Kenya County Climate Risk Profile: Migori County

Highlights

- The agricultural sector is the mainstay of Migori County's economy, accounting for 60% of total employment and slightly more than 30% of the county government's revenue.

- Climatic projections show that Migori County (Figure 1) will remain susceptible to drought and heat stress, both of which will affect crop and animal productivity. Between 1985 and 2015, the average duration of dry spells was 10 days; this average is projected to increase to13 days by 2050.

- Current and potential adaptation strategies for crop farming include the use of drought-tolerant, early-maturing crop varieties and efficient water-use technologies. In the livestock sub-sector, adaptation strategies include promoting adaptable livestock breeds, providing artificial insemination services, and adopting pasture and fodder conservation practices.

- Despite on- and off-farm efforts to increase climate change resilience, socioeconomic factors have kept farmers' adaptive capacity low.

- Creating value-addition jobs and increasing the resilience of the agricultural sector are necessary to fight food insecurity and poverty.

- The county has recently experienced climate changes, including unpredictable rainfall patterns, rising temperatures and precipitation amounts, frequent and prolonged dry spells, and periods of water scarcity.

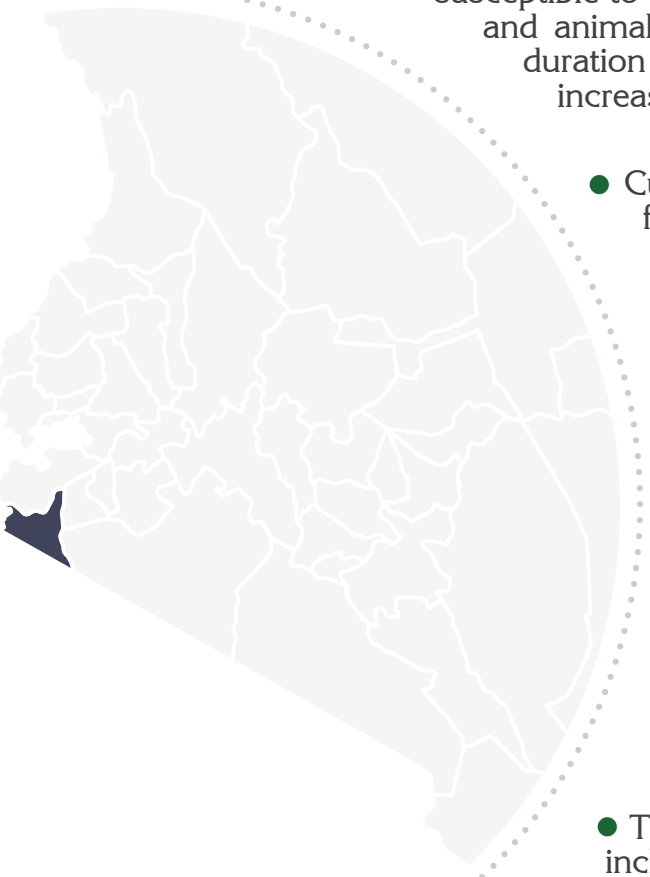

Figure 1: Map of Migori County

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ASDSP	Agricultural Sector Development Survey Program
CDD	Consecutive Dry Days
CIAT	International Center for Tropical Agriculture
CIDP	County Integrated Development Plan
GoK	Government of Kenya
KMD	Kenya Meteorological Department
KNBS	Kenya National Bureau of Statistics
KPHC	Kenya Population and Housing Census
MoALFC	Ministry of Agriculture, Livestock, Fisheries and Cooperatives
NARIGP	National Agricultural and Rural Inclusive Growth Project
NCCRS	National Climate Change Response Strategy
NEMA	National Environmental Management Authority
RCP	Representative Concentration Pathway
VC	Value Chain
VCC	Value Chain Commodity

Foreword

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

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

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

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

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1. Introduction

Climate change is becoming one of the most serious challenges facing Kenya. The country is susceptible to climate-related events, and projections indicate that these impacts are likely to affect the country in the future. In many areas, extreme and variable weather is now the norm: rainfall is irregular and unpredictable; some regions experience frequent droughts during the long rainy season; others are hit by severe floods during the short rainy season. The arid and semi-arid areas are particularly vulnerable to these extreme changes, putting the lives and livelihoods of millions of households at risk.

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

In 2010, Kenya developed a National Climate Change Response Strategy (NCCRS) which recognized the importance of climate change impacts on the country's development. This was followed in 2012 by the National Climate Change Action Plan (NCCAP), which provided a means for implementing the NCCRS and highlighted agricultural adaptation priorities. These initiatives are focused on the national level, 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 development objective is to increase 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 aim of the assessment is to provide information on current climate and possible future climate scenarios; to identify climate-related vulnerabilities and risks for major agricultural value chains and specific groups of people involved in agriculture; to identify adaptation options that address climate risks/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 implemented the assessment through a set of interrelated stages (Figure 2). It first initiated a desk review of the conceptual and analytical context of climate change risks at national and county levels. Effort was made to involve a wide range of institutions that have past and ongoing work on climate change at national and regional levels. The team used globally available data sources as well as collect data from relevant government departments (e.g. DRSRS, Kenya Meteorological Department, Drought Monitoring center, County development plans) and data portals e.g. Kenya Open Data Portal, etc, as possible. This assignment also collected data through focus group discussions, interviews with purposively identified key informants and observation, climate modeling, and three days sub national stakeholder workshops. The final reports were then presented and validated by national and county level stakeholders.

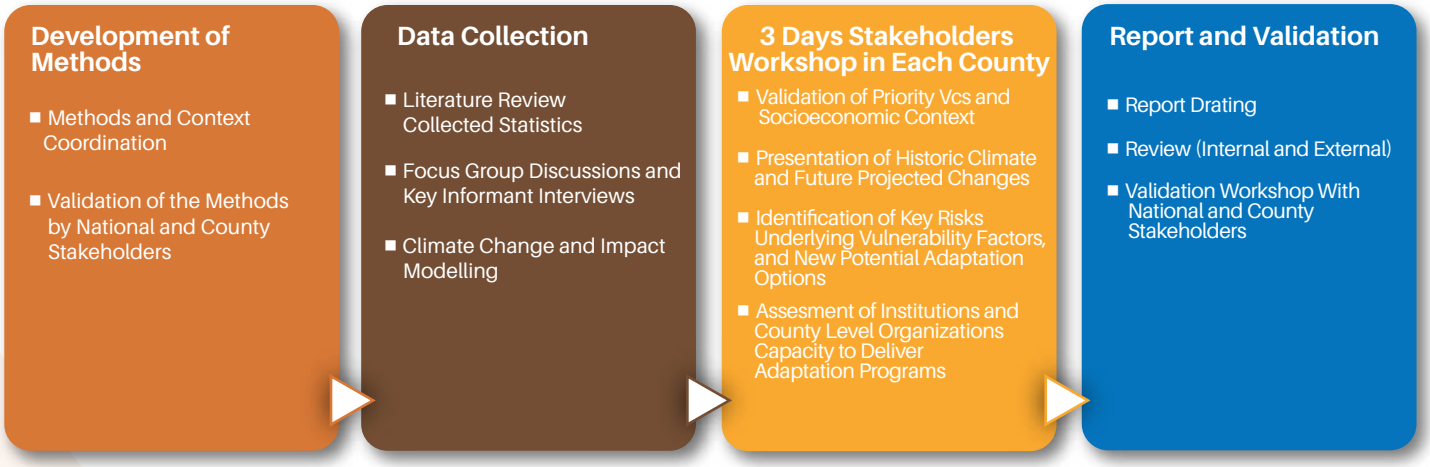

Figure 2: Stages in developing a climate risk profile

This document presents the Climate Risk Profile for Migori County. It is organized into six main sections, each reflecting an essential analytical step towards understanding current and potential adaptation options in key local agricultural value chain commodities. The first section offers an overview of the agricultural commodities that are key to food security and livelihoods in the county and then details the major challenges to agricultural sector development in Migori County. The second section identifies the main climate hazards, based on an analysis of historical climate data and future climate projections, including scientific assessment of climate indicators for dry spells, extreme rainfall, moisture stress, and heat stress, among others. The third section analyzes vulnerabilities to the risks posed by these climactic 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. The sixth section presents pathways for strengthening institutional capacity for addressing climate risks.

2. County Context

Migori County is situated in the southwestern part of Kenya. It borders the counties of Homa Bay to the north, Kisii and Narok to the east, and the Republic of Tanzania to the south (Figure 1). It also borders Lake Victoria to the west. It is located between latitude 1°24´S and 1°40´S and longitude 34°50´E. It covers an area of 2,597 km^2 with a water surface of 478 km^2. More than 80% (approximately 1,919 km^2) of the total land in the county is arable, while around 202 km^2 is non-arable. Annual rainfall averages 700-1,800 mm and annual mean temperatures range between 24°C and 31°C, with high humidity and potential evaporation of 1800-2000 mm per year (County Government of Migori, 2018).

2.1 Economic Relevance of Farming

Agriculture is central to the economy of Migori County. More than 80% of the population, especially those living in rural areas, derive their livelihoods from farming activities. In 2018, this sector contributed KSh 40 million[1] to the county's gross domestic product (ASDSP, 2019). The county had an average population of 9,939 dairy cattle with an estimated annual milk production valued at KSh 695 million; the goat population was 400,692 with a value of KSh 2 billion; and there was an indigenous chicken population of 3,754,530 birds whose estimated annual value for poultry meat production was KSh 2.44 billion. The total quantity of sweet potatoes was 10,920 kg, valued at KSh 8.7 million (ASDSP, 2019).

Major food crops grown in the county include maize, sorghum, rice, millet, beans, cowpeas, green grams, sweet potatoes, cassava, cabbages, tomatoes, kales, carrots, bananas, and mangoes. Sweet potatoes are mainly grown in the sub-counties Kuria East, Kuria West, Suna East, Suna West, and Uriri. The main cash crops are tobacco and sugarcane. Sugarcane is primarily grown in Awendo, Rongo, Suna East, and Suna West; tobacco covers Kuria East, Kuria West, and parts of Rongo (County Government of Migori, 2018).

2.2 People and Livelihoods

The total population of Migori County is 1,116,436, of which 48% is male and 52% is female; the youth (aged 15 to 30 years) make up 36% of the population (KNBS, 2019). The county has a population growth rate of 3.1%, higher than the national rate of 2.3%. The population is projected to reach 1,680,450 people by 2030. The average household size in the county is 4.6 persons, compared to the national average of 3.9. The county's average population density is 427 persons per km^2. Of the total population, 85% reside in rural areas while 15% is urban (KNBS, 2019).

In Migori County, 46% of the population lives in absolute poverty higher than the national level of 36% (Figure 3). Additionally, 50% of the county's population live below the poverty line (US$1.90 a day). This high rate of poverty can be attributed to climate-related natural disasters like frequent droughts, floods, and unreliable rainfall; livestock and crop diseases; poor crop and animal husbandry practices; and socio-economic issues.The county's literacy level currently stands at 89%. About 17% of heads-of-household have no education while 62% have attained primary education and 21% have attained secondary education.

Over 82% of households in the county rely on firewood as their main source of cooking fuel, while 10% use charcoal, 4% use kerosene, 4% use liquid propane gas, and 0.5% use electricity. The use of electricity is more common in male-headed households (6%), compared to female-headed households (4%). For lighting, 10.2% of households use electricity from the main grid, 29.7% use solar power, 12.8% use lanterns, 0.75% use torches, and 0.2% use candles (County Government of Migori, 2018).

