Kenya County Climate Risk Profile: Nyamira County

Highlights

- Nyamira County is located in the Lake Victoria region of Kenya (Figure 1). It has a tri-modal rainfall pattern which is well-distributed, reliable, and adequate for a wide range of crops. Agriculture plays a key role in the socioeconomic development of Nyamira County. It provides a source of livelihood for 90% of the county's population.

- Despite agriculture's significance in Nyamira County, poverty levels are still high, with over 46% of the population living below poverty line, as compared to the poverty level of 48% in the Lake Victoria region and the national poverty level of approximately 46%.

- Recently, climate variability and change have manifested in Nyamira County in the form of unpredictable, delayed, and extreme rainfall, increased temperatures, and dry spells.

- This study identified dry spells, extreme rainfall, heat stress, and strong winds as the most common climate hazards in Nyamira County. These hazards affect key agricultural value chain commodities across the county.

- Nyamira County is highly dependent on rain-fed agriculture, rendering it vulnerable to climate change, continuous food insecurity, poverty, and malnutrition.

- In response to the changing climate, farmers have adopted several on-farm adaptation strategies. These strategies impact both crop and livestock production. Several organizations are also supporting farmers through the provision of off-farm services.

- Effective climate risk management in Nyamira County is impeded by inadequate funding, policy and governance structures, inadequate human resource capacity, limited political will, and poor coordination and collaboration among relevant actors and stakeholders.

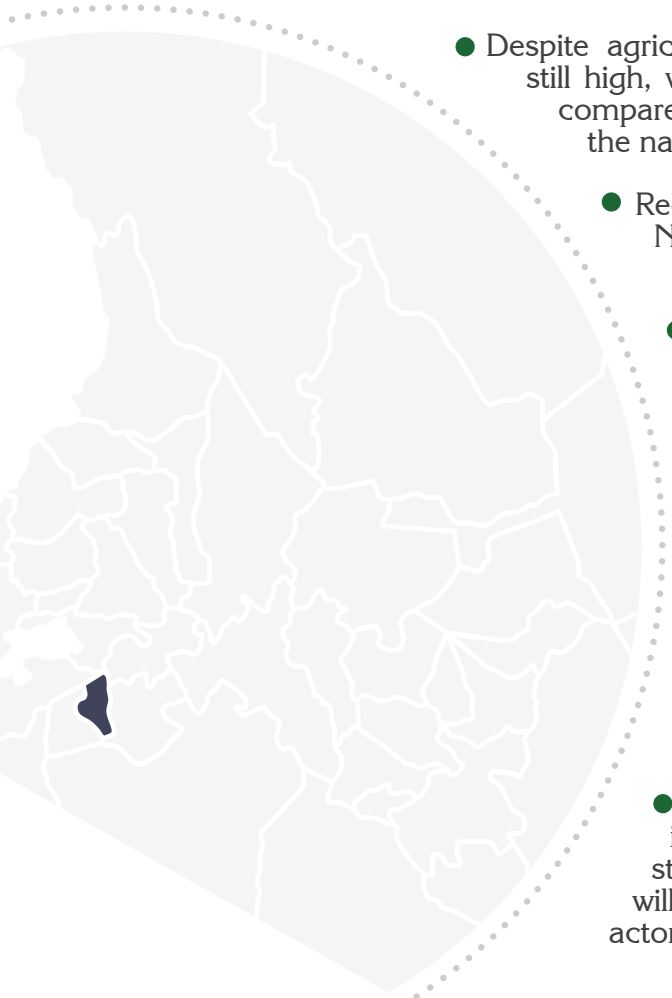

Figure 1: Map of Nyamira County

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List of Acronyms

AEZs	Agroecological Zones
AI	Artificial insemination
AR5	Fifth Assessment Report
ASDSP	Agriculture Sector Development Support Programme
ATC	Agriculture Training Centre
CIAT	International Centre for Tropical Agriculture
CIDP	County Integrated Development Program
CIGs	Common Interest Groups
CMIP5	Coupled Model Intercomparison Project Phase 5
CSA	Climate-smart Agriculture
FM	Frequency modulation
GAPs	Good Agriculture Practices
GoK	Government of Kenya
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated pest management
JICA	Japan International Cooperation Agency
JJAS	June-July-August-September
KALRO	Kenya Agricultural and Livestock Research Organization
KCSAS	Kenya Climate-Smart Agriculture Strategy
KDB	Kenya Dairy Board
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KMD	Kenya Meteorological Department
KNBS	Kenya National Bureau of Statistics
KSh	Kenyan shilling

Nyamira

MAM	March-April-May
NARIGP	National Agricultural and Rural Inclusive Growth Project
NCCAP	National Climate Change Action Plan
NCCRS	National Climate Change Response Strategy
New KCC	New Kenya Cooperative Creameries
NGOs	Non-Governmental Organizations
OND	October-November-December
SDCP	Smallholder Dairy Commercialization Programme
USAID	United States Agency for International Development

Foreword

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

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

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

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

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Principal Secretary

State Department for Crops Development and Agricultural Research

1. Introduction

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

The Kenya Vision 2030 is a national blueprint that seeks to transform Kenya into a newly middle-income country that provides a high quality of life to all its citizens by 2030 in a clean and secure environment. The agricultural sector is a crucial contributor to the projected annual national economic growth. However, it faces constraints such as inadequate access to quality inputs, marketing inefficiencies, a non-conducive investment environment, declining soil fertility, low mechanization, land fragmentation, and most significantly, climate change.

