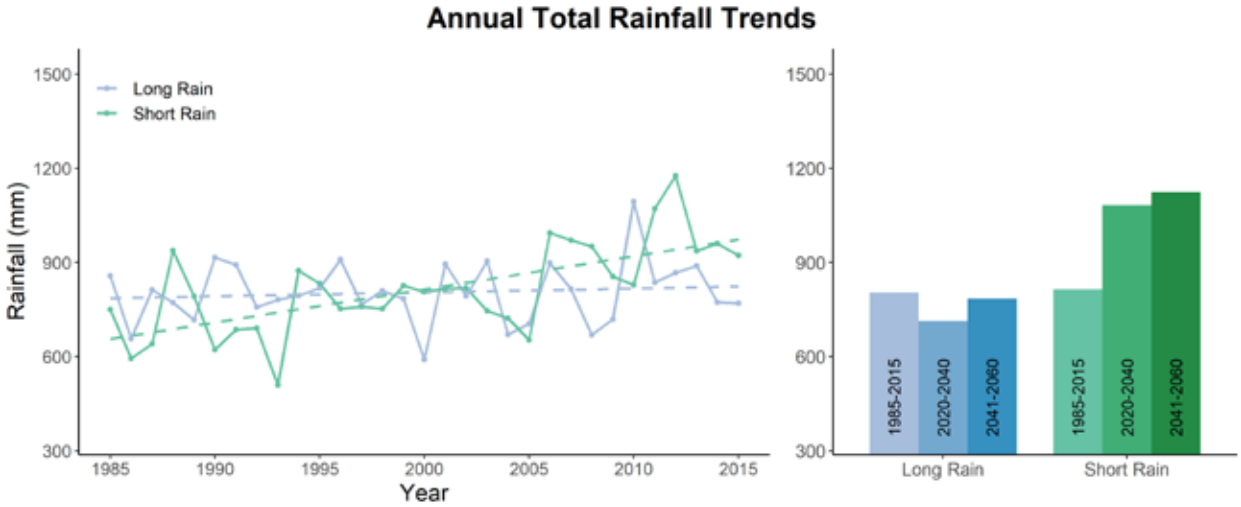

Figure 8: Annual total rainfall trends for the long rainy and short rainy seasons in the past (1985-2015) and in the future (2020-2040 and 2041-2060)

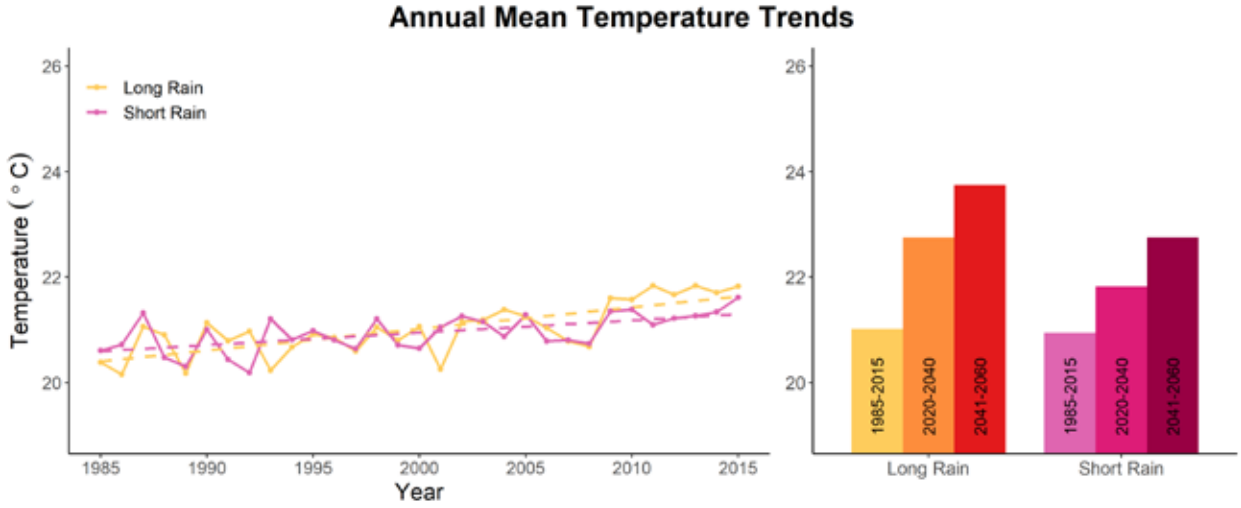

Figure 9: Annual mean temperature trends for the long rainy and short rainy seasons in the past (1985-2015) and in the future (2020-2040 and 2041-2060)

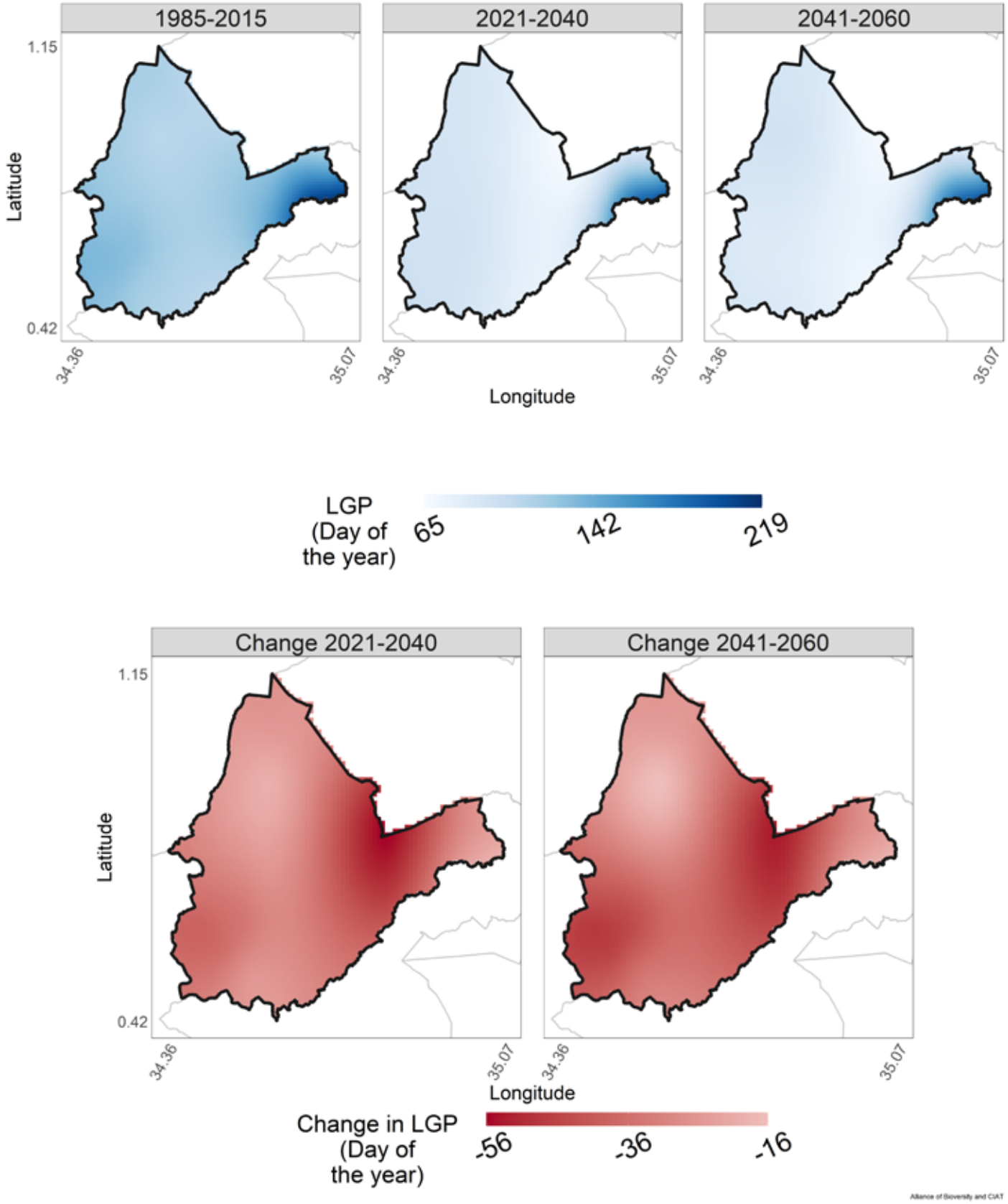

Figure 10: Historical (left, average 1985-2015), future projected (center), and projected change (right) for the length of the growing season (days) for the long rainy season