Approximately 90%of households do not have adequate access to clean water. The main water sources in the county are piped schemes, boreholes, shallow wells, springs, and water dams. The quality of water from many of these sources is relatively low and water typically needs treatment prior to domestic use (County Government of Migori, 2018). In the county, 28% of residents use improved water sources, while 46% use stream or lake water (KNBS, 2014). Access to clean water is extremely limited, given that less than 1% of county households have piped water, and less

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

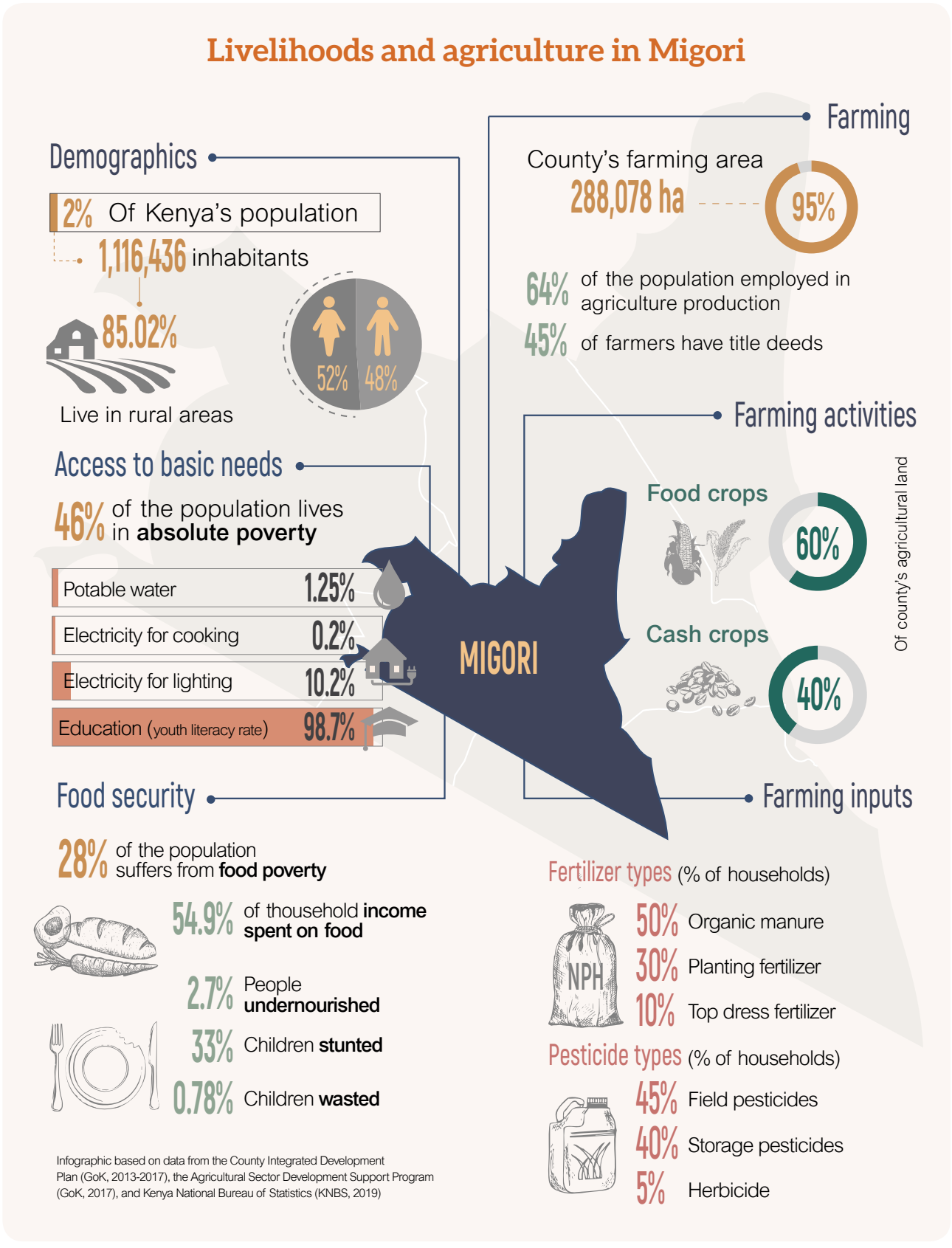

Figure 3: Livelihoods and agriculture in Migori County

than 3,000 households have access to potable water. Of the county residents, 52% use improved sanitation: about 0.2% use piped sewers, 15.3% use pit latrines with slabs, and 52.6% use pit latrines without slabs (KNBS, 2014). Improved sanitation is marginally higher in male-headed households at 54%, compared to female-headed households at 48% (ASDSP, 2019).

The prevalence of stunting among children was 26% while 8.6% of children in the county are wasted (County Government of Migori, 2013). Both mothers and children experience poor nutritional outcomes, which may be attributed to low levels of food security within the county.

The main livelihood activity in the county is agriculture (63%). Improved productivity and value addition are prioritized strategies for job creation and income generation in the agricultural sector.

2.3 Agricultural Activities

About 63% of the total land area in the county is devoted to agriculture, of which 60% is under food crops and 40% is under cash crops. Most of the livestock farmers in the county rear traditional breeds such as Zebu cattle, although some keep exotic breeds, mainly crosses of Friesian and Ayrshire cows. Livestock farmers also rear the East African goat, indigenous chickens, and keep bees. Capture and aquaculture fisheries form the main fishing activities, undertaken primarily in Nyatike sub-county (County Government of Migori, 2018).

The county has six agro-ecological zones (Figure 4) ranging from Upper Midlands (UM 1-4) to Lower Midlands (LM 1-5). UM 1-4 cover parts of Rongo, Kuria East, and Kuria West sub-counties; LM 1-5 cover parts of Rongo, Migori, and Nyatike sub-counties. These zones determine the types of agricultural activities undertaken in each area. The county experiences an inland equatorial climate, modified by the effects of altitude, topographical relief, and the influence of Lake Victoria. Nyatike, Karungu, Kegonga, and Muhuru sub-counties have harsher climatic conditions than other subcounties. The lakeshore sub-counties of Nyatike, Muhuru, Karungu, and parts of Kegonga experience unreliable and poorly distributed rainfall (County Government of Migori, 2013). Regions of high agricultural potential in Uriri, Awendo, Kuria East, Rongo, Suna East, and Kuria West sub-counties are used for food and cash crop production, thanks to their fertile soils and favorable conditions. The percentage of farmers in the county who hold title deeds is 45%. The average land holding size in the county is 3 acres for small-scale farmers and 7 acres for the large-scale farms (County Government of Migori, 2013).

2.4 Agricultural Value Chain Commodities

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

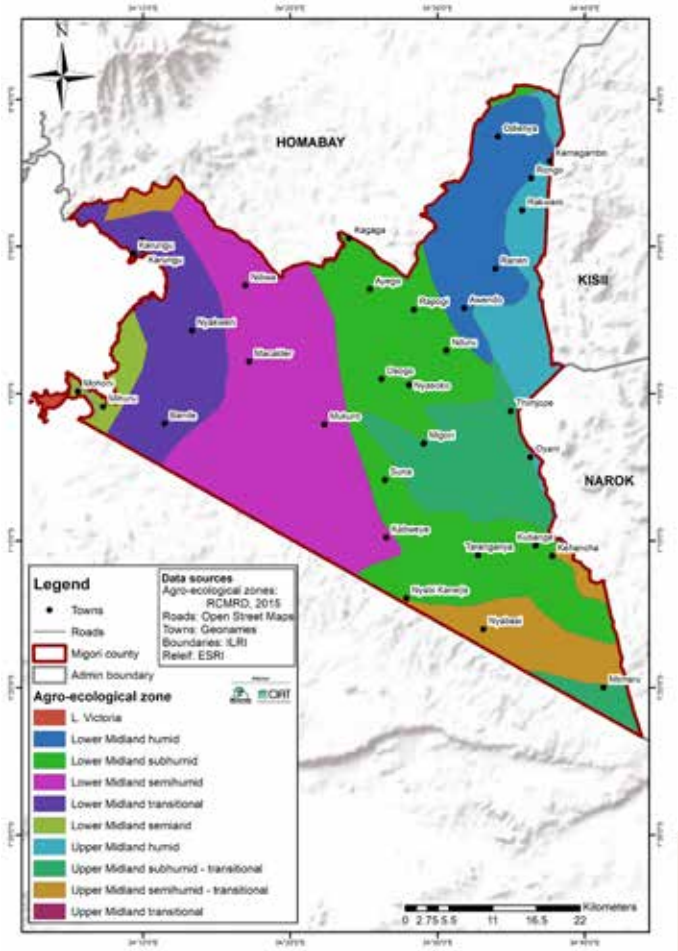

Figure 4: Map of agroecological zones in Migori County

2.4.1 Local Chicken

Local chickens make significant contributions to rural family incomes, especially for women, who are actively involved in chicken husbandry. Chicken products such as eggs and meat alleviate malnutrition by directly contributing to household protein needs. Most households in the county (81-100%) engage in the local chicken value chain. Local chickens are generally owned and managed by women and the youth. In rural areas, local chickens are generally kept in flocks of 10-50 birds in free-range systems. Free-range chickens scavenge for feed and may occasionally benefit from agricultural and household wastes. A ready market exists for eggs and chicken meat both within and outside the county. Farmers consume chickens in the home or sell them to traders who bulk and transport them to local markets.

In the local chicken value chain, farmers engage in the production, incubation, chick supply, feeding, brooding, cleaning, vaccination, aggregation, pricing, transportation, and selling of chickens. At the input supply stage, small- and medium-scale suppliers provide feeds, drugs, chicks, and extension services. These activities are important both for the reproduction and maintenance of flocks and for the prevention of disease. At the on-farm production stage, operations are both large-scale and small-scale. On-farm activities include incubation, brooding, and pest and disease control; these are all important in reducing mortality rates and increasing growth rates. The involvement of women in on-farm production is high, while youth involvement is low.

At the post-harvest stage, most processors are small-scale. Their activities include transportation, aggregation, and manure collection. Post-harvest actors link producers to markets, deliver products from farms to markets, and increase farm productivity. The involvement of women at this stage is quite high, while youth engagement is medium. The product output marketing stage involves wholesalers and retailers, most of who operate at small and medium scale. At this stage, the main activities include determining selling prices and creating market linkages, which improve the pricing of products.

2.4.2 Sweet Potatoes

Sweet potatoes have traditionally been viewed as a supplement to maize, which is the staple food of Migori County. Sweet potatoes are grown as a traditional food security crop. However, in the last two decades, sweet potato production has become an important economic activity in Migori County, contributing to both incomes and food security. Sweet potato tubers have high profit margins due to their low production costs and their continual yield for harvest. Annual sweet potato production in the county stands at 97,625 metric tonnes (Mt), with an average yield of 12.5 Mt/ha of marketable roots. However, this is far below a productivity potential of more than 20 Mt/ha (County Government of Migori, 2012).

Household engagement in the sweet potato value chain ranges from 61-80% in Kuria West and Kuria East to 40-60% in Suna East, Suna West and Uriri sub-counties. Men, women, and the youth are all highly engaged in sweet potato production. The main actors are suppliers, farmers, brokers, wholesalers, and retailers. At the input supply stage, small-scale suppliers provide clean and high-yielding planting materials (vines) to farmers. At the on-farm stage, farmers engage in land preparation, planting, and harvesting at small and medium scale. At the post-harvest stage, collection, grading, and transportation are the key activities, most of which happen at small scale. The engagement of wholesalers and retailers in the output market happens at small and medium scales; at this stage, promoting, pricing, and selling are the key activities.

2.4.3 Goat (Meat)

Goats have inherent physiological adaptations that allow them to survive in marginal areas unsuitable for crop production. They are capable of enduring prolonged water deprivation and they are better able to withstand heat stress than sheep and cattle. Goats also contribute to the economy through livestock sales, the sale of hides and skins, slaughterhouse fees, and the procurement of meat business licenses. Due to their adaptation potential and their low costs of maintenance, they are often the preferred small ruminant. Goat meat makes a significant contribution to the economy of Migori County. Compared to other red meats, it is also a good source of dietary protein and it has comparatively lower levels of total fat, saturated fat, and cholesterol.

Between 41-60% of the county´s population is engaged in the goat meat value chain. The engagement of women and youth is high at all stages. However, male engagement is highest for on-farm production and lower in other stages. At the input supply stage, service providers and suppliers—usually small-scale—are the main actors. The key activities at this stage include extension advice, acquiring feeds, and breeding. In the on-farm production stage, farmers are the main actors, most of who are engaged at a small scale. Their activities include feeding, spraying, and de-worming. At the post-harvest stage, farmers and small-scale processors are the main actors; their key activities include transporting goats to markets, slaughtering, and processing. At the product output marketing stage, services providers, wholesalers, and retailers are the main actors, most of whom are small-scale. The key activities at this stage include linking farmers to buyers, selling, and promoting goats; these are done via the involvement of extension officers, processors and suppliers and the use of mass media, seminars, barazas, road shows, and exhibitions.