In 2010, Kenya developed a National Climate Change Response Strategy (NCCRS) which recognized the importance of climate change impacts on the country's development. This strategy 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, Livestock, Fisheries and Cooperatives, the Government of Kenya (GoK) is implementing the National Agricultural and Rural Inclusive Growth Project (NARIGP) with support from the World Bank. The project objective is to increase agricultural productivity and the profitability of targeted rural communities in selected counties. To address the climate change risks and vulnerabilities that negatively impacts agricultural production, the Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT) was engaged to do a climate risk assessment. The aim of the assessment is to provide information about the current climate and about possible future climate scenarios, to pinpoint climate-related vulnerabilities and risks for major agricultural value chains and specific groups of people involved in agriculture, to identify adaptation options that address climate risks and vulnerabilities, and to assess the institutional capacity to deliver adaptation programs.

This climate risk profile seeks to inform county governments and stakeholders about the climate change risks and opportunities for agriculture. This report will therefore 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 1). It first initiated a desk review of the conceptual and analytical context of climate change risks at the national and county levels. An effort was made to involve a wide range of institutions that have worked on climate change at the national and regional levels. The team drew from globally available data sources like the Kenya Open Data Portal, from county development plans, and from relevant government departments like the Department of Resource Surveys and Remote Sensing, the Kenya Meteorological Department (KMD), and the Drought Monitoring Center. This assignment also collected data through focus group discussions, interviews with carefully selected key informants, observation, climate modeling, and three days of sub-national stakeholder workshops. The final report was then presented and validated by national and county-level stakeholders.

Figure 2: Methodology for developing the profile

This document presents the climate risk profile for Nyamira County. It is organized into six main sections, each reflecting an essential analytical step towards understanding current and potential adaptation options for key local agricultural value chain commodities. The document first offers an overview of the agricultural commodities key to food security and livelihoods in Nyamira County, and then lists major challenges to agricultural sector development in Nyamira. In the second section, it identifies major climate hazards based on an analysis of historical climate data and climate projections. These projections include scientific assessments of such climate indicators as dry spells, extreme rainfall, moisture stress, and heat stress. Thirdly, the report continues with an exploration of the vulnerabilities and risks posed by these climactic hazards to the respective 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 also provides snapshots of the enabling policy, institutional, and governance contexts for the adoption of resilience-building strategies. Finally, the sixth section presents pathways for strengthening institutional capacity to address climate risks.

2. County Context

Nyamira County is located in the Lake Victoria region of Kenya. It is adjacent to Homa Bay County to the north, Kisii County to the west, Bomet County to the southeast, and Kericho County to the east. Nyamira County lies between latitudes of $00^{0}30'$ North and $00^{0}45'$ South, and between longitudes of $34^{0}45'$ West and $35^{0}00'$ East. The county's topography is mostly hilly, called the "gusii highlands". The most predominant geographical features include the Manga Ridge and the Kiabonyoru, Nyabisimba, Nkoora, and Kemasare hills. Nyamira County stands at altitudes between 1,250 m and 2,100 m above sea level. Its elevation is conducive to growing tea, an important cash crop and source of income for farmers in the county.

2.1 Economic Relevance of Farming

Agriculture is Nyamira County's economic backbone. About 90% of the county's population depends on agricultural production and marketing, either directly or indirectly. Agriculture plays a key role in food security, poverty reduction, and job creation in Nyamira County. The county's agricultural practices include farming of both food and cash crops, livestock farming, bee keeping, and fish farming. Its major food crops include maize, beans, finger millet, sorghum, cassava, sweet potatoes, vegetables, and fruits. Its major cash crops include tea, coffee, pyrethrum, avocados, and bananas. In terms of animals, farmers mainly raise cattle for dairy and beef; goats; pigs; sheep; donkeys; poultry including indigenous chickens, layers, and broilers; rabbits; and bees. Nile tilapia and African catfish are the main fish farmed.