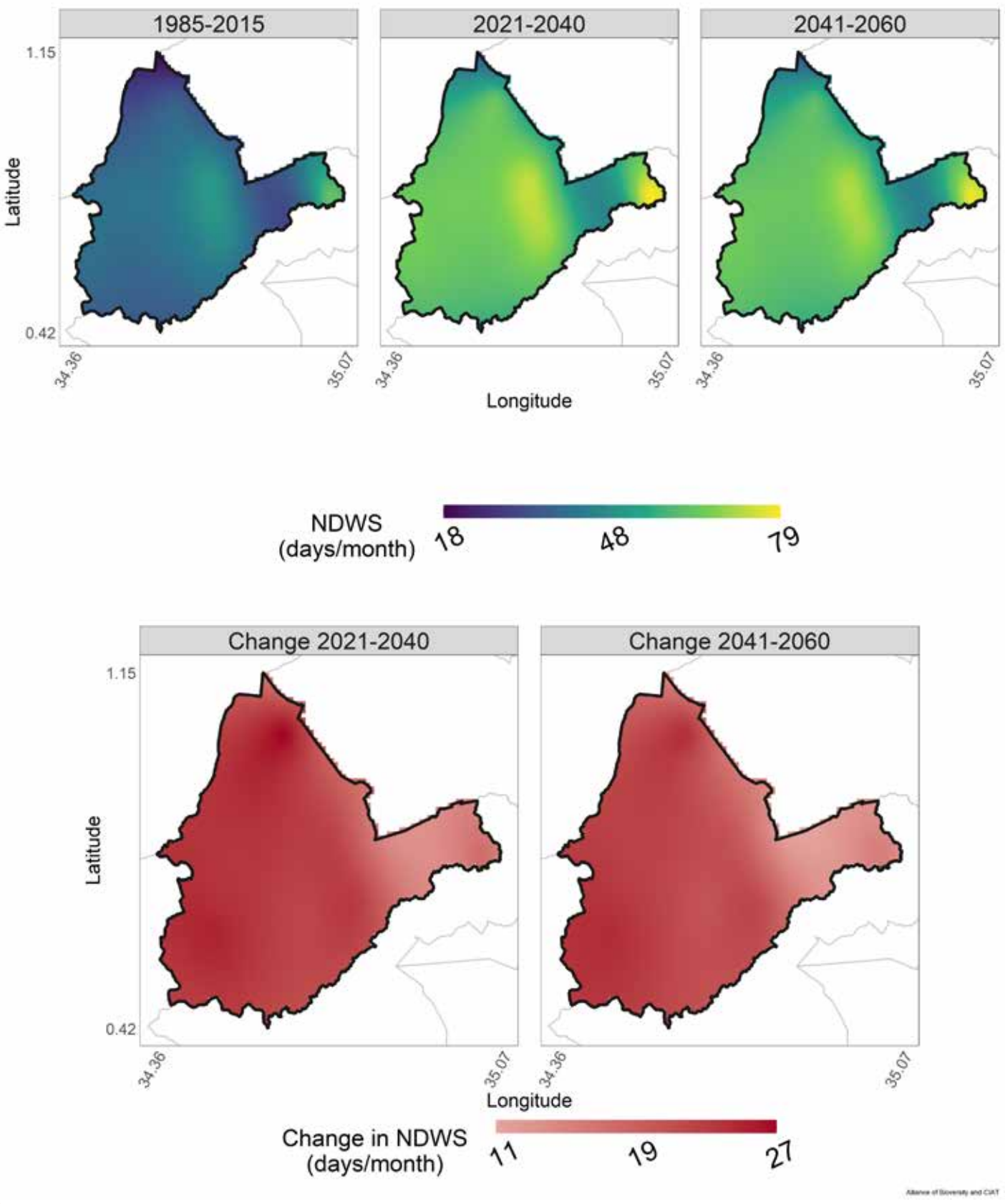

Figure 11: Historical (left, average 1985-2015), future projected (center), and projected change (right) for the number of moisture stress days for the long rainy season

3.2 The Climate from Farmers´ Perspective

It is important to understand how individual farmers perceive climate change, since they are the most vulnerable to climatic shocks. Beliefs and perceptions are central to most major behavioral models, and perceived risk is a central focus of research on responses to climate change. Farmers in Bungoma County agree that climate change is real and that its effects have been felt across the agricultural sector. About 90% of the households in Bungoma County report noticing changes in long-term environmental trends (ASDSP, 2014). These include changes in average temperatures and amounts of rainfall, which are indicated by degraded soils, the drying up of wells and rivers, reduced water volumes generally, and floods and landslides. Other noticeable changes include deforestation, incidences of new pests and diseases, the disappearance of indigenous plants and animals, and the emergence of new plants and animals not previously found in the area. The lives of farmers have been affected by climate change variability, with challenges including lack of food and increased poverty; malnutrition, particularly in vulnerable and marginalized groups; and social problems like domestic violence, broken families, early pregnancies, and drug and substance abuse.

Changes in seasonality due to novel rainfall patterns threaten crop production in Bungoma County. A farmer from Bumula sub-county reported: "We normally expect rain in March; we received rains in May in the last season, yet we had already planted our crops in March. This led to massive losses as the crops did not germinate. Planting dates have really been altered due to the unpredictability of the rains." Normally, the dry season runs from December to February. Delayed rainfalls have caused adverse effects like the drying of fodder, the emergence of pests and diseases, and increased incidence of foot-and-mouth disease in livestock. An increase in dry periods has contributed to poor crop yields. It has also affected livestock: most farmers in Bungoma practice free range systems of farming; prolonged dry periods cause vegetation to dry up, thus reducing feed availability for livestock.

Excess rainfall is a key threat to agricultural production in Bungoma County. Farmers on Mt. Elgon, especially in Cheptais and Chebyuk, have suffered from regular landslides and mudslides, with consequent loss of homes, property, crops, and livestock. Rains can also bring hailstorms. "Blight and hailstorms completely destroyed leaves on my bean crop," one representative farmer reported. Another farmer from the Namwela Farmers' Cooperative reported, "Coffee was affected by hailstorms as they came when flowers were forming. Also, the heavy rains and cold temperatures led to poor berry formation since the berries need warm temperatures to thrive." Cases of soil erosion, fertilizer leaching, and flooding were also reported as a result of excessive rainfall.

3.3 Climate Vulnerabilities across Agriculture Value Chain Commodities

Present and future climate scenarios indicate great threats to the agricultural value chains identified as important for Bungoma County. The relevant climatic hazards include variations in planting seasons, moisture stress, excess and unpredictable rainfall, and high temperatures. While all hazards ultimately effect each VCC in the county, this report focuses on the two primary hazards for each value chain.

3.3.1 Maize

The main hazards affecting the maize value chain in Bungoma County are variations in planting seasons and excess rainfall. Delayed or early rainfall causes variation in planting seasons. The consequences of changes include a scarcity of inputs that contributes to high purchase and land preparation costs due to the necessity of repeat cultivation. Other effects are a build-up of pests and diseases, poor germination resulting in low yields, and fluctuating prices due to high demand and low supply. Overstretched storage facilities also result in high storage costs.