2.4.4 African Leafy Vegetables

African leafy vegetables are an emerging, lucrative value chain that presents a niche market for smallholders in Migori County. The most popular local vegetables grown include amaranth (*Amaranthus spp.*), African nightshade (*Solanum spp.*), Spider plant (*Cleome gynandra*), cowpeas (*Vigna unguiculata*), Jute Mallow (*Corchorus olitorius*), and *mitoo* (*Crotalaria spp.*).

In Migori, African leafy vegetables are predominantly produced by smallholders in rural areas on a subsistence basis. However, some farmers have seen the economic benefits of local vegetables in locally available markets and have started allocating substantial portions of their farms for production. This has also encouraged a shift from rain-fed African leafy vegetable farming to cultivation along riverbanks and/or the use of supplementary watering during dry seasons. However, even with the changing profile of this value chain, most farmers still use traditional management practices such as broadcasting seed, which leads to closely-spaced plants in the field.

The proportion of households engaged in the African leafy vegetable value chain is estimated to be 21-40%. The engagement of men in the value chain is generally quite high; the engagement of women and youth is low. The main actors are input suppliers (agro-vets), farmers, middlemen, wholesalers, retail traders, processors, and markets/supermarkets. At the input supply stage, the main actors are medium-scale suppliers who provide quality seed varieties to farmers. The key activity at this stage is seed acquisition. At the on-farm stage, farmers engage in land preparation, crop management, and harvesting at a small scale. Post-harvest activities are carried out by farmers and processors at a small scale; they include sorting, grading, drying and preserving seeds, and value addition. At the marketing stage, wholesalers and retailers are primarily small scale, and their activities are aggregation, transportation, and selling produce.

African leafy vegetable food crops play an important role in food and nutritional security for the urban and rural poor in the county. *The popularity of these vegetables is driven by their nutritional and medicinal value and their large markets.* They are posed to address micronutrient deficiencies because they are rich in micro-nutrients such as vitamins A and C, calcium, zinc, and iron. Most of the local vegetables are consumed within households or sold in local markets. In addition, amaranth is being incorporated into composite flours because of its nutritional value (Abukutsa, 2010).

2.5 Agricultural Sector Challenges

Agricultural productivity in Migori County faces numerous challenges, including excessive reliance on subsistence farming, poor water management practices, soil erosion, the presence of pest and diseases, land degradation, and declining soil fertility, due in part to insufficient awareness of soil fertility management practices. Other challenges include poverty, cash constraints, and the limited development of input, output, and credit markets. Lack of market access is particularly acute among women and the youth, whose ability to purchase farm inputs such as fertilizer is thus limited. A lack of active farmers' cooperative societies and associations combined with the limited functionality of input and output market chains exposes smallholder farmers to exploitation by middlemen. The marketing process is further hampered by poor infrastructure that increases transportation costs and leads to inflated prices of food and other basic commodities. Despite a wide range of financial institutions, smallholder farmers in the county have limited access to credit and agricultural insurance; they are limited by their lack of collateral and the high risk associated with smallholder agriculture.

In the livestock sector, progress has been hampered by frequent livestock disease outbreaks, which are exacerbated by the limited availability of veterinary services, drugs, and vaccines. The potential of the goat meat sector is limited by the poor state of roads and a lack of modern abattoirs and livestock holding grounds.

The chicken sector is constrained by challenges including high chick mortality, low-quality chicken feeds, the high costs of inputs (especially feeds and vaccines), poor disease control and antibiotic misuse, undeveloped producer organizations, an unreliable supply of certified chicks, a lack of value addition, and unreliable aggregation centers. Farmers fail to take advantage of existing opportunities due to inadequate marketing informationand exploitation by middlemen; they sometimes lack entrepreneurial skills or are unable to meet rigorous certifications. A lack of technologies and facilities for processing or extending product shelf-life results in low returns for producers; those who lack certifications or who improperly handle products bear the result of reduced quality. Power tariffs are practiced for processing and storing chicken inputs and products are expensive; pricing is not regulated; and transport costs are high. (County Government of Migori, 2020). Other challenges are climate change, including frequent droughts and erratic rainfall patterns that affect scavenging resources for free-range chickens and a high rate of in-breeding due to uncontrolled mating (GoK, 2015).

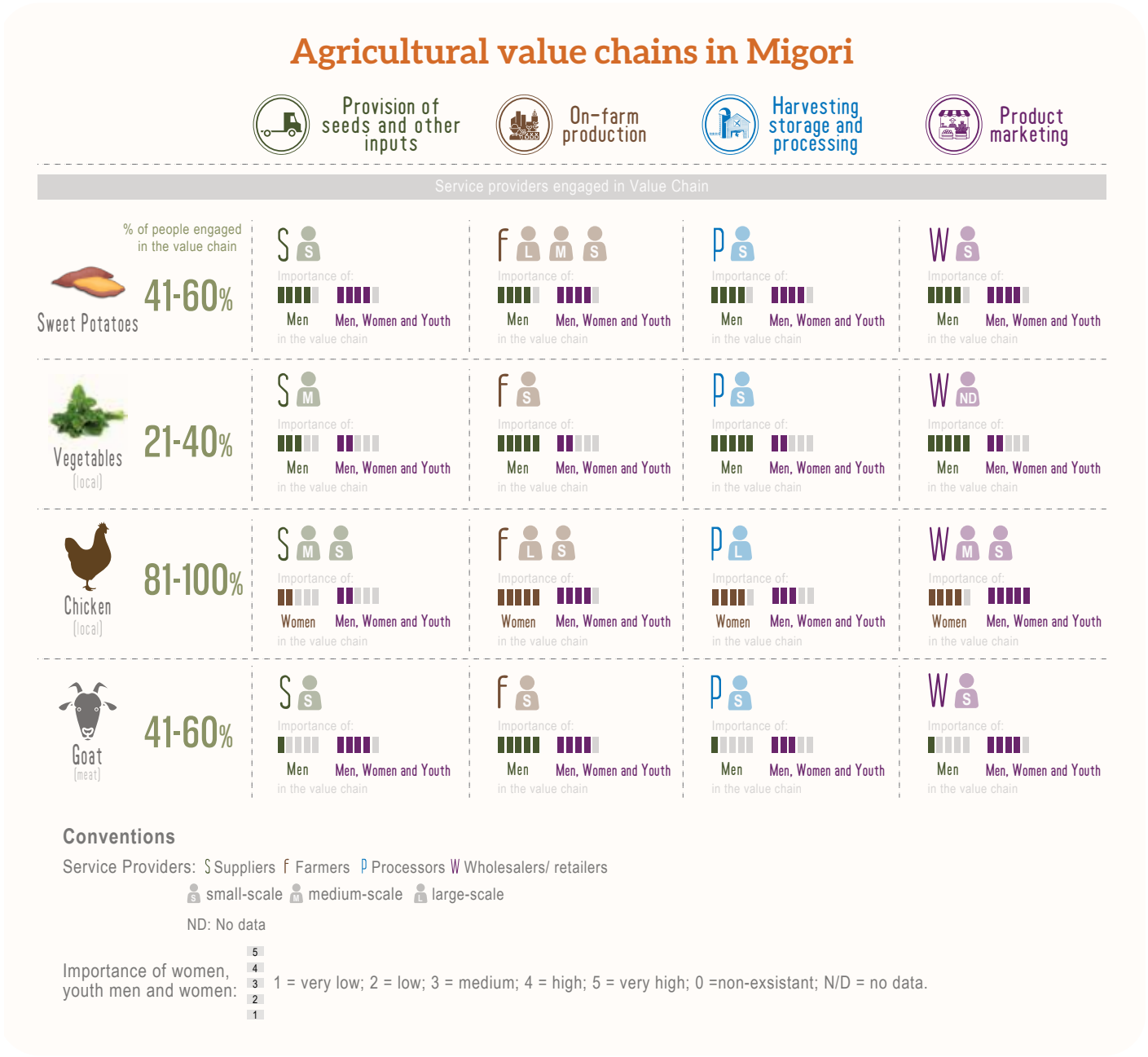

Figure 5: Characterization of selected agricultural value chains in Migori County

Some of the production constraints at the input stage of the sweet potato VC in Migori include limited availability and poor coordination between the production and distribution of clean and high yielding vines. At the production stage, farmers' skills are currently inadequate for exploiting existing potential, maximizing productivity, and increasing profitability. There is low engagement in sweet potato production among the youth, which creates labor constraints. Poor control of pests and disease reduces the quality and yield of produce. As produce, sweet potatoes are bulky and highly perishable; thus, transportation costs are high, improperpost-harvest handling results in high wastage and poor quality, and market access is limited. These factors conspire to reduce farm income (County Government of Migori, 2020).

A major impediment to the sustainable production of African leafy vegetables has been the availability of quality seed. Inadequate physical infrastructure also constrains the value chain; roads that are inaccessible due to heavy rains are a particular problem for the marketing stage. Information is not shared efficiently between various actors in the value chain, from seed production and distribution through production and marketing, right up to the point of consumption. Knowledge and awareness of the nutritional values of indigenous vegetables is limited among producers; community practices and attitudes also curtail the growth of the market.

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, and the start and length of the growing seasons in Migori 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 trajectories adopted by the Intergovernmental Panel on Climate Change (IPCC) for its fifth Assessment Report (AR5) in 2014. Future climate projections were generated based on an ensemble of multiple Coupled Model Intercomparison Project (CMIP5) models (Taylor et al., 2012), using RCP 8.5 for two future periods, 2030 and 2050.[2]

To assess droughts and dry spells, we focused on the maximum number of consecutive dry days (CDD), defined as days receiving rainfall measuring less than 1mm (precipitation < 1 mm day-1). We determined heat stress by measuring the total number of days with maximum temperatures greater than or equal to 35oC (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 the 5-day running average of rainfall—a measure indicative of flood risk—and the 95th percentile of daily precipitation, a measure of extremely high amounts of rainfall over a short period, which can lead to erosion and flash flooding. The 95th percentile of daily precipitation distribution based on the 100 wettest days per season per year and was calculated for each pixel.

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

3.1 Climate Change and Variability: Historic and Future Trends

Migori County has two main rainy seasons. The long rains fall between March and May while the short rains occur between September and November (Figures 6 and 7). Dry seasons are experienced in two annual phases: December-February and June-September (County Government of Migori, 2018).

The total annual rainfall trends showed a slight decrease since 1985 which will continue until 2040 for the long rainy season. In the opposite, the short rainy season will see a sharp increase in the precipitation (Figure 8). The annual mean temperature has increased since 1985 and will continue to do so until 2040 and then 2060 for both rainy seasons (Figure 9).

Historic and future climate scenarios align with farmers' perception that drought, heat stress, flooding, and flash floods are major hazards in the county. Climate scenario indicators identified drought (represented by the number of and days with moisture stress) and floods (represented by the magnitude of the wettest one-day event) as the biggest threats to the four selected value chains. Dry spells are currently 10 days long on average; they are projected to increase by 3 days by 2050. Similarly, the number of days with moisture stress is projected to increase from 25 to about 40 based on projected temporal patterns. The risk of flooding (measured by P5D) and flash-flooding (by the 95th percentile) is not currently high, although it increases significantly in future scenarios. As a result of these hazards, the length and suitability of the growing season will decrease.

The start of the growing season is estimated based on when the climatic conditions become suitable for crop growth. Historically the start of the growing season in the county ranged between early February to late March. In future, there was a strong spatial gradient where the entire county had an early start of the season apart from a small pocket in the north western regions. The change shows early starting of the first growing season of around 1 month in central regions. Climate advisory services will become critical to inform farmers about the optimum planting window and avoid crop loss.