Agriculture furnishes a significant portion of household income in Nyamira County, with crop-related activities generating the majority of the income. County households earn an average of 79,123 Kenyan shillings (KSh) per year, with crop-related activities contributing the largest portion of this income (ASDSP, 2014). Female-headed households earn an average KSh 86,962 per year from on-farm activities, compared to KSh 85,005 for male-headed households, and KSh 46,098 for youth-headed households. Female-headed households earn a majority (almost 79%) of their income from crops, as compared to male- and youth-headed households, which earn approximately 72% and 55% of their income from crops, respectively.

2.2 People and Livelihoods

Nyamira County has a population of 605,576, with a male population of 290,907 (48%) and a female population of 314,656 (52%). The population density is 675 people per km^2. The total number of households in Nyamira County is 150,669, with an average household size of 4 people (KNBS, 2019). The urban population constitutes about 7.8% of the total, including 22,666 males and 24,370 females. The rural population is larger, comprising about 92% of the total population, with 268,241 males and 290,286 females (Figure 2).

About 46% of the population lives in absolute poverty, as compared to 48% in the Lake Region and 46% nationwide (KNBS, 2016). Additionally, 50% percent of the population live below the poverty line (US$1.90 a day) .The Lake Region Economic Bloc is made up of Bungoma, Busia, Homa Bay, Kakamega, Kisii, Kisumu, Migori, Nyamira, Siaya, Vihiga, Bomet, Trans Nzoia, and Kericho Counties (County Government of Nyamira , 2018). Roughly 13% of the urban population lives in poverty, against 46% of the rural population. The major causes of poverty in Nyamira County include small land plots, poor crop and animal husbandry practices, inadequate safe and clean drinking water, low educational standards, and a high prevalence of disease. About 50% of households in the county had access to electricity for lighting, and 0.2% had electricity for cooking; around 59% had access to potable water (County Government of Nyamira, 2018).

Agriculture constitutes a source of income, food, and employment for Nyamira County, both directly and indirectly. A majority (74%) of the adults are engaged in crop and/or livestock farming, while 8% have formal salaried employment as public servants, private-sector employees, non-farming laborers, and domestic workers. About 11% are self-employed in agriculture-related business and trade activities, 4% depend on a pension scheme, and 3% rely on other occupations (GoK, 2014). Several types of businesses operate

in Nyamira County, employing many people (GoK, 2018). The annual average income from business is KSh 120,943, with male-headed households earning KSh 159,104, compared to female- and youth-headed households, which bring in KSh 126,000 and KSh 120,943, respectively (GoK, 2014).

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About 36% of the population are suffering from food poverty, with 9.6% and 25.5% of children wasted and stunted respectively (Figure 3). About 7.6% of the population are hardcore poor, meaning that even after spending all of their income on food, they still cannot meet their basic food requirements (KNBS, 2016). Food and nutrition security can be measured by considering food production, post-harvest losses, household size, food availability in terms of the number of meals per day, and seasonality in the food supply (ASDSP, 2014). Within a period of one week, 42% of female-headed households experienced low food availability, compared to 41% of male-headed households and 30% of youth-headed households. Overall, 55% of households do not have enough food to meet their dietary needs. At least 55% of adult male-headed households, 59% of adult female-headed households, and 55% of youth-headed households fall short of sufficient food to meet their needs during the year (ASDSP, 2014). Seasonality in food production also influences food security. Nyamira County experiences two distinct peaks of food scarcity: one during the months of October and November, and one from May to June (ASDSP, 2014).