Excess rainfall leads to the leaching of fertilizers; repeat application contributes to increased costs. Soil erosion is another result of too much rain, leaving the land less productive. The costs of weeding increase during rains since weeds grow more rapidly during rainy seasons and compete for nutrients with the crop. Heavy downpours at the stage when maize grains have begun to form can lead to massive losses due to rotting of maize grains at the farm. Post-harvest risks include incidences of aflatoxin contamination in stored maize that has not been dried to the required minimum moisture content levels. Heavy rains damage road infrastructure, making them impassable for transporting the produce to the markets. The most affected actors are small-scale farmers. Traders and institutions like NCPB also are affected by shortages and price fluctuations.

3.3.2 Beans

Moisture stress and uncertainty about rainfall are the key hazards affecting the bean value chain in Bungoma County. At the input acquisition stage, a lack of appropriately resistant seed is a key issue; other consequences of moisture stress at this stage include additional costs of inputs due to lack of germination in dry spells, or the leaching of fertilizers when there is excess water. These consequences are severe since they occur at the foundation of the crop cycle. At the on-farm stage, costs associated with soil testing are higher than many farmers can afford; unclear planting calendars and inappropriate agricultural practices affect germination, productivity, and the quality of the legumes. Reduced bean quality correlates with reduced shelf life and susceptibility to aflatoxins at storage. As

with most legumes and cereals, market prices in the bean sector are very unpredictable and dominated by middlemen, who offer lower prices.

Uncertainty in rainfall leads to changes in growing seasons and thereby adverse consequences across all the stages of the value chain. Compromised bean seed viability, indicated by low germination rates, and high, variable costs at the onset of the rains are major consequences of the unpredictable rains. The variable costs increase because demand for factors of production such as labor, inputs (e.g., fertilizers, seed, pesticides) is high. Unpredictable rains can also affect the physiological maturity window of beans and lead to uneven drying. At the output market, low volumes and poor quality of produce due to uncertain rains create shortages. Buyers are only attracted to areas with enough produce.

3.3.3 Indigenous Chicken

High temperatures and heat stress are key hazards to indigenous poultry production in Bungoma County. High temperatures reduce the potency and shelf life of vaccines and antibiotics; they also lead to low feed intake, low growth rates, and high mortality rates. Low-weight chickens fetch lower prices in the market. The quality of meat from slaughtered chicken is also reduced when temperatures are high. Farmers need extra packaging boxes to create more space for chicks and avoid high mortalities during transportation when it is too hot.

Excess rainfall is another key hazard affecting local chicken production. Heavy rains make roads impassable, affecting transportation of inputs, eggs, and chickens. Outbreaks of disease, for example coccidiosis and mild hypothermia, are common in times of heavy rains. The high number of infections contributes to increased costs of production due to increased cost of treatment. Increased feed intake and the necessity of heating equipment increase brooding costs. During heavy rains, expensive waterproof packaging materials are needed to minimize losses in transit. Excess rains increase chicken mortality, causing shortages of chicken products in the market.

3.3.4 Dairy Cows

Moisture stress has adverse effects on dairy production in Bungoma County. Fodder production is the most affected by moisture stress. The effects start at the point of nursery establishment, since most fodder seeds and seedlings thrive in fertile soils with adequate water. During periods of moisture stress (especially in dry seasons), seeds can dry before germination. This leads to fodder shortages and high prices. The formation of hard pans due to lack of moisture is common, posing difficulties to land preparation impeding fodder growth. Low production of fodder during dry periods means less fodder can be stored for the future either as dried fodder (hay) or wet fodder (silage). By-product utilization is also reduced, as a lack of feed leads to low dung harvest, less manure for farm use, less compost, and lower biogas production. Good nutrition affects animal physiology and general body condition. A cow needs dry matter fodder intake at a rate of 3.5% of its body weight, concentrates, minerals (e.g., salt licks), protein supplements, and clean drinking water. Lack or inadequacy of these requirements leads to delayed cycling in heifers and low conception rates. Milk production and marketing declines during these periods since the cows do not get the correct dry feed content required for production.

High temperatures are another hazard affecting activities in the dairy cow value chain in Bungoma County. Heat stress reduces the likelihood that a heifer will come into heat and increases the chances of losing calves. Pasture is affected due to loss of water through evaporation. Excess heat interferes with the silage-making process, because it is detrimental to the lactic acid bacteria necessary for successful fermentation and it leads to damaged protein in the silage. Milk production volumes are low in times of heat stress and heat contributes to further losses by spoilage, especially during transportation and bulking. Exotic breeds—the high milk producers—are harder hit by heat stress than indigenous cows.

4. Adaptation to Climate Change and Variability

4.1 Factors Determining Future Vulnerability and Impacts of Climate Change

A number of underlying factors render some farmers in Bungoma County more susceptible to climate risks than others. One important factor is disparity in incomes: most small-scale farmers do not earn enough income to implement the interventions necessary to curb climate change risks. Road networks in the rural areas are also quite poor, reducing market reach. Access to weather forecast information is another challenge, as is the rate of illiteracy among farmers, which makes it difficult to implement adaptation options.

Likewise, there is a dearth of policies supporting research work on the best crop varieties suitable for different areas. Little has been done in the county on policies that support climate change, market structures, research, and organization in different value chains. In addition, there are no proper storage facilities that would enhance the shelf life of the legumes and grains. Insufficient farm input subsidies continue to be a key challenge.

Land ownership is mainly dominated by men, while women and youth are segregated or forced to lease land. Cultural beliefs dictate that most household incomes are controlled by men. This contributes to the vulnerability of women and youth, although they are

the main workers at the farm level. Labor in farms is mainly manual and largely done by women and youth, leading to high costs of labor. Fluctuating prices for most value chains can reduce farmers' profit margins as can the presence of middlemen, who reduce the margins by offering lower prices.

The technologies that can supplement water in times of moisture stress, such as irrigation and the construction of cut-off drains for crops, or silage making in the livestock sector, are expensive. Most small-scale farmers cannot afford them due to poverty.

4.2 Climate Change Adaptation Options

Adaptation to climate change means anticipating adverse effects and taking appropriate actions to prevent or minimize the damage they can cause, or, conversely, taking advantage of opportunities that may arise. It has been shown that well planned, early adaptation actions save money and lives in the future (EU, 2020). Agriculture in Bungoma County is highly vulnerable to climate variability; farmers must take steps to increase their resilience. Approximately 69% of households in Bungoma County are making adaptations to climate changes (ASDSP, 2014). The main sources of climate-related information in Bungoma County come from traditional practices and radio, which reaches around 35% of all farmers, regardless of gender. Other sources of information are television (10%) and research institutions (6%) (ASDSP, 2014).

4.2.1 Ongoing Adaptation Practices

In response to climate hazards in Bungoma County, farmers are purchasing hybrid seeds, cultivating early maturing crop varieties, conducting soil tests, and applying the recommended fertilizers. Farmers also use traditional knowledge and methods to predict pest infestations. They practice soil conservation strategies like constructing terraces and gabions. Dry planting, or timing planting so that germination will occur around the start of the rains, is another adaptation technique used in the county. Harvesting crops at the correct maturity index helps to curb some climatic shocks. Some maize farmers are even harvesting and selling green maize. Storage of grains in hermetic bags has greatly improved shelf life and reduced the costs of storage pesticides. Changing crop types is a popular adaptation method in the county. Just over 40% of households in the county are changing crop types as a climate-change adaptation measure (ASDSP, 2014). Some farmers are shifting to early-maturing varieties, while others are replacing maize and beans with high-value horticultural crops like tomatoes.