Future climate analyses for Migori project significant increases in moisture stress (Figure 11) and, conversely, increased flood risk in the second season. Projections indicate an increasing number of CDD, representing an increased risk of droughts in the long

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

rains season, between 2020 and 2040. However, after 2040 CDD are expected to decrease due to increasing rainfall. Future climate projections indicate that P5D will increase significantly, by 2-7 mm across the county, with the eastern regions experiencing more extreme rainfalls than the western regions (Figure 10). Future climate projections indicate that 95th percentile intensity will mainly concentrate in the central and eastern regions, locally increasing erosion risks. Projections indicate a general increase of flash floods by 2 to 7 mm throughout the county. Heat stress risks are projected to increase in the future, with up to 30 days equal to or greater than 35°C in some years.

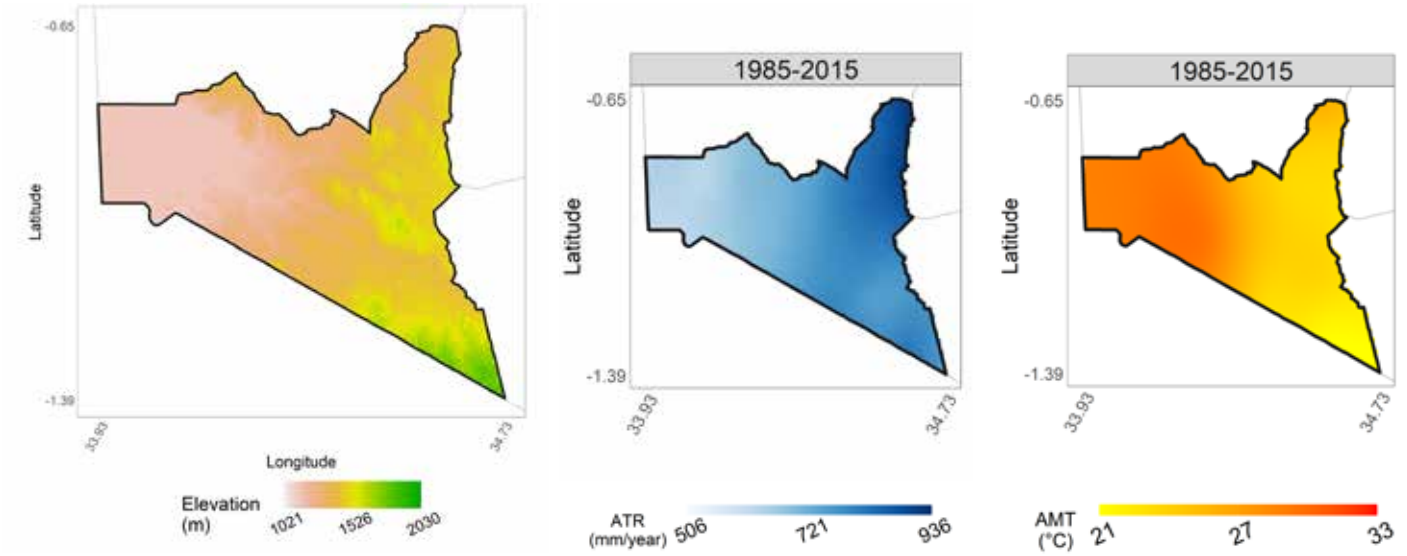

Figure 6: Elevation (left), historical (1985-2015) annual mean precipitation in mm (center), and historical (1985-2015) annual mean temperature in °C (right) for Migori County for the long rainy season

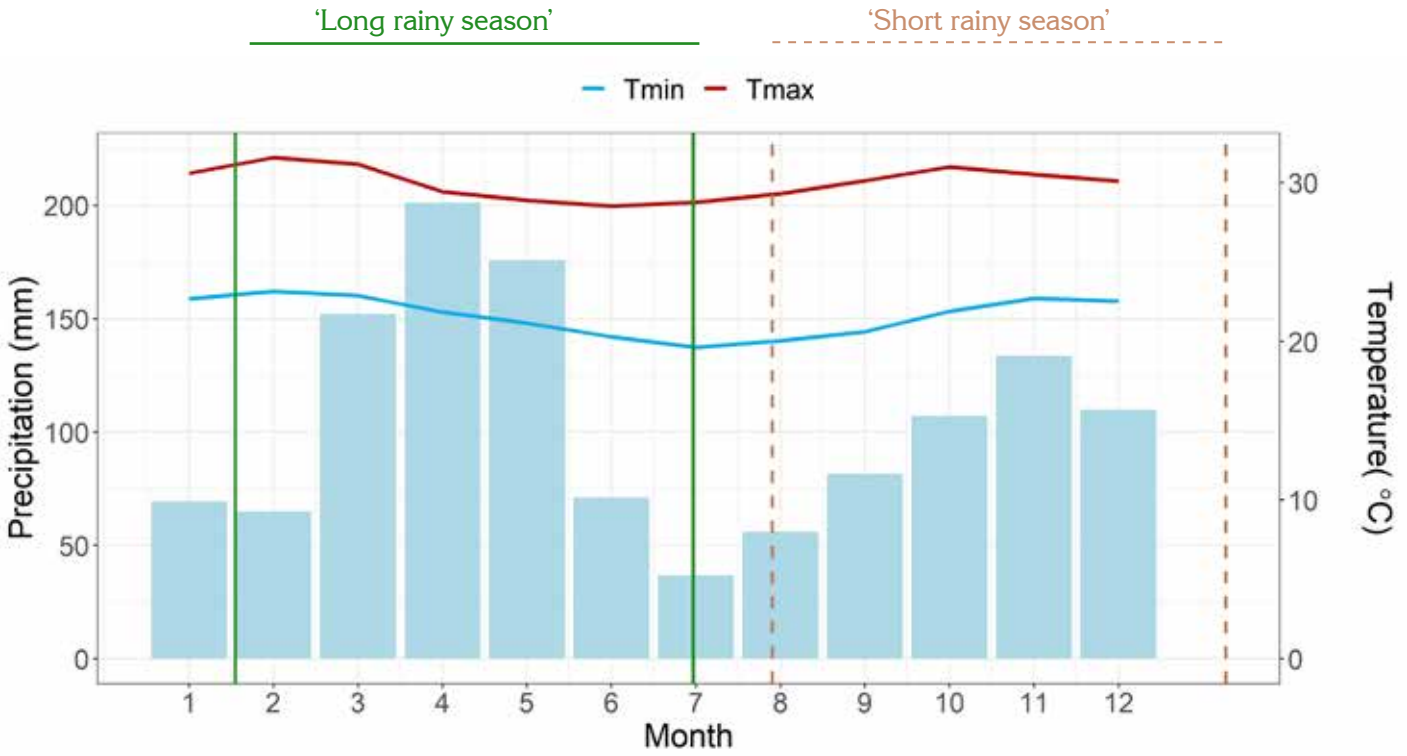

Figure 7: Historical monthly mean temperature and precipitation (average 1985-2015) for Migori County. The first long rainy season is the 100-day wettest period from January to June, while the second, the short rainy season is the 100-day wettest period from July to December. The bars represent total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

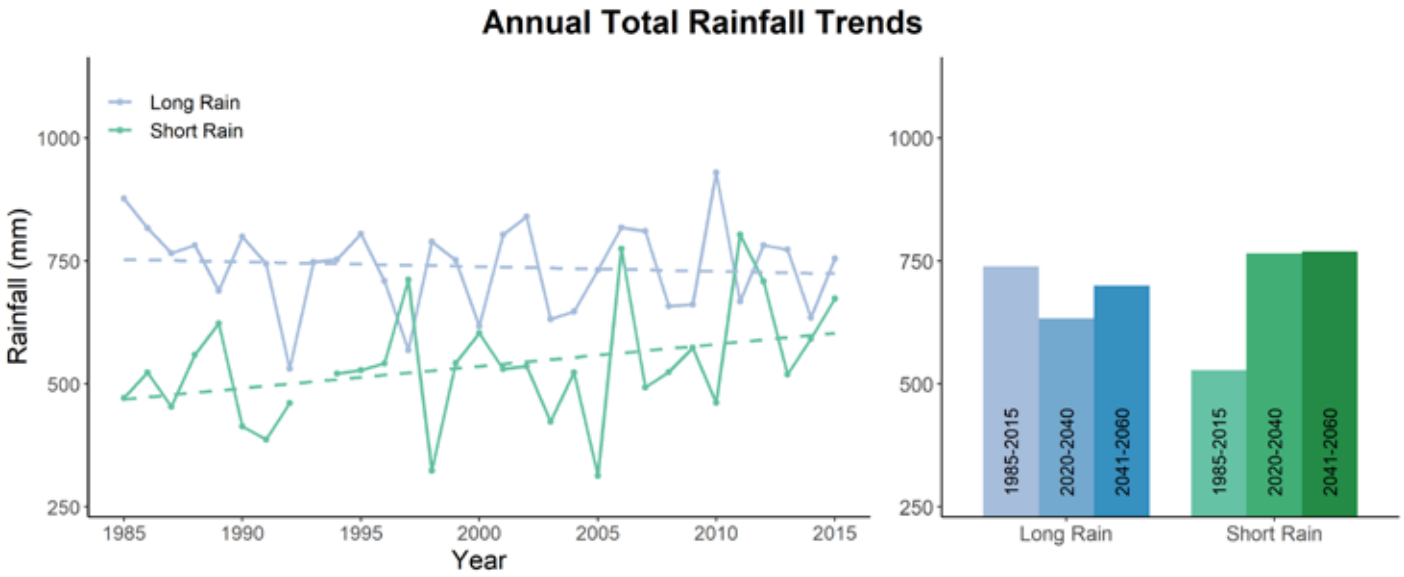

Figure 8: Annual total rainfall trends for the long rainy and short rainy seasons in the past (1985-2015) and in the future (2020-2040 and 2041-2060)

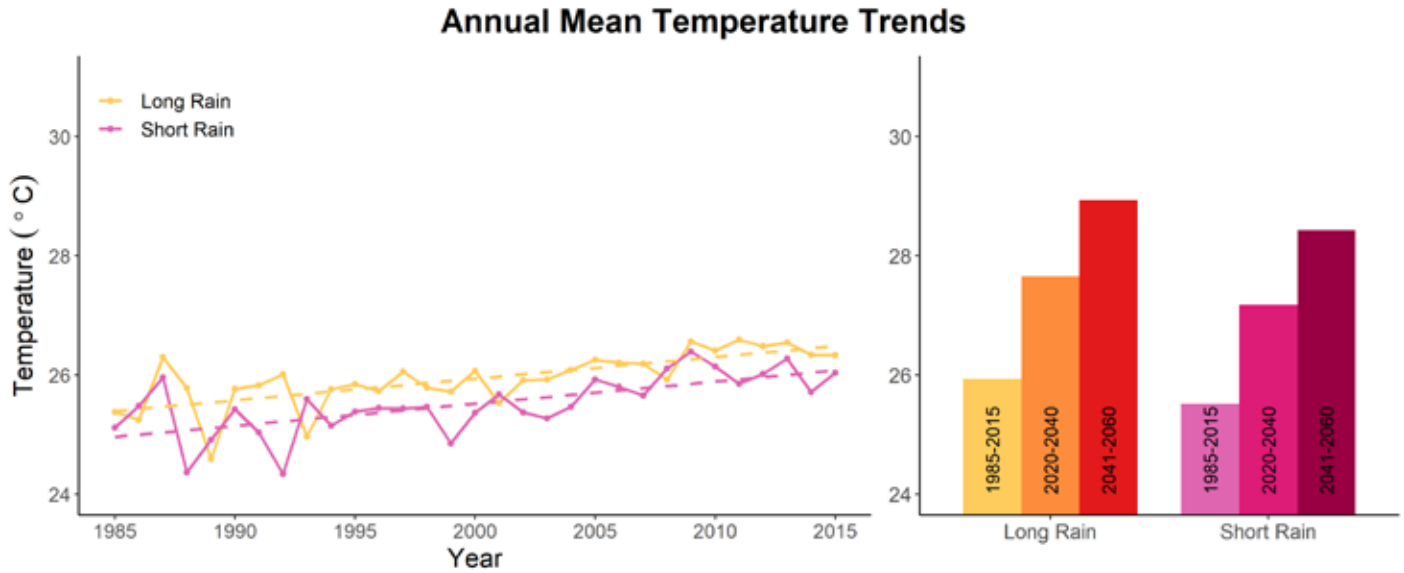

Figure 9: Annual mean temperature trends for the long rainy and short rainy seasons in the past (1985-2015) and in the future (2020-2040 and 2041-2060)