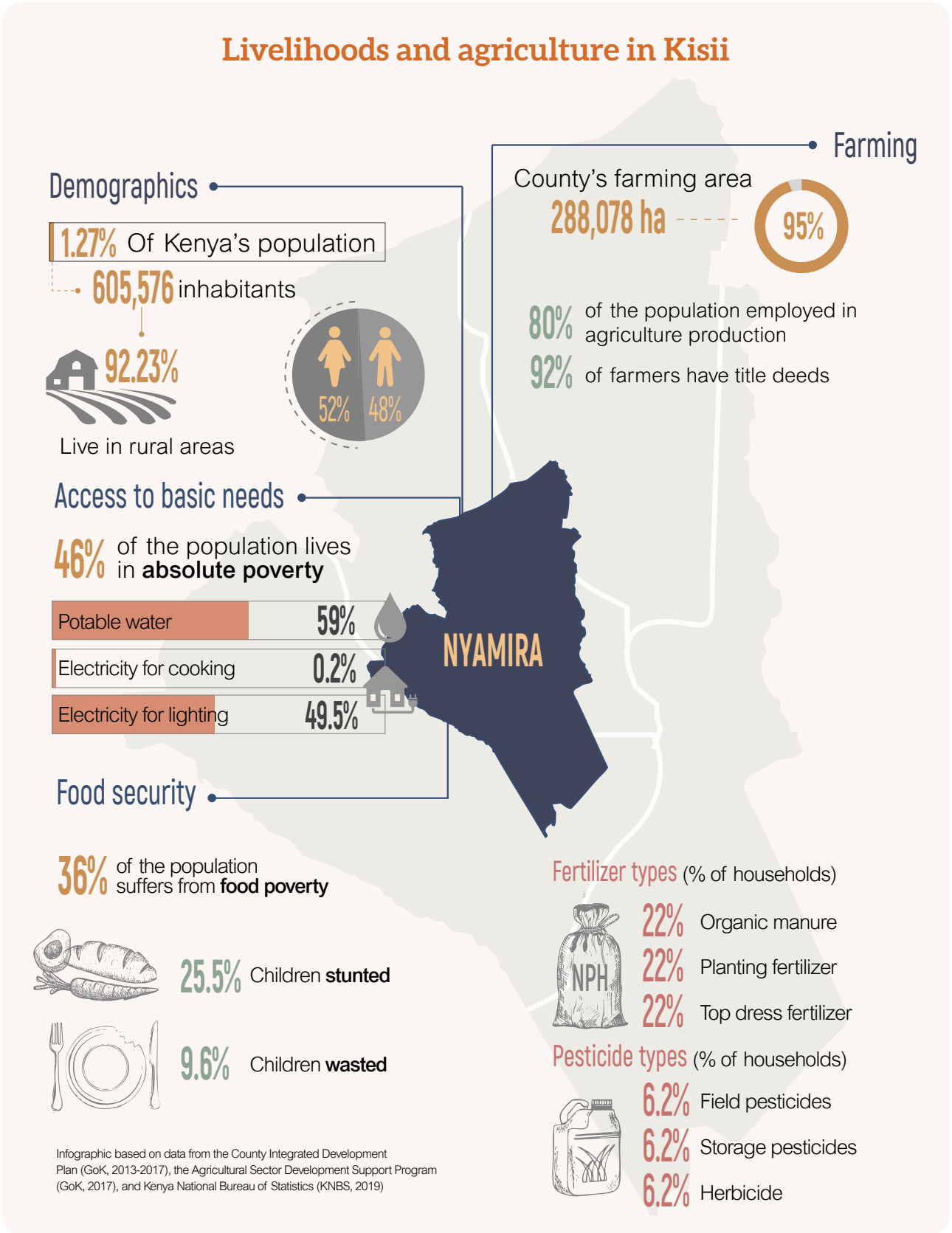

Figure 3: Agriculture and livelihoods in Nyamira County

2.3 Agricultural Activities

Nyamira County's total area is 899.4 km^2, out of which 818 km^2 or 91% is considered arable and 40.5 km^2 or 4.5% is non-arable. Just 2 km^2 or 0.2% of the county's area is water, while the remaining 38.9 km^2 or 4.3% is urban (KNBS, 2015). The majority of the arable land is used for agriculture. The average farm size is 0.7 acres for a small-scale farm and 10 acres for a large-scale farm. As regards land use, 58,394 ha are dedicated to food crops and 48,543 ha to cash crops. These numbers have remained relatively constant.

Nyamira County is divided into two major agroecological zones (AEZs). The lower highland (LH1 and LH2) covers 82% of the county, while the upper midland zone (UM1, UM2, and UM3) encompasses the remaining 18% (Figure 4). Nyamira County has two rainy seasons (long and short rains)long rains start inFebruary and end in June or July, while the short rains start from August and end December. The highest peak of precipitation occurs during the MAM "long rains" season. Nyamira County records the highest amount of rainfall in Kenya. The rainfall is well-distributed, reliable, and adequate for a wide range of crops. The average annual rainfall in the county is 1600 mm, with the annual rainfall ranging between 1200 and 2100 mm. The maximum daytime temperature is 28.70C and the minimum nighttime temperature is 10.10C, resulting in an average temperature of 19.40C - favorable for both crop and livestock farming.

More than 70% of the land in Nyamira County is freehold. Approximately 72% of land parcels in the county have title deeds, while the rest are in different stages of acquiring title deeds. Nyamira County has three main types of land holdings, of distinct sizes, in different sub-counties. They consist of large-scale, medium-scale, and small-scale farmers. Medium- and large-scale farms account for a small percentage of the holdings but cover the largest area. Borabu Sub-County and some parts of Nyamira North Sub-County contain large parcels of land owned by multinational companies for tea growing and processing as well as for settlement schemes. The four remaining sub-counties encompass smaller parcels of arable land. Manga Sub-County features the smallest farm area, followed by Masaba North. Multinational farmers hold less than 10% of Nyamira County's land. Individual, large-scale farmers hold an average of 4 ha in Borabu Sub-County, whereas small-scale farmers hold an average of 0.7 ha in other sub-counties. It is worth noting that the number of land holdings is increasing fast, due to the continued subdivision of both small- and large-scale farm holdings (County Government of Nyamira, 2018).