Tree planting and agroforestry practices have been embraced as an adaptation strategy to climate change in the county. About 44% of households plant trees for alleviating the effects of climate change (ASDSP, 2014). The Ministry of Agriculture engages communities in planting indigenous trees along riverbanks and ensuring that cultivation policies on river buffer zones are strictly enforced. The Fisheries Department also encourages farmers to plant trees around community-established fishponds. Forestry Farmer Field Schools are an ongoing effort by the Forestry Department. Farmers have established woodlots, planting trees on their farms with the aim of conserving the environment while providing wood fuel and timber for construction. The Forestry Department has established a central tree nursery in Bungoma County in collaboration with the Kenya Forestry Service (KFS) for the purpose of providing seedlings to farmers. Forests act as carbon sinks and help reduce the amount of greenhouse gases in the atmosphere, thus mitigating climate change.

Likewise, soil water conservation strategies are increasing. Approximately 35% of households use these adaptation methods in Bungoma County (ASDSP, 2014). There are three main techniques in soil water conservation. The first is minimum tillage, which improves soil structure and moisture storage within the soil. Second is permanent soil cover, which involves maintaining ground cover crops, mulch cover, crop residues, and green manure on the soil surface to stop soil degradation and improve on fertility. Farmers in Bungoma County prefer cover crops like *mucuna, dolichos lablab*, *desmodium*, bananas, *Canavalia*, and cowpeas, all of which are suitable in the county. The third strategy is crop rotation over several seasons in a given field. In addition to minimizing the buildup of diseases or pests, crop rotation is essential in sustainable farming; it allows differential use of the soil over time, thereby optimizing plant nutrient use by exploiting synergies between different crop types. In addition to crop rotation, farmers in the county practice intercropping cover crops with main crops as is traditional practice. Intensive soil preparation by traditional hoe or plough contributed to soil degradation; it is being replaced by the use of conservation agriculture equipment such as subsoilers, direct Ox- or tractor- seeders and planters, zam weeders, and other tools.

Water harvesting can also improve farmers' adaptive capacity. Just under 20% of households have embraced this technique (ASDSP, 2014). Water harvesting methods include the construction of water pans and the gutters at the household level with which to collect rainwater. Water harvesting is being scaled up gradually through efforts of development partners.

In the livestock sector, ongoing efforts by the county government of Bungoma encourage feed conservation and diversification in order to address the problem of food shortages. About 14.6% of households in the county conserve animal feed in one form or another as a climate change adaptation strategy (ASDSP, 2014). Hay is an alternative feed that helps dairy farmers increase their resilience during dry seasons. Farmers are also adopting for use as animal feed crop residues that previously used to be left on the fields

or burned, such as maize stalks, sunflower stalks, and tree shrubs. Farmers are slowly transitioning to semi-intensive and intensive production systems like zero grazing. A significant population preserves fodder by making silage. The shelf life of milk during transit has been improved by a shift from plastic containers to metallic ones. Some farmers are also using injectable hormone boosters to enhance the fertility of their breeding stock. The emphasis on crop production in the county has, however, reduced grazing land and, consequently, animal stock. Farmers are also switching to improved breeds that are more productive and resistant to pests and diseases. Approximately 16% of farmers changed livestock as an adaptation method (ASDSP, 2014). Value addition is increasing as dairy cooperatives package milk, ferment milk, and make yogurt or other milk products. One example is Kitinda Dairy Cooperative in Bungoma town.

In the poultry sector, incubators for hatching chicks are slowly being adopted, although most producers still hatch conventionally, using hens, which results in lower hatching rates. Specialized charcoal stoves commonly referred to as brooder '*jikos'* are the most common sources of heat in chicken houses. Due to the rising cost of feeds, home feed formulation is common adaptation strategy. For success, home feed formulation requires animal nutritionists and extension workers to supplement traditional knowledge with scientific formulation procedures. Due to the costs involved in purchasing antibiotics and vaccines, some farmers opt to use herbs like aloe vera for the treatment of diseases.

4.2.2 Potential Adaptation Practices

In order to minimize the effects of climate change on food security, county stakeholders proposed a group of adaptation practices. Solar dryers should be promoted for drying grains to minimize cases of aflatoxin contamination, especially in the cold seasons. The use of vermiculture (production of earthworms for rapid decomposition of manure) was proposed as an adaptation method for boosting soil fertility. Decentralization of storage facilities, improving roads, building of aggregation centers, and contract farming with millers and other buyers are seen as key pillars in promoting value chains and adapting to climate change.

The county government of Bungoma is at the forefront in climate change matters. Under CIDPs, it aims to have 50% of rural households employing rainwater harvesting and management facilities in year one of its planning, which it plans to scale up to 70% in year two (County Government of Bungoma, 2018). The county has four operational irrigation schemes, at Kamusinga, Chebukui, Kuywa, and Stabicha. The county's irrigation potential can be realized by harnessing the waters the Nzoia River and the rivers that originate on Mt. Elgon, including Terem/Kuywa, Kibisi, and Lwakhakha/Malakisi. Gravity-fed irrigation systems are preferable because of their low maintenance costs.

Given that the population of indigenous cows is greater than that of exotic breeds, it is necessary to improve crossbreeding and AI services to boost the production of dairy cows and commercialize the value chain. Silage making and feed conservation also must be upscaled to cushion against dry-season shortages. In the poultry sector, the use of infra-red bulbs, brooders with automated temperature regulators, or use of solar heaters needs to be expanded. The county also should support CIGs and poultry cooperatives as they establish commercial hatcheries and work to source equipment like incubators for them to improve chick sourcing within the county.

Farmers are being encouraged to use alternative, efficient, and improved cooking energy sources and to minimize their continued dependence on wood fuel from trees, as this leads to deforestation. The encroachment of farms on wetlands negates tree-planting efforts and contributes to weather changes. MoALFC continues to work closely with KFS, the Forestry Department and NGOs like VI Agroforestry to use ongoing extension services to train farmers in on-farm tree planting. The county's aim is for a threshold of 10% forest cover.

Vaccination is widely understood and practiced by farmers in Bungoma County, but it is still important to educate farmers on the correct vaccination programs. Training about how to vaccinate in instances where veterinary officers may not necessarily be required will also expand vaccine coverage in the county.

Livestock and crop insurance helps to protect farmers against losses from climatic hazards. These services are offered by providers like the Cooperative Insurance Company. Another key insurance product for the maize value chain is *Kilimo Salama*, or "Safe Agriculture," which insures maize and wheat crops against drought and excess rain. Despite concerted efforts to encourage the uptake of insurance products, the results have not been very encouraging. Low income among farmers and their perception that the conditions set by service providers are overly stringent limit adoption. Only 0.7% of households in Bungoma County have bought insurance for their agricultural production systems (ASDSP, 2014). It is important to educate and support farmers in the uptake of insurance.