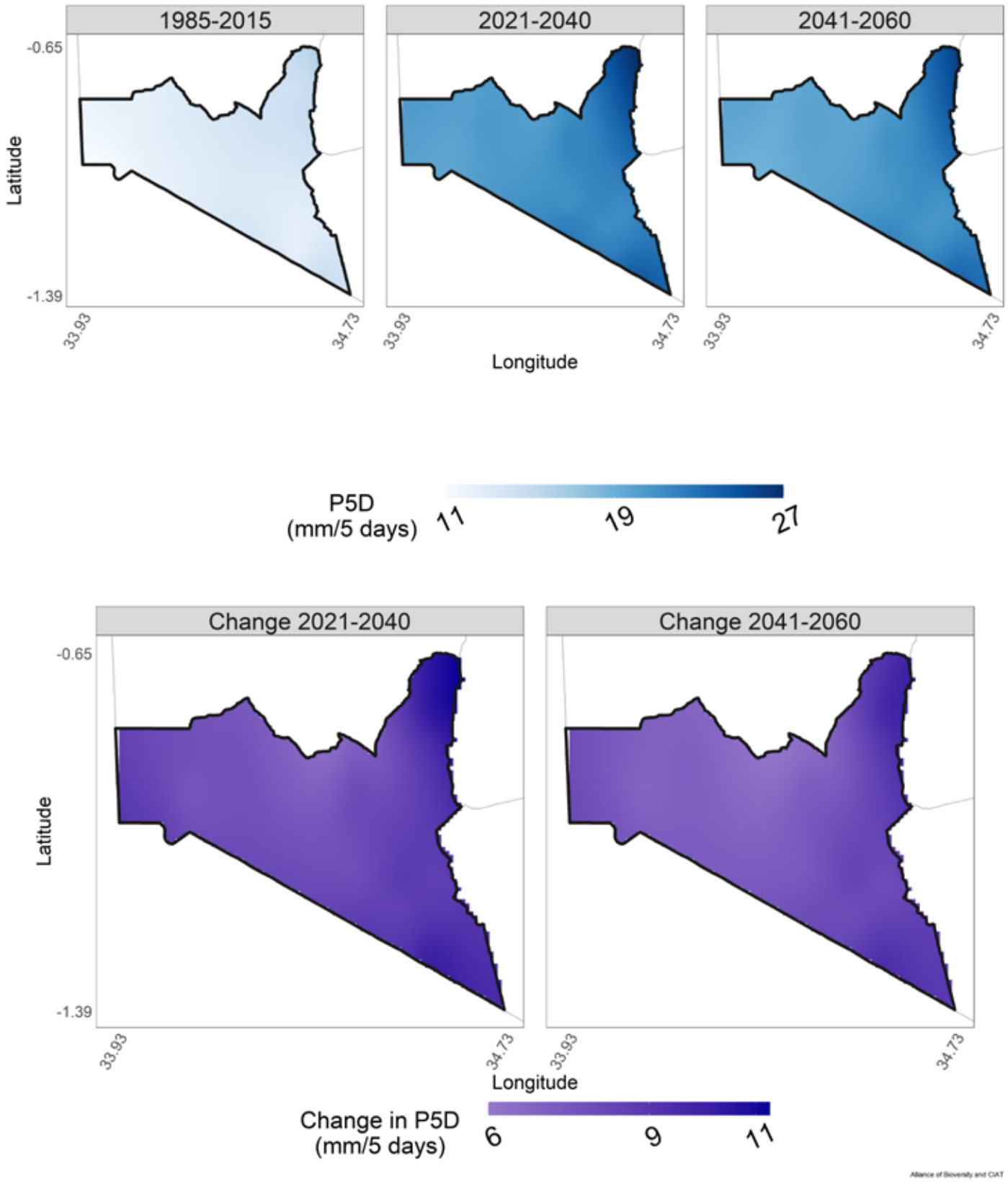

Figure 10: Historical (left, average 1985-2015), future projected (center), and projected change (right) for maximum 5-day running average precipitation in mm for Migori County for the short rainy season

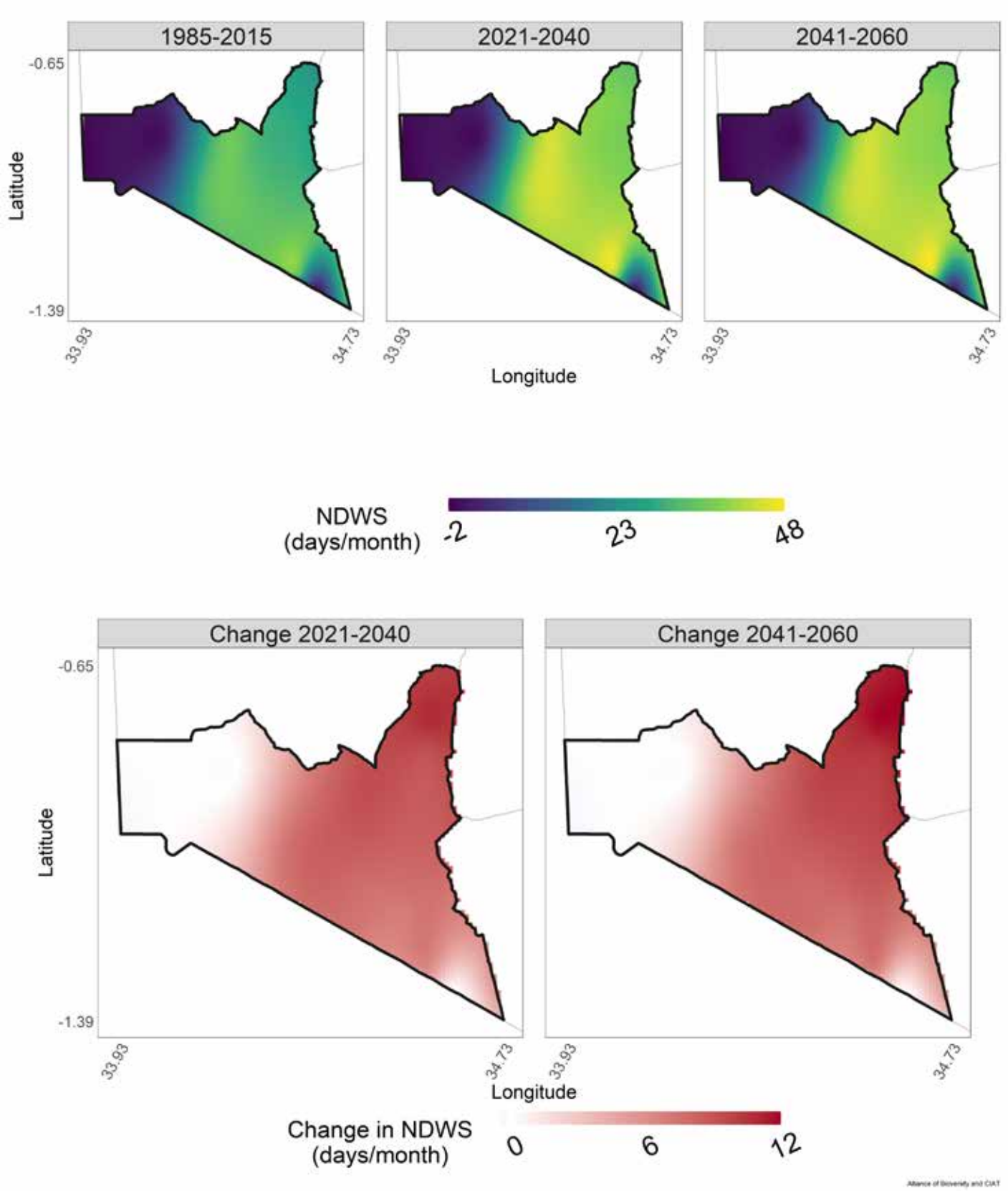

Figure 11: Historical (left, average 1985-2015), future projected (center), and projected change (right) for the number of moisture stress days in Migori County for the long rainy season

3.2 Farmers' Perspectives on Climate Change

Farmers in Migori County report that their agricultural activities have been impacted negatively by climate change effects. Climate change effects and variations have economic and social consequences, including income losses, increased poverty levels, and malnutrition. An overwhelming majority of farmers reported a perceived increase in average temperatures and average precipitation over the last 10 years. Farmers also cited unreliable rainfall, increased water scarcity, and recurrent periods of drought as risks that have caused acute food shortages in some parts of the county.

Farmers reported that the temperature in Migori varies so little throughout the year—remaining between 20-31°C—that it is not meaningful to discuss hot and cold seasons. Insofar as there are variations, farmers report that April, July, and October could possibly be considered colder. Mornings and evenings are normally cooler than the middle of the day, especially in the highland areas of Rongo sub-county.

Frequent crop failures due to droughts and rising temperatures increase the county's vulnerability to food insecurity and poverty. High temperatures generate moisture and heat stress that destroys crops and pastures. In Migori County, high evaporation rates caused by high temperatures necessitate supplemental irrigation of food crops. Heat stress reduces the rate of animal feed intake, resulting in poor growth performance and low production of milk, eggs, and meat.

Migori County experiences extreme seasonal variations in monthly rainfall. Rainfall can be erratic and unpredictable, especially in Nyatike and Kuria East sub-counties. In these areas, the depletion of water reservoirs requires women to travel long distances in search of water; it has also led to the migration of men and the youth to urban and gold mining areas in search of gainful employment. On the other hand, the northern region of the county (Rongo) has reported increasing occurrences of flooding. Excessive flooding leads to soil degradation and increased outbreaks of pests and diseases. Farmers observed that human activities, like environmental degradation and deforestation for agriculture, have led to erratic rainfall, increased river siltation, and reduced water availability. All these environmental factors have, in turn, affected agricultural productivity negatively. Therefore, there is need to integrate traditional and scientific knowledge in responding to climatic hazards/disasters for example, to enhance local coping mechanisms.

3.3 Climate Vulnerabilities across Agricultural Value Chain Commodities

Climate variation and change pose serious threats to the VCCs prioritized in this study. The specific hazards include drought, flood, increased temperatures, heat stress, extreme rainfall, and moisture stress. Drought and heat stress were identified as the most concerning hazards, now and in the future, for crop and animal productivity.

3.3.1 Local Chicken

Drought and heat stress are the most pressing hazards on the indigenous chicken value chain in Migori County. The biggest consequence of drought at the input supply stage is increased prices of chicken feed because of scarcity. Chick and feed production are both reduced when raw materials (e.g., cereals) are insufficient or expensive. Drought also increases transportation costs for inputs (chicks and feeds) due to their scarcity and storage requirements. The severity of drought impacts at on input production is moderate to high. At the on-farm production stage, the cost of regulating temperatures during incubation is high; temperature fluctuations therefore affect brooding activities. Drought leads to reduced hatchability due to heat stress, increased incidences of pests and diseases, increased chick mortality rates, and reduced production and productivity. Consequences at this stage are moderate to severe, with impacts on both men and women. At the post-harvest stage, the notable consequences of drought include increased transportation costs due to chick shortages and reduced aggregation activities. The severity is moderate at this stage, with both genders impacted. Drought necessitates increased investments for packaging and handling chicks. The output market stage is also impacted, as drought increases the prices of agricultural commodities, reduces the volumes of produce in the markets, depresses turnout among buyers and traders, and increases the difficulty of market penetration due to high transportation costs. The severity is moderate to severe at this stage, with all genders impacted.