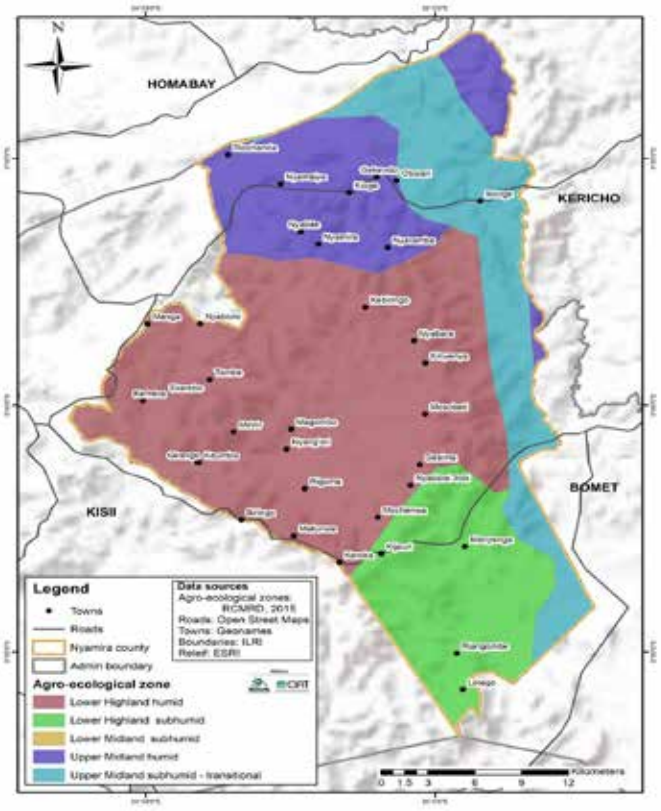

Figure 4: Map of agroecological zones in Nyamira County

Nyamira County's agricultural production is mostly rain-fed, which leads to fluctuation and seasonality in food production. Irrigation is limited, with only ten small irrigation schemes distributed across the county. Only 1.4% of county farmers practice irrigation (ASDSP, 2014). Improved seed is mainly used for maize in season 1 and beans in season 2. Manure, meanwhile, is widely used for maize, beans, finger millet, and sorghum. At least 60% of the farmers who grow perennial crops apply organic manure, while 37% use topdressing fertilizers (ASDSP, 2014). Foliar sprays and pesticides are applied minimally, but at least 20% of Nyamira County's farmers utilize field pesticides. Improved seed is also used for planting tea, coffee, and multipurpose trees. Planting and topdressing fertilizer is mainly applied to grow bananas and tea. Manure use is widespread for perennial crops like bananas, coffee, tea, and Napier grass. The county's most common inputs in livestock production are acaricides for dipping or spraying, mineral supplements like salts, and de-wormers, with some usage of artificial insemination (AI), veterinary drugs, fodder, hay, and silage, and crop residue (ASDSP, 2014).

Zero-grazing dairy farming is gaining popularity in Nyamira County due to diminishing land availability, weather conditions, and a ready market for milk. Bee keeping or apiculture is also growing in popularity.

Nyamira County has promoted apiculture over the last five years, and as a result, farmers have recorded improved yields per hive. The county is not a major fish producer, but an uptake of fish rearing has been recorded after government intervention through the Economic Stimulus Program in 2009 (ASDSP, 2014, County Government of Nyamira, 2013). It is estimated that Nyamira County's four constituencies have over 1,722 operational fishponds (County Government of Nyamira, 2013).

2.4 Agricultural Value Chain Commodities

Among the diversity of agricultural commodities grown in Nyamira County, several are prioritized by the County Integrated Development Plan (CIDP), by development programs such as the NARIGP and the Agricultural Sector Development Support Programme (ASDSP), and by 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 the 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 nutritional characteristics like dietary energy consumption (Kcal/capita/day) and protein, iron, zinc, and Vitamin A content. The list was presented to stakeholders during a 3-day workshop for in-depth analysis and selection. The selection process was further refined by the following set of criteria which were determined with the stakeholders: resilience to current and future climate change impacts, measured on a scale from low to high; the percentage of the county's population involved in each value chain; and the involvement in their value chain of economically and socially vulnerable groups such as poor people, women, and youths, on a scale from low to high. Each value chain was assessed against each criterion, and we chose the value chains that engage the highest percentage of the population along with poor people, women, and youths. The four VCCs which were selected for this report are the banana, local chicken, dairy, and indigenous vegetable value chains (Figure 4).