Adaptation strategies used in selected value chains in Bungoma County

Beans	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Variation in Planting Season & Rainfall Uncertainty Consequences	Extension advisory services become less appropriate to clients due to uncertainty; yield potential is affected by crop viability; costs rise at rainfall onset	Uncertainty in planting affects farm operations; ill-timed planting impacts physiological maturity, causing low quality/quantity yields; unevenly dried crops are susceptible to aflatoxin contamination, low quality, and low pricing	Unpredictable labor requirements; unpredictable quality of produce; sorting and grading becomes very cumbersome; poor quality of produce and high fluctuations of prices; uneven drying makes beans susceptible to aflatoxin contamination; low quality; and low pricing	Uncertain volumes of production thus affecting pricing and penetration to new markets; affects commodity supply and demand negatively
Magnitude of Impact	Major-Severe	Severe	Severe	Severe
Farmers' Current Coping Strategies	Combination of indigenous technical knowledge (ITK) and extension services; selection from the best-performing seeds and use of hybrid varieties; composting farmyard manure	Soil testing and analysis; intercropping; the use of animal power; adherence to the traditional planting cycle; hand pulling	Sun drying on canvas; spreading in well ventilated structures; physical sorting and grading; use of gunny bags dressed with chemicals dust for protection; organic production; use of ITK	Contract farming; use of middlemen and selling at farm-gate; use of extension staff, mutual negotiations
Potential Adaption Options	Enhanced linkage between extension and research; use of certified seeds and improved soil fertility; policies addressing pricing and value addition	Expanded soil testing and analysis; enhanced farm mechanization; planting calendar designs; meteorological advisories; enhanced extension research linkages; mechanical harvesting	Use of motorized mobile driers; adoption of collapsible bags; enhanced use of hematic bags and vacuumed silos	Contract farming; farmers' cooperatives and organizations; warehouse receipting mechanisms; commodity exchange through e-commerce; group approach (farmers pulling together)
Underlying Factors	**Institutional**: lack of policies to respond to hazards; seed and manure produced by farmers are not protected by policy; **infrastructure**: road network is poor; cultural: economic instability of many households; decision making in the household is done by the head (usually men)	**Biophysical**: the soil structure and texture effects; no clear policy to cushion vulnerable farmers; **infrastructure**: poor road networks; weather forecasting information not easily accessible	**Cultural**: education level affects post harvesting handling under good safety practices; **policy**: no postharvest policy management	**Economic**: unorganized markets lead to unprofitability; **policy**: no policy to streamline market structures
Moisture Stress Consequences	Inappropriate information or crop performance; inadequate information on the availability of appropriate seed quality; increased cost of seeds; difficulty predicting input costs	Affects both methods and equipment unpredictably thus increasing service charges; uncertainty in farm plans; unclear planting calendar; inappropriate GAPs used; reduced crop performance and yield; unpredictable yields	Uncertainty in executing farm activities; renders farming unpredictable, cumbersome, time-wasting, and costly; quality and quantity are unpredictable; produce susceptible to aflatoxin and reduced shelf life; unpredictable storage charges and warehousing security	Uncertainty in market planning and penetration; uncertainty regarding whether quality and quantity of produce are sufficient to access markets; difficulty in determining prices and estimates contributes to an unpredictable market
Magnitude of Impact	Severe	Severe	Severe	Severe
Farmers' Current Coping Strategies	Indigenous Technical Knowledge and extension advisories	Minimum tillage, intercropping, and harvesting; soil testing and analysis; conventional planning; meteorological advisories	Sun drying done manually by winnowing	Growing and selling; reliance on middlemen and farmgate selling; formation of policy on pricing; value addition
Potential Adaption Options	Enhanced linkage between extension and research; harmonization of extension and meteorological advisories; enhanced research on seed technology; implementation of policies for protecting seed producers; integration of ITK and extension advisories; farmers' associations for bulk purchasing; e-voucher systems	Promotion of soil testing and analysis; conservation agriculture; enhanced use of meteorological advisories; extension/research linkages; irrigation agriculture and conservation agriculture; enhanced use of physiological indicators; cropping calendars; selective harvesting	Motorized driers; usage of hematic bags, collapsible canvas, and enhanced warehousing storage; crop aggregation	Contract farming; adopting warehousing receipting mechanisms; farmers' organizations and e-commerce; mutual negotiations
Underlying Factors	**Economic**: moisture supplementation techniques are expensive	**Policy**: no policy to support forward marketing structure; factors that affect yield, like soil fertility, organic matter, and PH are frequently absent in GAP charts	**Infrastructure**: no proper storage facilities to enhance adequate storage	**Infrastructure**: no formal market structure; **institutional**: weak linkage between production and market-structured infrastructure; **policy**: no policy on market outlay, research, and organization

Maize

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Variation in Planting Season & Rainfall Uncertainty Consequences	Variation in planting seasons require new seed varieties that are tolerant; seed inadequacy drives up prices; fertilizer shortages increase prices; low supply of and high demand for specific pesticides leads to a counterfeit market	High costs of land preparation; repeat cultivation leads to buildup of pests and diseases; poor crop germination; low yields; buildup of storage pests	Reduced maize quality due to broken grains; high cost of drying and aflatoxin control due; high cost of storage and over-stretched storage facilities	Fluctuating prices, high demand, and unstable supply; high demand and insufficient means increase transport costs; unreliable market information leads to poor linkages along the value chain
Magnitude of Impact	Moderate-Major	Moderate-Major	Moderate	Minor-Moderate
Farmers' Current Coping Strategies	Use of early-maturing varieties; early purchase of seeds, and use of hybrid seeds; use of organic manure; early purchase of recommended fertilizers; use of IPM and organic pesticides; cultural methods to predict pest infestations; early planting	Early land preparation; conservation agriculture; and use of-farm machinery; early maturing varieties; early weeding; early planting and dry planting; early harvesting; harvesting at the right maturity index	Use of harvest machine in and varieties with good threshing traits; use of sun drying; harvesting maize at full maturity; hematic bags for storage; aerated storage spaces; use of storage clusters; disposal of maize immediately after harvesting	Early harvesting; proper sorting and grading; and use of motorized equipment e.g., motorbikes, tractors, lorries; information sharing by use of mass media
Potential Adaption Options	Use of improved, drought- and disease-resistant varieties; soil testing and use of recommended fertilizer; building capacity through TVETs; policy on soil testing for all farmers; early scouting of pests and diseases; use of recommend-ed certified pesticides	Use of climate-smart agriculture and weather forecasting given by KMD; conservation agriculture, e.g. minimum tillage, and use recommended chemicals (e.g. herbicides); use of farm machinery for harvesting	Tractor-mount threshing; use of combine harvesters; development of new varieties with thresh ability traits; use of portable solar dryers; use of metallic silos for storage; use of hematic bags; use of NCPB/government storage facilities	Contract farming; building bulking centers; synchronized harvesting of the crop; use of social media
Underlying Factors	**Farmers**, especially women and youth, who are poor acquire local varieties and uncertified seed; labor-intensive harvesting is done manually by women and youth **Agro-dealers-** experience reduced profit and purchasing ability	**Farmers-** are affected by biophysical factors since land terrain in some parts of the county cannot allow use of machines; land is mostly owned by men, leading to land segregation or forced to lease **Service providers**: - increased servicing costs due to increased wear and tear on farm machinery **Agro-dealers-** incur losses due to reduced volumes sold	**Farmers-** are impacted due to high costs of processing with limited resources; labor is manual and mostly done by youth and women; lack of sufficient storage facilities; inadequate policy framework to support subsidy of government services **Millers-** lack quality material for milling thus increasing price of production	**Farmers-** infrastructure, especially in rural areas, affects transportation of goods and services leading to low sales; fluctuating market prices reduces farmers' profit margins **NCPB-** Lack of enough government stores due to low yield and high transportation costs
Excess Rainfall Consequences	Increased demand for seeds leads to increasing prices and hoarding; high cost of production due to increased amount of fertilizers; scarcity leads to increased prices; leaching of nutrients	High costs of land preparation; formation of hard pans in the soil; increased soil erosion; high costs of planting; high cost of weeding; leaching and soil erosion; increased labor costs at harvest; increased losses due to rotting	Increased labor costs; increased post-harvest losses (rotting); broken grains and stalks; poor quality produce; high storage costs	Leads to low produce prices and low demand; high costs of transportation due to poor roads; decreased accessibility of production areas; deterioration of produce quality due to delayed market access; poor market linkages; poor access to market information; low prices
Magnitude of Impact	Moderate	Moderate-Severe	Major	Major
Farmers' Current Coping Strategies	Early purchase of certified seeds; use of tolerant varieties; use of organic manure; use of inorganic fertilizers; use of foliar fertilizers	Multiple land preparation; use of ox-drawn and manual land preparation; manual planting; early planting; manual weeding; stacking of maize before de-husking	Use of motorized threshers and use of hand labor; sun drying; selling green maize; use of gunny bags and storing in houses	Early selling; selling to NCPB; use of tractors and motorcycles; use of animals (donkeys and ox-carts); Individual traders look for produce; middlemen bridging between farmers and traders; use of social media for communication
Potential Adaption Options	Early purchase of certified and tolerant seed varieties; slow-release inorganic fertilizer; use of semi-culture technologies (rapid decomposition for production of organic manure); development of resistant varieties	Conservation agriculture; use herbicides; use of herbicides to control weeds; use of hand-held planters; use of combined harvesters	Use of combined harvesters; mobile solar driers; motorized driers for high quantities of maize; use of hematic storage bags; use of small metallic silos	Contract farming; use of early maturing and resistant varieties; construction and upgrading of roads; decentralization of storage facilities; formation of marketing associations; construction
Underlying Factors	Economically, the income level of farmers is low. Low yields lead to low income, continuing the vicious cycle	N/A	**Lack** of policies for protection against buying contaminated produce	Poor roads lead to breakdowns and increased operational cost