The consequences of heat stress at the input supply stage include limited packaging of chickens and high transportation costs. Moreover, the shelf life of critical inputs like drugs and vaccines is reduced due to insufficient storage infrastructure. The severity of these consequences ranges from minor to moderate. At the on-farm stage, heat stress reduces the hatchability of chicks, decreases their feeding and growth rates, and increases mortality rates due to dehydration and high incidence of pests and diseases. These effects

are moderate to severe, with both genders impacted. Heat stress necessitates cage modifications, cooling systems, and special packaging of birds, raising transportation costs at the post-harvest stage. Increased investment is required during aggregation, as low supply forces traders to travel long distances to procure enough birds for market. Heat stress also reduces manure quality by compromising its nitrogen content. The severity of effects is moderate to severe at this stage and both genders are impacted. Regarding output marketing activities, reduced supply of local chickens leads to high prices for consumers.

Underlying factors that increase the vulnerability of the indigenous chicken value chain to climate change effects include a lack of capacity building among technical staff and farmers on technology and innovations; the high cost of chick production; insufficient aggregation centers; poor road networks that threaten the availability and increase the prices of inputs; a lack of value addition machinery; high transportation costs; pest and disease outbreaks; high taxes on feeds and drugs; a lack of regulated pricing for chicken products; and weak, uncoordinated institutional marketing structures and linkages. Most farmers also perceive that increasing temperatures will raise the price of poultry products and cause a reduction in stock density. Consequently, women, youth, and poor farmers countywide are rendered even more vulnerable to the negative effects of droughts and heat stress in the local chicken value chain.

3.3.2 Sweet Potatoes

Drought and floods were identified as the most recurrent and severe hazards affecting the sweet potato value chain in Migori County. Effects are especially felt by farmers in Kuria West, Kuria East, Suna East, Suna West, and Uriri sub-counties. The consequences of drought at the input supply stage include increased prices or unavailability of planting materials. Drought has a detrimental effect on sweet potato production at the on-farm production stage, since it renders land preparation more difficult due to compacted soil layers. It also reduces crop growth rates and yields if it does not completely impede harvest. At the post-harvest stage, drought effects are felt during the collection, grading, and transportation of produce; low production leads to increased costs. At the output marketing stage, selling, pricing, and produce promotion are affected with high prices due to supply and demand considerations and low turnout among buyers and traders.

At the input stage, flooding decreases land availability due to waterlogging and thus curtails the multiplication of sweet potato vines. At the on-farm production stage, floods impede land preparation when farmland is covered by water. Later in the growing season, they can lead to the widespread destruction of crops. At the post-harvest stage, collection and grading are paralyzed by low supply and post-harvest loss. Floods severely affect transportation, as the county has poor, flood-prone road infrastructure. Inadequate sweet potato supply due to climate hazards leads to high prices for produce that affect pricing, selling, and promotional activities at the output market stage.

Key underlying factors tied to these hazards in the sweet potato value chain include limited access to land and assets, especially among women and the youth; limited access to drought-tolerant, early-maturing, and high-yield sweet potatoes varieties; poor road, electricity, and water infrastructure; a lack of appropriate market and storage facilities; ineffective marketing policies; and high taxes imposed on sweet potatoes producers.

3.3.3 Goat (Meat)

Heat stress and extreme rainfall are the most notable climate hazards affecting the goat meat value chain in Migori County. Heat stress at the input supply stage leads to reduced quantity and quality of feeds. The severity of heat stress during the input stage ranges from moderate to major; because men are the primary actors at the input acquisition stage, they are the most impacted. At the on-farm production stage, heat stress results in abrupt body temperature fluctuations that lead to goat mortality. It also limits the availability of feed, leading to weight loss, increased vulnerability to diseases, and an increased cost of drugs. Heat stress causes increased mortality rates during transportation due to dehydration. At the output market, production, there is a low supply and demand of goat meat due to high mortality as a result of heat stress. Malnourished goats fetch low prices in the market due to low body weight, weak body condition, and low market turnout of traders.

The consequences of extreme rainfall at the input supply stage in the goat value chain include reduced extension services due to poor road networks, reductions in feed quality and quantity, and increased spoilage. Increased demand for vaccines and veterinary services leads to higher production costs due to disease outbreaks. At the on-farm production stage, extreme rainfall causes an increase in pests and diseases while simultaneously reducing the frequency of deworming due to reduced access to drugs and the washing-away of acaricides. Rainfall-related limitations on the ability of goats to browse results in an increased mortality rate. At the post-harvest stage, the supply of goat meat for processing is reduced. Processors are further hampered by the power outages that increasingly occur during periods of extreme rainfall. Moreover, poor road networks increase the cost of transportation at this stage. In the output market, farmer-market linkages are reduced due to a poor mobile communication network. There is also a low of supply of goat meat at the markets, and what is available fetches low prices.

Both extreme rainfall and heat stress trigger farmers to reduce their flocks, selling their goats to avoid losses. This is the most common adaptation strategy in Migori County to deal with cases of heat stress and extreme

rainfall. Farmers will also sell off animals to generate income that cushions their households against climate shocks like high food prices. Community members with smaller livestock holdings and less-developed social support networks are generally more affected by heat stress and extreme rainfall.

3.3.4 African Leafy Vegetables

Drought and moisture stress are the main hazards affecting African leafy vegetable production in the county. Drought affects all stages of the value chain. At the input supply stage, its effects are moderate to severe and include limited seed acquisition, insufficient capital to buy inputs due to low income as result of drought, and limited land acquisition due to decreased farming activity. In terms of the on-farm production stage, droughts severely affect land preparation, lead to poor crop management, and result in low yield and poor harvests. At the post-harvest stage, the impact is moderate to severe; drought leads to reduced quality and quantity of produce for sorting and grading. Similarly, the drying and preservation of leafy vegetables is reduced by low quantities and limited produce for value addition. At the output market stage, a low volume of produce for aggregation as result of low yields leads to limited transportation and sales.

During periods of moisture stress, the activities in the input supply stage are affected by farmers' insufficient purchasing power for seeds and land. At the on-farm production stage, moisture stress reduced land preparation, crop management, and harvest activities. Moisture stress increases crop susceptibility to pests and diseases, leads to low yields, and reduces the quality of the produce. In the post-harvest stage, the activities of sorting, grading, drying, and preserving seeds are affected, as are value addition activities, due to low yield and quality. Output market activities, including aggregation, sales, and transportation, are affected by low of supply and low demand for produce. In most cases, farmers obtain seed from the previous season's crop rather than using certified seed or improved varieties. While seeds are commercially available in agro-vets around the county, the availability of quality seed still limits the sustainable production of indigenous vegetables.

4. Adaptation to Climate Change and Variability

4.1 Factors Determining Future Vulnerability to the Impacts of Climate Change

Migori County is vulnerable to recurrent climate hazards. Moreover, the county has high population density and poverty rates that render it especially vulnerable to climate change impacts and contribute to its food insecurity. Key underlying factors include inadequate technical knowledge, insufficient technology development and innovation skills, a lack of capacity building among technical staff and farmers on technology and innovations, and uncoordinated institutional marketing structures and linkages. All these factors influence the adoption of activities along the value chain. Women and the youth are more likely to suffer from climatic hazards; despite their deep involvement in the selected value chains, they often lack the financial capacity and knowledge to deal with extreme events.

4.2 Climate Change Adaptation Options

4.2.1 Ongoing Adaptation Practices

In response to some of ongoing climate change impacts, farmers in Migori County have come up with a wide range of on-farm adaptation measures that increase the resilience of their production systems and livelihoods in the face of a changing and unpredictable climate.

While some strategies are specific to certain value chains, others are cross-cutting (Figure 11). Ongoing adaption options in the sweet potato and African leafy vegetable value chains during drought include the use of drought-tolerant, early maturing crop varieties; the use of wood ash to preserve vegetables; sun-drying vegetables; and using oxen to plough. For flood mitigation, crop farmers are adapting by digging drainage channels, practicing water harvesting, and constructing cut-off drains to direct excessive water away from farms. Farmers also harvest runoff water and create water pans for irrigation.

In the goat value chain, ongoing adaptation measures include promoting adaptable livestock breeds; promoting cross breeding; planting shade trees; constructing goat sheds with good ventilation; planting fodder trees; promoting resilient local breeds; the use of artificial insemination services; zero grazing; scheduled deworming; using hand pump sprayers; regular and increased provision of water to the livestock; purchasing vaccines; improving feed formulation; pasture and fodder conservation; and constructing dips, sheds, spray races, and slaughter houses.

Adaptation strategies for local chicken include constructing and maintaining improved chicken housing; increasing feed formulation from locally available foods; and the control and treatment of disease.

The Migori County government is providing farmers with subsidized farm inputs with the goal of improving farmers' access to high quality and affordable inputs to increase yields and improve incomes. There are also ongoing efforts to increase the acreage suitable for irrigation (currently at 25,000 to 40,000 ha) to reduce

the county's dependence on rain-fed agriculture. Other measures are being taken to enhance agricultural mechanization and provide extension services that aim to enhance agricultural productivity among small-scale farmers. However, poverty and cash constraints still limit farmers' ability to access or purchase farm inputs such as fertilizer and seeds (County Government of Migori, 2018).

In Migori County, various stakeholders facilitate off-farm services. The Kenya Meteorological Department provides early warning services through mass media, pamphlets, and brochures. It also makes recommendations for planting and livestock migration times and locations based on drought and flood projections. As most of the population has access to radios, this is a viable means of delivering seasonal forecasts. To enhance the dissemination of resilience and adaptation information, alternative widespread methods such as radio and bulletins can be used. Subsidizing farm inputs, especially artificial insemination services, drugs, and feeds, will benefit resource-poor farmers.

MoALFC, non-governmental organizations, development partners are working together to facilitate extension and training services and to subsidize inputs such as high-yielding seeds, fertilizers, irrigation equipment, and storage facilities. These services can all increase farmers' adaptive capacity in the face of climate change. To build farmers' capacity on new farming technologies, the county is initiating extensive farmer trainings through the establishment and equipping of agricultural training centers. One is already in place at Miyare. The Cooperative Development Department facilitates savings mobilization, improved access to affordable credit, processing activities, insurance, other financial services, and the marketing of value-added goods and services (County Government of Migori, 2018). Banks, micro-finance institutions, and cooperatives provide credit services to farmers for infrastructure, operational costs, and basic needs. However, a lack of collateral, especially among rural farmers, limits credit access.

4.2.2 Potential Adaptation Practices

Potential adaptation practices include transitioning to sustainable agriculture practices, including improved livestock practices and conservation agriculture. Specifically, adaptations should focus on efficient water use technologies; the use of improved, drought-resistant crop varieties; the use of inputs such as fertilizers and pesticides; the adoption of innovative post-harvest technologies; diversifying and scaling up the use of early-maturing seed varieties; the establishment of common collection centers to facilitate the transportation of produce to markets; value addition; the expansion of agricultural mechanization; the subsidization of agricultural inputs such as fertilizer and certified seeds; the provision of post-harvest storage facilities; developing markets for agricultural produce; the provision of market information; affordable credit; increasing the number of vehicles and motorcycles used for transport; the use of ventilated trucks for transporting goats; the construction of refrigerated cold storage areas; the construction of dams, water pans, boreholes, and shallow wells; and an emphasis on animals, such as indigenous livestock breeds and chickens, that are more resilient to climate-related shocks.

Off-farm services that could catalyze the uptake of adaptation practices include establishing demonstration training centers at the ward level; promoting group production and marketing; forming marketing groups to cushion livestock farmers against extra costs; linking value chain actors with formal financial institutions; forming cooperative societies; linking farmers to financial institutions; enhancing extension services by increasing the number of technical staff vehicles; adopting electronic extension (e-extension); utilizing mass media, radio, and mobile phones; strengthening training on adaptation to climate change; and increasing access to agricultural insurance services and socially-inclusive financial services.