2.4.1 Bananas

In Nyamira County, bananas comprise an important value chain. They are produced for subsistence and commercial purposes almost everywhere in the county. In 2013, the area under banana production was estimated at 2,105 ha with a production of 31,575 tons (15 tons/ha); by 2017, the total area under production was 2,259 ha, yielding a total production of 42,475 tons of bananas (County Government of Nyamira, 2018). Bananas grow well in fairly hot and humid areas that lie within an altitude of 0 to 1800 m above sea level. They require rainfall of at least 1000 mm per year, but in order to achieve good yields, they should receive a regular supply of 200-220 mm of water per month. Temperature is a major factor in banana growth; the optimal temperature ranges from 28°C to 38°C. Below 13°C, the bananas' growth is retarded, and they are vulnerable to chilling injuries. The plants can tolerate a pH of 4.5 to 7.5, but their ideal pH falls between 6 and 7.5 (Mbwana et al., 1998). Nyamira County's climate is well-matched to bananas' needs.

The banana value chain engages 81-100% of the county's population. The main varieties grown in the County include dessert, cooking, and dual cooking-and-dessert varieties. The cooking varieties include Ngombe, Nusu Ngombe, and Uganda Green, which is native to Kisii; the dessert varieties include Grand Naine, Williams, Chinese Cavendish, and Giant Cavendish; and the dual varieties include FHIA 17 and FHIA 18. Banana plantations are commonly established with tissue culture planting materials. Tissue culture plantlets technology, which is now available, offers farmers healthy planting materials that are free of disease and pests, have higher vigor and chances of survival, mature early, yield more, and involve well-known fertilizer and manure application regimes.

Input supply is done on a small scale within Nyamira County. Because it encourages quality production, the acquisition of clean, quality planting materials, such as tissue culture banana plantlets, is considered the most important part of input supply. The main suppliers of these plantlets are Aberdare Technologies Ltd., KALRO, and Kisii and Jomo Kenyatta University of Agriculture and Technology. Production and post-harvest processes also take place on a small scale, while marketing occurs at medium-scale. Because land is a limited resource in Nyamira County, most farmers grow bananas on a small scale, for subsistence. Post-harvest processes are limited because of the high demand for fresh bananas, but small-scale processors such Hobanapo Cooperative Society Ltd. are adding value in a modest capacity. Hobanapo Cooperative Society Ltd. has a processing facility for banana crisps, flour, bread, and other bakery products, which fetch better prices than raw bananas in the market. Marketing is also limited because of poor market linkages and inadequate organized collection and bulking centers. Most of the farmers, with few exceptions, sell their banana in the local market and through middlemen (brokers). However, the middlemen have been exploiting farmers by offering very low prices for their bananas.

Men are most involved in the input supply and post-harvest stages of this value chain, while women are more engaged at the marketing and production stages. Nyamira County's male youth population participates strongly in the post-harvest stage, while the female youth population is highly involved in marketing. Although the female population takes part in this value chain, it is predominately men who control the proceeds and make the key decisions relating to banana production (ASDSP, 2014). Their limited decision-making power and differential access to

resources, compounded by social and cultural norms and beliefs, exacerbate women farmers' vulnerability to climate change hazards and also lessens their adaptive capacity.

2.4.2 Local Chickens

Local chickens anchor another crucial value chain in Nyamira County, which engages 61-80% of the population. Almost every household, especially in rural areas, practices chicken farming. Small-scale farmers keep fewer than 100 chickens, but the majority of farmers are medium-scale with up to 600 chickens. A few large-scale farmers keep up to 1,000 chickens. This value chain is popular because the local chickens can tolerate a harsh climate, come with low production costs, and require less labor than exotic breeds. The chickens are kept mainly for meat and eggs; the local market is the major outlet for these products. Input suppliers are involved on the small, medium, and large scales, while farmers, processors, wholesalers, and retailers are involved on a small scale. The majority of farmers practice on-farm production on both small and medium scales due to limited market access and finances. Processors are mostly small-scale because of inadequate processing skills, capacity building, storage, and processing facilities. Because so few processers are involved, there is a low rate of value addition, limited to dressing, differentiation, and packing (ASDSP, 2014). Very few retailers and wholesalers are involved in the value chain.

Female farmers, who are mostly involved in the on-farm production, post-harvest, and marketing stages, dominate this value chain. Men and male youths are mostly involved at the input supply stage, with low participation in the on-farm production, post-harvest, and marketing stages. Female youths are primarily engaged in the on-farm production stage of this value chain, with low involvement at the input supply and post-harvest stages. Most decisions (61%) about the chicken value chain are made by adult women, whereas adult men make about 21% of decisions, and youths make about 18% (ASDSP, 2014).

2.4.3 Dairy Cows

In Nyamira County, the dairy cow value chain is also significant. It involves 81-100 % of the population, and almost every household owns a dairy cow, especially in rural areas. Common breeds include local, crossbred, and exotic cattle, such as Friesian, Ayrshire, Jersey, Guernsey, and Zebu, a local breed. Zebu cows are hardy and are mainly kept in the marginalized lower parts of the county, in the Nyamaiya, Bomwagamo, and Bokeira Wards. These areas are dry throughout most of the year and do not sustain fodder production (County Government of Nyamira, 2018).