Chicken (Local)

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
High Temperature Consequences	Reduces hatching rates; reduces availability of feed; reduces vaccine potency or denatures vaccines; reduces shelf life of medicines	Leads to low feed intake, dehydration, and slow growth rates; increases mortality rates; reduces vaccine potency	Increased mortality rate; increased perishability of processed birds; reduced meat quality; increased requirements for packing containers to space chicks	Low weight chickens fetch lower prices; decreased supply increases demand; high demand leads to fast-moving stock
Magnitude of Impact	Major	Major	Major-Severe	Minor-Severe
Farmers' Current Coping Strategies	Use incubators or other birds (e.g., ducks) for hatching chicks; obtaining raw materials from own farms; using their own feed formulation; using refrigeration to store vaccines; extension training services	Constructing well-ventilated fowl runs; isolating sick and weak birds and administering drugs; administering drugs for heat stress; packaging and transportation vaccines in insulated boxes; training farmers to administer vaccines on-farm	Use of ventilated vehicles for live birds and refrigerated vans for processed birds; use of aerated boxes and ice or freezers; slaughtering at cooler times, e.g., morning; commercial slaughtering lines; increasing packing materials and space for transport	Formulating own feed for chickens to reach the right weight; regular vaccinations; communication between farmers by word-of-mouth, social media, and phones; online services to contract buyers; special orders
Potential Adaption Options	Commercial hatcheries; introduction of new breeds; commercial feeds; increased farmer training; increased availability of deep freezers to store vaccines	Construction of modern poultry structures or updating existing poultry structures; educating farmers on available technology; anti-stress agents in feeds; training farmers on use of anti-stress agents; following prescribed instructions on vaccines; increasing the availability of cold storage; timely, efficient vaccine distribution	Aggregation centers equipped with cold rooms; high-capacity incubators; fabrication of aerated carts for smaller means of transport, e.g., bikes; use of refrigerated equipment at collection centers; equipping trucks and vans with temperature regulators	Use of commercial feeds; educating with internet, social media, and mass media; using social media as means of selling; formation of producer organizations
Underlying Factors	Despite gender disparities and a cultural belief that men are most affected by fluctuations in the poultry value chain, poultry farmers are affected regardless of gender; illiteracy and low income; lack of institutions in the poultry value chain	Gender disparities in on-farm activities (e.g., women and youth brood while men vaccinate); limited access to finance due to the economic status of poor farmers; lack of policies ensuring ward-level, no-cost farmer trainings	Poor infrastructure, especially roads, impedes transport; gender disparities across production stages, e.g., men are more involved in post-harvest activities; lack of infrastructure like cold chain management systems, e.g., the non-functional slaughter slab at Chwele	Men are more affected by output market- men control household assets and money accruing from sales; input suppliers' stock of vaccines and drugs vulnerable to high temperatures
Excess Rainfall Consequences	Increases mortality; decreases accessibility of farms and increases transport costs due to poor roads; causes supply delays and spoilage	Excess rainfall causes hypothermia, increasing the incidence of disease; heat and feed costs increase at the brooding stage; increased feed intake; increased vaccination costs	Impassible or difficult roads increase transportation costs; transportation issues cause contamination and delays; waterproof materials required; labor requirements for packaging increase	Reduced access to markets; reduced quality of live birds for sale; increased market prices; rainfall increases the cost of promotion, e.g., destroying posters; decreased supply and increased demand
Magnitude of Impact	Severe	Severe	Minor-Severe	Minor-Severe
Farmers' Current Coping Strategies	Increasing packaging materials to transport chicks; use of motorbikes to access market on impassable roads; preparing own feed on farms; use of ox-carts, motorbikes, and tuk tuks; use of service providers for vaccination; buying vaccines from local veterinarians	Use of brooding unites like mekos, pots, jikos, and bulbs; providing heat to reduce high feeding rates; intensive management, e.g., keeping chickens in from rains; culling the stock	Use of smaller vehicles, such as motorbikes, to access hatcheries, farms, and markets; construction of major access roads; aggregation centers near markets; slaughtering under shelter; using water proof materials to package processed birds; using aerated vans and packages for chicks	Farmers sell at low prices due to culling; use of social media, radio, word of mouth, and print media for sales; travelling or transport to distant markets; slaughter and storing chicken rather than selling live birds
Potential Adaption Options	Improve road networks; construction of more accessible hatcheries; use of commercial feeds; localized feed manufacturers; drones delivery of vaccines direct to farmers; training farmers to provide vaccinations to flock	Provision of affordable modern brooders with temperature regulators; training farmers on proper brooding; use of clay brooding pots; use of solar heaters; providing subsidized solar heaters; encouraging intensive management; vaccination of stock before onset of rains	Use of drone transport; renovation of air strips; construction more roads; incorporating slaughter lines into aggregation centers; incorporating meat inspection section into slaughter lines; expanding use of non-carcinogenic packaging materials for processed birds; increased capacity capability of packages (boxes, crates) and vehicles	Holding stock until market conditions have improved; selling in other counties; formation of cooperatives; use of social media, radio, word-of-mouth, and relevant print media; facilitation of exports; improved road infrastructure; creation of a modern market structure specifically for chicken; value addition through slaughtering and dressing
Underlying Factors	Men are the most affected because they are the main investors in poultry production; cultural status also gives them power to be main decision makers	Gender segregation of work in raising poultry	Farmers incur extra costs due to excess rainfall and funds may not be readily available; transporters suffer from poor-quality roads; road to rural areas and farms are seasonal and nearly impassable during rains	Male farmers participate in pricing, advertising, and selling as the main investors in poultry production; men are expected to take charge of economic situations of the household therefore they are the most affected in the output market fluctuations