Adaptation strategies used in selected value chains in Migori County

Sweet Potatoes

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Drought Consequences	Drought increases the availability of land; planting materials are, however, unavailable or costly; household income is channeled to food procurement at the expense of production	Land preparation rendered more difficult; sweet potatoes are not planted during drought; little to no harvest	Drought can reduce the amount of moisture in tubers; minor effects on transportation; effects on sweet potato grading	Low supplies increase the prices of sweet potatoes during periods of drought
Magnitude of Impact	Minor-Severe	Severe	Minor	Minor-Severe
Farmers' Current Coping Strategies	Acquiring land near water sources; bucket irrigation for vine nurseries near water sources; transfer of money from income-generating activities by farmers' groups to sweet potato production	Increasing the number of oxen used in ploughing; planting around riverbanks and water pans; using ox-ploughs to expose roots; hiring labor to help in harvesting	Preorganized collection by the buyers immediately after harvesting; covering roots with soil and watering them; buying water from vendors to wash sweet potatoes; grading by size	Farmer negotiate directly with buyers; selling to regular customers on credit; using middlemen to deliver produce to markets
Potential Adaption Options	Establishing more water pans and encouraging rainwater harvesting; establishing large-scale irrigation methods for vine multiplication; using shade nets; providing means of credit from financial institutions	Mechanized farming; increasing the use of climate-smart agriculture methods/technologies; mechanized harvesting	Establishing collection centers with storage sheds; procuring transportation vehicles via farmers' associations; improving road networks; using piped and harvested rainwater at collection points	Use of mass media, including posters and fliers, to create awareness of sweet potato production; collective marketing; forming sweet potato cooperatives and societies
Underlying Factors	Women and youth have little access to and no control over land; limited research, technological development, and innovation; limited access to drought-tolerant, early-maturing and high-yielding sweet potato varieties; asymmetrical consequences across farmers based on economic ability; irrigation for vine multiplication will generate political goodwill	Drought makes land preparation more difficult; cultural attachment to land preparation methods can lead to delayed or untimely preparations; drought-tolerant innovations to reduce impacts are not always available; lack of policies on drought management may influence drought's effects on production; lowlands are especially prone to drought	Poor roads make collection difficult; lack of storage facilities; lack of cold storage trucks for transport; insufficient storage reduces sweet potatoes prices; high taxes are imposed on the producers	Insufficient marketing policy allows middlemen and cartels to exploit farmers; lack of political goodwill reduces the development of key infrastructure like roads, electricity, water, markets, and storage facilities
Flood Consequences	Inadequate land suitable for sweet potato production; floods reduce vine multiplication on farms; capital is shifted from production to food purchase	Land preparation is delayed; planting is interrupted; no harvesting; rotting of sweet potatoes root tubers	Floods render roads impassable, reducing transportation; paralyzed collection reduces grading and sorting efforts	Inadequate supply of sweet potatoes leads to high prices; low supply caused by rotting and sweeping away of tubers
Magnitude of Impact	Severe	Severe	Severe	Moderate-Severe
Farmers' Current Coping Strategies	Constructing drainage channels to mitigate floods; using raised nursery beds	Using drainage channels where possible; waiting until floods recede; planting in areas with established drainage channels or relatively low floods; not harvesting	No transport because of impassable roads, hence no adaptation; no ongoing adaptation option since there is no grading activity	Selling at local markets or consume at household level
Potential Adaption Options	Establishing cut-off drains to direct excess water away from farms; promoting hydroponics for rapid vine multiplication; using raised beds to produce vines	Establishing protective dikes along riverbanks; waiting until floods subside	Mobilise farmers to upscale to processing sweet potatoes into various products e.g. puree, chips, flour	Eliminating market dominance by middlemen over-drawing profits from the value chain compared to farmers; introduce pricing regulation system that benefits producers
Underlying Factors	For cultural reasons, women are not involved in drainage construction; political good will-enables construction of drainage structures; economically enabled farmers can construct their own drainage structures	Economically secure farmers can afford to drain land with lower-magnitude floods; a lack of policies on flood management increases the effect of floods on sweet potatoes; lowlands are more prone to flooding; availability of flood-tolerant sweet potato varieties reduces the effects of floods on sweet potato production	Poor road networks increase the cost of collecting sweet potatoes; high transportation costs; low sweet potato quality due to floods	Insufficient marketing policies allow middlemen and cartels to exploit farmers; lack of political goodwill leads to insufficient development of key infrastructures such as roads, electricity, water, and storage facilities; political interference leads to a lack of cascading policies to support flood mitigation

Vegetables (Local)

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Drought Consequences	During drought, lending institutions reduce lending; reduced need for land acquisition; reduced seed acquisition	Land preparation reduced; crop management reduced since routine operations (e.g., weeding) may expose crops to stress and soil disturbance; low leaf yield and premature formation due to seeds which are not fully developed	The quality and quantity of vegetables are compromised; the preservation of seeds reduced by initial compromises on quantity during harvesting; due to low production, the produce is used for subsistence purposes	Low volumes available for aggregation; low quantity of produce transported to markets; limited quantity for sale
Magnitude of Impact	Moderate-Severe	Moderate-Severe	Moderate-Severe	Severe
Farmers' Current Coping Strategies	Use of early-maturing seed varieties; increased use of drought-resistant varieties; resorting to SILC as alternatives to formal financial institutions	Small scale irrigation; minimum tillage; timely harvesting	Incorporating wood ash or sun drying for preservation; integrated pest management	Adoption of low-cost transportation systems; farm-gate sales
Potential Adaption Options	Diversifying and upscaling the use of early-maturing seed varieties; diversifying adaptable varieties; linking value chain actors with formal financial institutions	Establishing dams to collect and store water during rainy seasons; crop rotation; using herbicides to control weeds; relying on weather information updates	Adopting climate-smart innovations (e.g., solar driers); adopting innovative post-harvest technologies	Establishing common collection centers to facilitate transportation of produce to market; forming marketing groups and MIS to caution farmers against extra costs
Underlying Factors	Low purchasing power affects acquisition of inputs; most women have no land ownership rights, reducing their access to loans from financial institutions	Low levels of disposable income among farm-families render them unable to undertake land preparation and farm management activities in a timely manner	Limited technical knowledge, skills in technology development, and innovation renders preservation and storage difficult	Lack of agricultural policies that support marketing and production of ALVs
Moisture Stress Consequences	Low yields lead to low loan repayment	Routine management activities minimized to prevent soil disturbances; low yield; low harvesting	Low yields lead to low production and low quality of produce; low yields seed quality increases the need for preservation; minimal level of value additions from low production	Low volumes available for aggregation due to low yields; limited quantity to transport to market; low sales as a result of low yields
Magnitude of Impact	Moderate	Moderate	Moderate	Moderate
Farmers' Current Coping Strategies	Using early-maturing seed varieties; using more drought-resistant seed varieties; resorting to SILC as an alternative to formal financial institutions	Mulching; sprinkling water on vegetable leaves to prevent desiccation	Sprinkling water on vegetable leaves; establishing aggregation/collection points	Use of cost-effective transport systems (e.g., motorbikes)
Potential Adaption Options	Diversifying and upscaling of early-maturing seed varieties; using drought-resistant seed varieties; expanding financial institutions to support input acquisition	Cover cropping; mixed cropping; sprinkling water on leaves to prevent drying	N/A	Adoption of technologies like MIS (radio and related media)
Underlying Factors	N/A	Acquisition and purchase of irrigation kits; farms in the lake region often experience high moisture stress as a result of high temperatures	Preservation and value addition are affected by inadequate technical knowledge; low levels of technology development skills, and reduced innovation	Lack of agricultural policies and strategies that support the production and marketing of African leafy vegetables

Goat (Meat)

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Extreme Rainfall Consequences	Reduced extension services; slowed food delivery and feed rotting lead to poor diets; stress leading to miscarriage and kid mortality; reduced survival of desired breeds	Reduces goats' ability to browse freely; acaricides are washed away; increased pests and disease; increased mortality; reduced rate of acaricide supply; reduced frequency of deworming; reduced access to drugs; reduced growth rates	Limited access to goat meat; reduced processing rates; reduced income for processors; power outages; reduced frequency of quality checks by public health officers; poor road networks	Poor network connections interfering with communication; delivery hindered, increasing post-harvest losses; power outages; limited ability to gather; limited access to markets; poor road networks; low supply and increased prices at market
Magnitude of Impact	Major	Major	Minor-Major	Moderate-Major
Farmers' Current Coping Strategies	Using peer farmer and training the trainer; feed conservation (e.g., hay and silage); use of crop residues in feed formulation; crossbreeding	Using concentrates, hay, silage, and fodder trees; constructing sheds; deworming practices	Grading roads; using alternative power sources (generators); using transport services; road construction	Use of mass communication technologies (radio, TV, mobile phones); constructing roads; collective marketing
Potential Adaption Options	Using media; feed formulation; artificial insemination services	Intensive rearing (e.g., zero grazing); adopting spraying crush with a resting area; scheduled deworming procedures	Increasing access to renewable energy and tarmacked roads; establishing slaughtering sites	Using modern technology to reach all communities; collective marketing
Underlying Factors	Poor road networks and storage conditions; lack of adequate skills; substandard inputs delivered; vested interest by leaders or politicians; unaffordable inputs	Lack of skills for better management practices; unaffordable cost of housing, spraying, and feeds	Slaughtering based on religion; poor road networks, storage facilities, and storage techniques; increased prices for transportation and processing; policy insufficient to meet public health requirements	Poor communication networks, roads, and storage facilities; lack of marketing skills; unaffordable marketing costs
Heat Stress Consequences	Reduced working hours for extension officers and farmers; reduced quality of feeds; reduced conception and success of breeding; low supply of goat meat; increased prices	Loss of appetite and weight loss; increased rate of disease and increased treatment expenditures; body temperature fluctuations causing stress; sudden death	Low supply, quality, and quantity of produce; goats may die during transportation; reduced mobility of goats	General body weakness; goats may look sickly; reduced sales due to health condition and low market turnout
Magnitude of Impact	Moderate-Major	Minor-Major	Minor-Moderate	Minor
Farmers' Current Coping Strategies	Using open, spacious venues; providing shade; providing drinking water for goats	Providing shade and water; using hand-pump sprayers; zero grazing	Providing sheds; transporting goats to slaughterhouses using motorbikes	Use of telephones and site visits; providing goat sheds in exhibitions; using tree shades
Potential Adaption Options	Planting shade trees; constructing sheds; properly ventilating sheds to promote cross-breeding	Planting fodder and shade trees; well-ventilated sheds; spraying crush with well-ventilated resting area; scheduled deworming practices	Well-ventilated processing structures; establishing more slaughtering space; using ventilated trucks	Using improved technologies; online exhibitions; constructing market shades; using refrigerated trucks for transport and refrigerated storage areas
Underlying Factors	Lack of housing that allows for temperature regulation; lack of access to medical services; lack of funds to construct animal structures; lack of knowledge and skills	Lack of knowledge and skills; lack of funds to hire experts for spraying and deworming; inability to afford vaccines and drugs; inadequate housing	Expensive medical services; housing and storage limitations	Insufficient access to medical services; refrigerated storages and transport facilities