Dairy production is mainly small-scale, with zero grazing due to reduced availability of land. The exotic breeds are high milk producers, but overly vulnerable to disease, particularly tick-borne diseases. Conversely, the Zebu breed has high resistance to diseases, but produces less milk. In order to encourage milk production in the Zebu breed, the Department of Livestock has promoted crossbreeding using AI. As a result, the dairy cow population has increased from 121,502 in 2013 to 187,692 in 2017, with corresponding increases in milk production from 47,887,650 L in 2013 to 66,321,000 L in 2017 (County Government of Nyamira, 2018).

Women dominate this value chain; they are highly involved in its production, post-harvest, and marketing stages. Men are intensely engaged in input supply, but least involved at the post-harvest and marketing stages. Youths, meanwhile, participate strongly in the input supply, post-harvest, and marketing stages, and are least involved at the production stage. Although stakeholders in Nyamira County opined that youth involvement at the production stage of the dairy value chain is limited, milk production was highest in youth-headed households during the dry season (ASDSP, 2014). Among youth-headed households during the dry season, about 4.2 L of milk was recorded per local cow per day, 5.6 L per crossbred cow per day, and 6.8 L per exotic cow per day. Female-headed households measured 1.6 L per local cow per day, 4.5 L per crossbred cow per day, and 5.8 L per exotic cow per day. During the wet season, youth-headed households produced the largest amounts of milk from crossbred cows, while female-headed households recorded the most milk from exotic breeds (ASDSP, 2014).

Most of Nyamira County's milk producers sell much of their milk directly to local consumers. They sell to neighbors, low-income urban dwellers, local vendors, milk bars, nearby schools, and restaurants. A few farmers split their milk and sell part of it through dairy cooperatives and producer groups, especially during the rainy season when production volume increases (Auma, 2018). Few producers (15%) sell their milk to large-scale clients like private processors such as Highland Creameries, Brookside Creameries Ltd., and the New Kenya Co-operative Creameries Ltd. (New KCC) (GoK, 2019). The producer-to-individual consumer channel accounts for 40% of milk sales in Nyamira County (Auma, 2018). The price varies with the marketing channel, season, volume, transport costs, and, in some cases, with time. About 85% of the milk is consumed locally and is unprocessed (SDCP, 2016). However, some value addition is performed at the household level -- mostly through fermentation which accounts for 57% of the value addition, sometimes through cooling, making yogurt, flavoring and boiling which account for 14%, 2.3% 0.5% and 0.6% respectively (ASDSP, 2014).

2.4.4 Indigenous Vegetables: African Nightshade and Spider Plant

Stakeholders reported that the indigenous vegetable value chain is vital in Nyamira County. Indigenous vegetables have value as a staple food and a commercial

product. Almost every household engages in vegetable production, mostly through kitchen gardens, which consume little space. Indigenous vegetables are very resilient to climate change and can survive across Nyamira County's wide range of climates and soil types. The most popular local vegetables are African nightshade (*Solanum nigrum*) and spider plant (*Cleome gynandra*). Approximately 61-80% of the county population engages with this value chain. Production primarily occurs through small-scale cropping systems. Most farmers produce on less than ¼ of an acre.

The indigenous vegetable value chain predominately involves female farmers who participate intensively at all stages of the value chain – input supply, on-farm production, post-harvest, and marketing. Men are occasionally involved at the input supply stage. Female youths are highly engaged in the on-farm production, post-harvest, and marketing stages, while male youths seldom take part. The stakeholders' views confirm findings from a baseline survey for Nyamira county which showed that female farmers accounted for majority of the indigenous vegetable producers-in comparison to male and youth farmers (GoK, 2019). Input suppliers are involved on a small scale and limited to agro-vets and retailers because most farmers in Nyamira County recycle their own seed and rely on locally made farm inputs such as farmyard manure, compost, and organic pesticides (GoK, 2019). Farmers have reported that organically produced indigenous vegetables are healthier, tastier, and have a longer shelf life (GoK, 2019). Indigenous vegetables are seldom processed, although some farmers perform value