Dairy (Cow)	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Moisture Stress Consequences	Negatively affects the choice, location, and cost of land; affects nursery establishment and the bulking of seed/planting materials; pricing of feeds and planting materials increased; influences acquisition of breeding stock; feed shortages impact the proper physiological functioning and body condition of breeding stock	The formation of hard pan affects land preparation; reduced availability and quality of feeds during dry periods; delayed cycles and low conception rates	Low moisture leads to scarcity of feeds, pasture, and fodder, leading to low milk production that affects the volumes required for processing; drying feeds for storage is affected by low moisture	Low feeding reduces quality dung harvest, manure, and biogas availability; reduced production of milk, fodder, and pastures; low milk volumes cause to poor market linkages
Magnitude of Impact	Major	Major	Major	Minor-Major
Farmers' Current Coping Strategies	Afforestation activities to increase chances of enhancing rainfall; simple irrigation techniques for the nurseries and bulking sites; move towards intensive farming practices (e.g., zero grazing	Afforestation efforts; construction of moisture conservation structures; silage and hay production, which ensures the availability of commercial feeds throughout the season; farmers use conserved and commercial feeds; intensive farming practices to improve the nutrition and physiological functioning of the animals	Use of crop residues and shrubs to supplement feed; use of conserved and commercial feeds to improve milk production; formation of dairy cooperatives	Irrigation; afforestation; composting farm waste to supplement manure and biogas production; diversification of pasture and fodder crops, including drought-resistant grasses; value addition to milk; forming farmers' cooperatives to increase milk volumes and market linkages
Potential Adaption Options	Afforestation efforts to enhance rainfall; making land arable and more attractive for potential buyers; upscaling irrigation and conservation agriculture; climate-smart livestock production using technologies like zero grazing	Upscaling of afforestation efforts; modern seed conservation technology to make feeds available throughout the season; upscaling of hay and silage production; modern technology for detecting when heifers are in heat; hormone supplements to improve fertility rates	Upscaling use of alternative feeds (e.g., crop residues and wastes); upscaling feed conservation strategies and use of feed supplements; upscaling irrigation in feed production	Increasing irrigation; composting; use of new technology in biogas processing that utilizes small amounts of inputs; increasing the diversification of fodder and pasture with a focus on drought-resistant varieties; formation of farmers' cooperatives to improve market linkages and increase milk volumes
Underlying Factors	N/A	Depressed water levels affect farmers' ability to access mechanized services due to high costs during dry periods	**Infrastructure**: poor drainage and road infrastructure hamper efficient production and transport of milk; Inadequate feed storage facilities like hay barn, strategic feed stores, milk coolers; lack of processing plants; **biophysical**: lack of agroforestry practices to promote conservation; need for enhanced soil and water conservation structures and measures	**Social**: difficulties in raising farmers' awareness leads to poor interventions; exploitation of farmers due to poor access, limited market linkages, cartels and brokers as middlemen; weak or absent cooperative societies
High Temperatures Consequences	Reduces choice of land as temperature-prone areas are unattractive to farmers; pasture and fodder production negatively affected, leading to increase in input prices; fewer heifers come into heat; increased chances of calf loss	High temperatures accelerate the formation of hard pans, kill important micro flora, and cause and loss of soil nutrients through evaporation; heat stress in fodder and pastures makes feed scarce and expensive; proper physiological functioning of heifers leads to poor feed utilization and delays in estrus cycle	High temperatures interfere with silage making; low yields of fodder; milk spoilage during transportation and bulking	High temperatures lead to lower feed production and reduced dung and biogas production; reduced fodder reduces milk quantities and general farm productivity; increased milk spoilage; reduced milk quantity is insufficient to sustain and spur farmer linkages
Magnitude of Impact	Major	Major	Major	Minor-Major
Farmers' Current Coping Strategies	Moving to intensive dairy farming systems; use of irrigation and drought-resistant pasture and fodder varieties	Afforestation; small-scale irrigation; drought-resistant pasture and fodder varieties; zero grazing; use hormone boosters to enhance fertility of breeding stock	Making silage and storing hay under shades; use of metallic cans and improved plastic containers for milk transport; use of chilling tanks to control fresh milk temperatures; clean, hygienic milk production, transportation, and processing	Afforestation efforts; composting plant residues to supplement manure and biogas; diversifying into new fodder/pasture varieties; selling at farm gate; using conserved feeds to maintain milk production during high temperatures; forming and joining dairy cooperatives
Potential Adaption Options	Upscaling intensive dairy farming technologies; upscaling modern technology of nursery management; maintenance of drought-resistant fodder and pasture varieties; upscaling use of modern farming systems and computerized dairy management systems	Upgraded irrigation technologies; agroforestry to improve forest cover and soil moisture; upscaling the cultivation of drought-resistant varieties; zero grazing; modern breeding technologies like hormone boosters	Upscale technologies for making hay and silage; investment in cold chain and cooling facilities to maintain low temperatures; upscaling modern technologies like UHT and good management systems like HACCP	Enhancing composting technologies; alternative biogas production from plant residues and wastes; fodder and pasture diversification; milk value addition; enhanced use of conserved and commercial feeds to increase milk volumes; formation of dairy cooperatives
Underlying Factors	**Economic**: poverty levels place suitable land out of reach for many farmers; low feed production increases prices and decreases sales; reduced calving rates lead to heavy losses	N/A	Poor storage infrastructure and low feeds mean that farmers must buy form the market, incurring additional costs	Weak linkages between farmers, cooperatives, and processors

Figure 12: Climate change adaptation strategies across major value chain commodities in Bungoma County

5. Policies and strategies in climate change

The current laws and contextual policies addressing climate change in Bungoma County are insufficient. However, some of the national policies upon which the county bases its program designs incorporate climate change and building resilience. The key departments that deal with matters of climate change in the county are the Department of Environment, Water, and Natural Resources; the Department of Agriculture, Livestock, Fisheries, and Cooperatives; and the NARIGP project. An overview of enabling and supportive policies and programs is presented in Table 1.

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

Policy	Year	Policy Objective(s) at the County Level	Climate Change Adaptation and Mitigation Interventions	Challenges and Policy Gaps
National Climate Finance Policy	2016	Establishing mechanisms to mobilize climate finance	County Climate Change Fund regulations are at the draft stage	Lack of political goodwill Weak coordination between the public (state) and private sector (non-state) actors Lack of budget for climate change issues Inadequate capacity building on climate change issues Poor coordination of activities Weak links in the enforcement of regulations Insufficient policy frameworks at the county level that align to the national policies Slow implementation of policies
National Climate Change Action Plan	2013-2017	Increasing forest cover Rehabilitating degraded lands	Reclamation of riparian land Formulating bylaws to control deforestation Planting trees Sensitization and awareness creation among communities	
The Kenya Forest Conservation and Management Act	2016	Establishing the Kenya Forest Service (KFS) Protecting and managing the Mt. Elgon forest water catchment area	Established the Forest Conservation and Management Trust Fund Provided education and training on forestry across the county	
The Lake Victoria Basin Commission Climate Change Adaptation Strategy and Action Plan	2018-2023	Presenting a roadmap for addressing and adapting to climate change impacts in the Lake Victoria Basin, including Bungoma.	Addressing issues related to agriculture and food security that are important economic drivers for sustainable development	
Climate Change Act	2016	Mainstreaming climate change into sector functions	Provided the legal foundation of the National Climate Change Action Plan	
National Climate Change Action Plan	2018-2022	Investigating the impacts of climate change on Kenya's socio-economic sectors Identifying strategic areas where climate action is linked to "Big Four" agenda pillars	Establishing afforestation and reafforestation programs Protection of Mt. Elgon tower Revamping existing water schemes Including climate change management strategies in the County Integrated Development Plans	
Kenya Climate Smart Agriculture Strategy	2017-2026	Adapting to climate change and building the resilience of agricultural systems Minimizing greenhouse gas emissions Enhancing food and nutritional security Improving livelihoods	Establishing good agricultural practices	
Agriculture Sector Development Strategy	2010-2020	Improving production and productivity in rural smallholder sectors Increasing equitable income, employment, and food security for male and female target groups	Built capacity in value addition, entrepreneurial skills, group dynamics, sales, marketing, and the certification and standardization of products	

6. Institutional Capacity on Climate Change

Climate risk management and adaptation strategies are addressed by collaboration between state and non-state actors. The state actors in Bungoma County include the Department of Agriculture, Livestock, Fisheries, and Cooperatives; the Department of Water, Environment and Tourism; and government parastatal entities such as the KMD, KFS, and National Environmental Management Authority. The non-state actors include NGOs such as The International Fund for Agricultural Development (IFAD), VI Agroforestry, and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

Institutions are key in the design of policies and investment frameworks, knowledge development and sharing, technological development, and the delivery of financial and nonfinancial incentives for agricultural investments. The following are some of the institutions that operate in Bungoma county.