Chicken (Local)	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Heat Stress Consequences	Packaging and transportation of chicks affected by cost increases; heat stress causes dehydration; quality and shelf life of drugs and vaccines reduced	Cost of regulating temperature is high; reduced hatchability and productivity; drought creates drafts that increase chick mortality; high incidences of pests and diseases	High transportation costs due to modification of transport cages and reduced packing of birds together; centers call for increased investment; high heat reduces nitrogen in compost due to hurried decomposition	Limited market coverage; few consumers; increased prices; limits on visitors travelling with chicks
Magnitude of Impact	Minor-Moderate	Moderate-Severe	Moderate-Severe	Moderate
Farmers' Current Coping Strategies	Using aerated boxes during transportation; using open trucks during transportation of feeds; transporting the drugs in refrigerated trucks or cooler boxes	Using automated incubators; using sawdust to regulate hatching box temperature; building more aerated structures in brooding areas; using automated brooders; properly combining and using pesticides; regularly changing litters	Using aerated cages and fabricated trucks for transportation; using aerated structures in market centers; constructing shaded structures to protect manure from heat	Adopting aerated cages for display; adopting refrigeration for value addition; contract farming; structured marketing; market promotion and advertising
Potential Adaption Options	Adopting aerated boxes and use of open tracks; transporting drugs in refrigerated trucks or cooler boxes; establishing county vaccine storage centers	Using automated incubators; constructing aerated structures in the brooding areas; practicing proper sanitation and routine vaccination	Upscaling the adoption of aerated cages and fabricated trucks for transportation; establishing aerated aggregation centers and cold storage facilities; constructing chicken manure yards; applying auto manure management techniques	Establishing cold storage and aerated cages at market centers; establishing chicken slaughter slabs; collective, structured marketing and pricing; contract farming; promotion and advertising
Underlying Factors	Lack of technology and innovations; insufficient extension staff-to-farmer ratio; limited institutions providing capacity building on chick rearing, feed formulation, and drug prescription and administration; weak institutional marketing structures; chick hatcheries located outside the county	High costs of chick production and incubation facilities; lack of good guidelines and policies for hatching	High transportation costs and unreliable aggregation centers; poor manure collection techniques	Uncoordinated market structures; low market prices; insufficient market linkage networks
Drought Consequences	Increased production costs for chicks and feeds; reduced raw materials for feed production; increased cost of raw materials; high transportation and storage costs for drugs	Reduced hatchability; high costs of heat regulation; reduced feeding and growth; dehydration-related mortality; increased incidence of disease outbreaks	Increased transportation costs due to reduced number of chicks packed; reduced aggregation activity; waste and underutilization	Drought affects the number of birds being transported and increases cost of feeds; consumers are required to pay more; market penetration becomes difficult; high transportation rate; fewer birds reach the market
Magnitude of Impact	Moderate	Moderate-Severe	Moderate	Moderate-Severe
Farmers' Current Coping Strategies	Supplying chicks in curated boxes; proper packaging and use of open trucks; using cold containers and refrigerated trucks	Using automated incubators, sawdust to regulate temperature, and open hatching boxes; using automated brooders; increased aerated structures and water feeders; proper sanitation and use of pesticides; changing litter regularly; ring vaccination	Using aerated cages and refrigerated trucks; using aerated structures in market centers; constructing shaded structures to protect manure from heat	Adopting aerated cages for display; value addition under refrigeration; contract farming; structured marketing, marketing promotion, and advertising
Potential Adaption Options	Using curated chick boxes during transportation; using open trucks and proper packaging; transporting drugs in refrigerated trucks or cooler boxes	Use of automated incubators; adding aerated structures to brooding areas; proper sanitation and routine vaccination	Adopting the use of aerated cages and refrigerated trucks for transportation; establishing aerated aggregation centers and cold storage facilities; constructing chicken manure yards; applying manure management techniques	Establishing cold storage and aerated cages at market centers; establishing chicken slaughter slabs; collective, structured marketing and pricing; contract farming; increased promotion and advertising
Underlying Factors	Taxes levied on chick supply; feeds and drugs are expensive, raising production costs	Technology adoption for incubation; the cost of brooding facilities is high; increased incidences of insect pest and diseases	High transport costs due to fuel costs; lack of aggregation centers due to high investment costs; manure transportation is expensive due to bulkiness; lack of value addition and processing machineries	Lack of regulated pricing for unprocessed chicks; lack of formal market linkages

Figure 12: Climate vulnerabilities and adaptation strategies across selected value chains in Migori County

5. Policies and Strategies on Climate Change

The county government in Migori has identified climate change as a major challenge and has begun to develop a Climate Change Adaptation Plan in line with the National Climate Change Action Plan, 2018-2022 and the Kenya National Adaptation Plan 2015-2030. In response to climate variability and change, the county has developed and implemented several policies and programs with a focus on adaptation and mitigation (Table 1).

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

Policy	Year	Policy Objective(s) at the County Level	Climate Change Adaptation and Mitigation Interventions	Challenges and Policy Gaps
National Climate Change Action Plan	2018-2022	Reducing climate vulnerability and emissions while and improving agricultural production potential Providing climate information services and early warning systems to enable the delivery of priority climate actions	Improved breeding of animals Drought-tolerant crops Water harvesting Integrated soil fertility management Mainstreaming climate change into agricultural extension services	Current lack of legislation on climate change describing entities and methods of enforcement Reduced coordination and collaboration among entities
National Adaptation Plan	2015-2030	Outlining short-, medium-, and long-term climate resilience-enhancing actions inthe agriculture, livestock, and fisheries value chains	Focus on agriculture and food security, with investments in several irrigation activities along the Lake Victoria and major rivers aimed at reducing reliance on rain fed agriculture.	Low community awareness levels of county plans, acts, and policies
Farm Input Subsidy Policy Bill	2014	Promoting agricultural productivity through subsidy of farm inputs	Improved productivity at farm level	Lack of political good will
The Sweet Potato Bill	2019	Establishing a sweet potato processing plant corporation	Providing the institutional framework necessary for the regulation, growth, and development of sweet potatoes in Migori County	
The National Agricultural and Rural Inclusive Growth Project	2017	*Increasingthe agricultural productivity and profitability of targeted rural communities*	Responding to any disaster affecting the agricultural sector	Weak coordination and collaboration between public and private sector actors
The Agricultural Sector Development Support Programme Phase II	2019	Transforming crop, livestock, and fishery production into commercially oriented enterprises Ensuring sustainable food and nutrition security in the county	Application of green growth and Climate Smart Agriculture approaches to value chain development Environmental resilience for value chain actors promoted	

6. Institutional Capacity on Climate Change

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

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

Off-Farm Services	Institutions	Specific Interventions	Challenges
Agriculture Research and Extension Services	Ministry of Agriculture, Livestock, Fisheries, and Cooperatives	Providing extension services and inputs	Poor coordination among the organizations leads to duplication and overlap of roles and efforts Inadequate training and technological support to cope with current agricultural practices Insufficient funding also contributes to inadequate human capacity in terms of both staffing numbers and expertise in almost all government departments and other relevant organizations
	Kenya Agricultural Livestock Research Organization	Providing research and technologies on food crop and livestock product value chains	
Water Conservation Strategies	Ministry of Water and Irrigation	Dealing with water technologies, such as irrigation infrastructure and schemes	
Forest Research and Extension	Kenya Forest Research Institute	Promoting conservation of forest resources	
	Kenya Forestry Service	Afforestation programs	
Research and Extension Services	Department of Environment, Natural Resources, and Disaster Management	Natural resource conservation Disaster early warning bulletins Disaster response programs	
Climate Information Services and Agro-Weather Advisories	Kenya Meteorological Department	Providing weather bulletins and seasonal weather forecasts in the local language via multiple media channels	
Early Warning Systems and Participatory Scenario Planning	Kenya Meteorological Department	Issuing early warning warnings on disasters like flooding	
Non-Financial Subsidies	United States Agency for International Development	Supporting large-scale technology and innovation applications (e.g.,solar power) Energy generation and backup	
	Heifer International	Supporting the dairy and poultry value chains by working with smallholder farmers to increase their productivity and market orientation	
	Nuru International Kenya	Supporting the establishment of farmer-led, -managed, and -owned cooperatives through capacity building	

7. Synthesis and Outlook

Numerous extreme weather events and climate change impacts have rocked Migori County, making it a climate change hotspot. The increased frequency and severity of climatic shocks such as drought, floods, heat stress, extreme rainfall, and moisture stress have negative impacts on agriculture and food security. Concerted efforts at the farm, community, and national levels are necessary to deploy the variety of solutions, interventions, and instruments necessary to address the impacts of climate change on agriculture. These efforts should involve critical, short- and long-term adaptation measures that the target production systems and value chains necessary for the population's food security and livelihoods. In addition to these measures, a long-term vision for the agricultural sector requires addressing the underlying factors that increase farmers' vulnerability and diminish their capacity to carry out climate adaptation activities more effectively.

Farmers with adequate knowledge and skills for the management of local chickens are less vulnerable to changes in climate than farmers with limited or no knowledge and skills. Efficient extension services for chicken rearing and marketing information will be required to cope with and adapt to climate variability and its resulting impacts. The sweet potato value chain has an immense potential to contribute to communities through improved productivity and profitability. To realize these increases, the county government needs to train all sweet potato farmers on good agricultural practices and post-harvest management. This will entail identifying entrepreneurial individuals or groups interested in becoming seed merchants, offering training and technical support to produce certified sweet potato vines and identifying suitable locations for sweet potato collection centers. Adopting varieties that are high-yielding and disease- and pest-resistant is recommended to increase production, especially during drought. Farmers in Migori County should be encouraged to form cooperatives and associations that can develop appropriate storage facilities and marketing linkages for fresh produce. Efficient use of water application technologies through minimum and conservation tillage, both of which prevent soil erosion and help keep water on the farm, is also recommended.

Goat meat's high productivity can be exploited by smallholder livestock keepers to ensure a market supply adequate to meet rising demand. It is therefore necessary to improve shelters to reduce the severity of heat stress. Investments in infrastructure are needed across the county to deal with the poor state of roads, the lack of modern abattoirs, and insufficient goat-holding grounds. Overall, efficient extension services for goat meat technologies and marketing information will be required to cope with and adapt to the impacts of climate variability and change. While goat meat is already known to play a significant role in food security at the household level, its contributions can be magnified by highlighting and creating public awareness about its nutritional benefits.

Linking African leafy vegetable value chains to food and nutrition security is a key component in building policies and strategies that better integrate smallholders in emerging, high-margin value chain segments. To mitigate the adverse impacts of climate change on the productivity and quality of local vegetable crops, the county needs to develop sound adaptation strategies that emphasize improving awareness of the nutritional value of indigenous vegetables; improving post-harvest handling and the utilization of indigenous African leafy vegetables; the development of marketing strategies specific to African leafy vegetables; and the promotion of educational programs for farmers and other community groups.

To complement on-farm adaptations, off-farm services such as early warning systems and extension can prepare and equip farmers with the knowledge and capacity to manage the risk; these should be increased. Other initiatives that should be enhanced include improving access to agricultural mechanization; increasing access to agricultural insurance services; promoting horticulture; and providing subsidized farm inputs. Extension services on modern agricultural technologies, value addition, market linkages, and other beneficial farming practices should be made available so that households can enhance production and improve their livelihoods. Adaptation programs will require the involvement of multiple stakeholders, including policymakers, extension agents, non-governmental organizations, researchers, and farmers.

The mainstreaming of adaptation efforts in the agricultural sector is a dynamic process that goes beyond introducing new techniques. It must also cover institutional reforms, policy and regulatory mechanisms, and market-based instruments. Implementation may also require policy dialogue towards institutional reform and the creation of new governance structures necessary for climate adaptation and sustainability. Attention should be placed on identifying and introducing climate-compatible strategies and policies and on improving existing policies and programs to bring them in line with broader, national policies and cross-sectoral climate change strategies. To manage and decrease the impacts of climate change and extreme weather events, mitigation measures and adaptation strategies are necessary to increase the resilience of farmers and the agricultural sector against extreme climatic events. The agricultural sector is the major source of employment and incomes in Migori County; without appropriate planning and intervention measures in place, many county residents will lose their livelihoods. Furthermore, increasing the alignment of public and private agricultural development funds with the sector's needs—with a focus on the local and national economy and on food security—would

facilitate the functioning of institutions which currently lack the resources to effectively deliver services.

Finally, new agriculture technologies will need to be disseminated to women, to support their extensive involvement in farming. It is concerning that the youth are developing a negative attitude farming as a livelihood; their exposure to modern farming technologies is limited and they lack successful farmers as role models. Value chain prioritization for female and youth engagement should focus on the interests and vulnerabilities of these groups. A review of existing legislation is essential to create an enabling environment for climate resilience that reflects current challenges and opportunities at the local level. Existing policies should be improved and climate-compatible strategies that are in line with national policies and cross-sectoral strategies should be introduced. Improving the enabling environment through policy action and governance reform requires synergies that are both horizontal—across ministries and government agencies—and vertical—between public and private sectors, especially between the government and vulnerable stakeholders, including small-scale farmers, women, and the youth.

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10. Annexes

10.1 Glossary

Climate change: A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external changes such as modulations of 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, 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 forconsequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as the probability of the 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).

Drought: A prolonged, potentially disastrous period of abnormally low rainfall leading to a shortage of water.

Dry spell: A short period of low rainfall, usually lasting not more than a month.

Heat stress: Physiological stress experienced because of excessive heat.

Moisture stress: Physiological stress experienced by a plant because of a lack of available moisture or a low water potential in the soil (also called water stress).

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).

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