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

Off-Farm Services	Institutions	Specific Interventions in Bungoma	Challenges
Agriculture Research and Extension	Ministry of Agriculture, Livestock, Fisheries, and Cooperatives	On-farm training and demonstrations on the new technologies, innovations, and management practices	Lack of a climate change department that streamlines the activities of all actors.
	Mabanga Farmers Training Centre Kibabii University	Offering trainings on good agricultural practices Offering agricultural courses to students	
	Department of Environment, Water, and Tourism	Rehabilitating community water schemes Connecting households to piped water Drilling boreholes Constructing additional water harvesting structures (tanks)	Inadequate budget towards climate change among different organizations
	Kenya Forestry Service VI Agroforestry	Promoting conservation Protecting water catchment areas like Mt Elgon Farm and dry land management Educating the public on forest conservation	
	National Environment Management Authority	Promoting sustainable environmental management Integrating environmental considerations into development policies, plans, programs, and projects	Climate adaptation planning and management is reactive rather than proactive
	International Centre for Research in Agroforestry	Through the Strengthening Rural Institutions project, facilitated a county policy dialogue process Revealed some critical issues requiring county government policy initiatives (e.g., land fragmentation, pollution, and environmental degradation)	
	Deutsche Gesellschaft für Internationale Zusammenarbeit	Supporting initiatives aimed at soil conservation Supporting the Department of Agriculture in building capacity for agricultural extension services Advising on adapting national strategies to the county level Supporting young people's associations Assisting Bungoma County in planning and realizing sustainable development	Poor coordination among the organizations that leads to duplication and overlap of activities geared towards climated change
	Anglican Development Services	Supporting the department of agriculture through extension	

Off-Farm Services	Institutions	Specific Interventions in Bungoma	Challenges
	Community Research in Environmental and Development Initiatives	Supporting the Department of Agriculture in building capacity for agricultural extension services	Deliberate operational planning for climate change is still limited: in many cases,
	International Fund for Agricultural Development	Implemented the Smallholder Dairy Commercialization Programme (Bonilla, J, McCarthy, N, Mugatha, S, Rai, N, Coombes, A and Brubaker, J 2017) Strengthening dairy farmers' organizations for improved financial returns	
	Directorate of Livestock Private Veterinary Officers	AI services Animal selection for agroecological zones	
	Kibabii University	Technology Transfer Offering agricultural courses	Inadequate personnel in the extension service across the county.
Climate Information Services and Agro-weather Advisories	Kenya Meteorological Department	Weekly bulletins and seasonal weather forecasts in the local language Employing a variety of media channels, including local radio and TV, social media platforms like WhatsApp, and short message service (SMS) through phones	
Early Warning Systems and Participatory Scenario Planning	Kenya Meteorological Department	Issuing warnings on disasters like mudslides and landslides. Offering advisories on weather updates Supporting the planning of farm activities	The central government dominates issues of Policy formulation and other actors are inadequately involved
Non-Financial Subsidies	One ACRE Fund	Provides planting fertilizers	
	National Cereals and Produce Board	Provides subsidized farm inputs (e.g., certified seeds)	
	UNGA Feeds Coopers K Brands East Africa Seeds Co. Ltd.,Kenya Seeds Co OSHO Chemicals Bayer East Africa Baraka Fertilizers Ltd, Agrovets	Distributing and selling agrochemicals and other farm inputs Providing training and demonstration on the use of these inputs	
Financial Services	One ACRE Fund	Providing financing to support on-farm and input supply	Farmers' cooperative societies and associations are often weak or disorganized with no clear governance structure, leaving farmers susceptible to exploitation by intermediaries
	Savings and Credit Cooperative Societies	Provide savings and credit facilities to members	
	Banks	Provide savings platforms, loans, and transaction platforms	
	Microfinance Insurance	Provides short- and long-term loans to farmers for farm operations Provides crop and livestock insurance to cushion against risks such losses from floods, droughts, etc.	
Market Services, Infrastructure, and Linkages	Kenya Dairy Board New Kenya Cooperative Creameries Brookside Dairy Ltd	Milk sales and value addition Processing and marketing of milk	

7. Synthesis and Outlook

The most common climatic hazards in Bungoma County relate to the intensity and patterns of rainfall and to temperature changes. They include unpredictable rains, which lead to variations in planting seasons; excess rainfall; moisture stress, mainly due to CDD; and extreme temperatures. Inhabitants of the county have experienced adverse effects stemming from these hazards including increased costs of production; landslides around Mt. Elgon; increased emergence of pests and diseases; the destruction of infrastructure and property; and poor yields across all agricultural value chains. These effects manifest as low incomes, increased poverty, and poor livelihoods. Bungoma County was among the counties worst hit by the fall armyworms maize infestation of 2017. Although the county enjoys good soils that should support agriculture, climatic changes have had a massive impact on agricultural productivity in Bungoma. Small-scale farmers with little technical knowhow concerning possible interventions are typically the most affected. Women and youth—key players in on-farm activities—are also heavily affected. Low productivity decreases farmers' access to a balanced diet, leading to malnutrition among these groups.

Localized climate information services will become critical for maintaining production given projected changes to the start of the growing periods. Climate advisory services will also help to inform farmers about the optimum planting windows to avoid crop loss. Adoption of heat-tolerant plant varieties will also improve crop production in times of heat stress.

Projections indicate that the LGP will decrease. A shorter LGP has serious implications for farming; current crop varieties will not have sufficient time to meet their plant growth requirements, leading to significantly reduced production. Shorter-duration crop varieties will help to cushion against these changes to some extent. Climate advisory services will also play a critical role in informing farmers about the earliest planting window. Unless shorter-duration crop varieties are introduced to the region, it may be extremely difficult to ensure or improve food security.

In the livestock sector, it is necessary to promote AI services in the dairy sector to improve breeds. Currently, most cows are indigenous breeds, which produce lower quantities of milk. Building capacity for the vaccination of birds and cattle will also go a long way in protecting these animals from diseases. Chicken farmers need support to procure incubators to boost their value chain. The county government needs to partner with other stakeholders to encourage farmers to join producer organizations or groups where they can reap greater benefits jointly.

Bungoma County mainly depends on policies from the national government when it comes to climate change. It is necessary to develop localized county policies that resonate with local communities. Since Bungoma is an agriculture-oriented county and climate change is a key threat here, it is important that the county form a Climate Change Department with its own structure and funding. This department could streamline all interventions geared towards climate change and consolidate funds from different stakeholders while establishing priorities among areas of need.

A strong policy framework is also necessary to ensure accelerated soil conservation activities aimed at better vegetative soil cover. Riparian revegetation programs also need to be adopted. According to CIDP recommendations, the county needs to formulate and enforce riverbank buffer zone regulations. Additionally, the county government needs to develop and implement a sustainable land use policy in addition to implementing water harvesting, storage, and flood mitigation policies so as to reduce demand for farming on wetlands and in riparian sections.

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10. Annexes

10.1 Glossary

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

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

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

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

The 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).

Greenhouse Gases: Atmospheric gases responsible for causing global warming and climate change. The major GHGs are carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). Less prevalent but still powerful greenhouse gases are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and Sulphur hexafluoride (SF6).

Food Poverty: The inability to acquire or consume an adequate or sufficient quantity of food in socially acceptable ways, or the uncertainty that one will be able to do so.

Tropical Livestock Units- These are livestock numbers converted to a common unit, for example 1 unit = 250 kg.

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