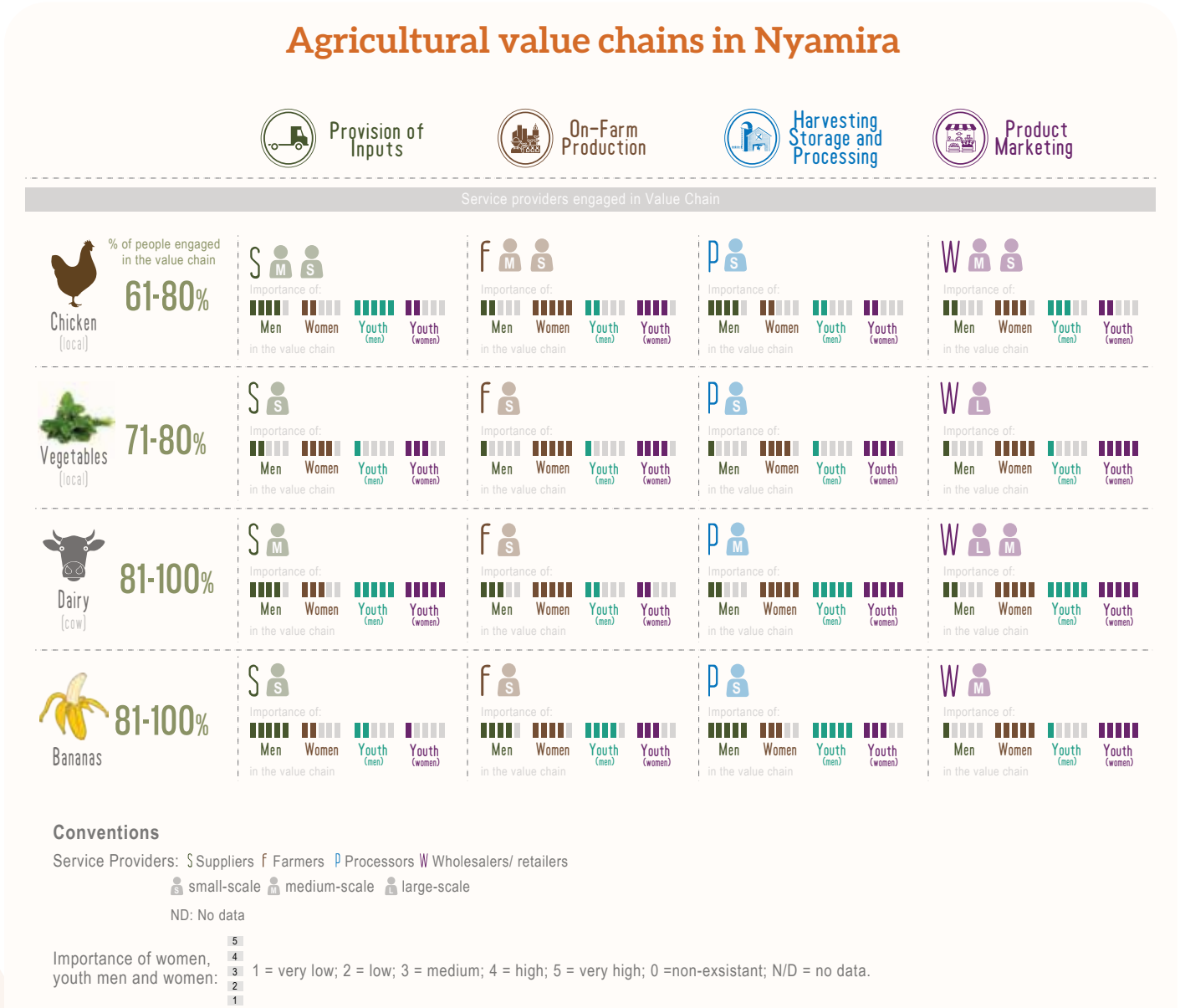

Figure 5: Characterization of Selected Agricultural Value Chains in Nyamira County

addition, such as solar drying in order to preserve vegetables for the dry season. Effective processing is limited by a dearth of technology; also, due to the low volumes of vegetables produced, most indigenous vegetables are consumed within households or sold locally through retail market outlets.

2.5 Challenges to the Agricultural Sector

Despite agriculture's economic prominence in Nyamira County, it is dogged by many challenges. Pest and diseases are a threat to agricultural production. At least 41% of farmers have experienced some form of new insect pests or diseases (ASDSP, 2014). These new pests include the fall armyworm; the Maize Lethal Necrotic Disease, which mostly damages maize; and *Tuta absoluta,* which affects tomatoes. In addition, post-harvest pests account for 50% of crop losses (GoK, 2019). Diseases have also long been a menace to livestock because Nyamira County's veterinary services are understaffed and under-serviced with drugs and vaccines. Common livestock pests such as ecto-parasites and endo-parasites remain a major challenge.

Recently, Nyamira County has faced challenges that are associated with climate variability and change. These include delayed and unpredictable rains and the untimely cessations of seasonal rains, which impact the timing of key activities like land preparation, planting, and harvesting. Other challenges include skewed rainfall distribution and intensity, occasional hailstorms, extremely high rainfall that leads to soil erosion and flood risks, and occasional storms during the flowering and harvesting stage, which affects crops such as beans (ASDSP, 2014).

Lately, Nyamira County has also experienced a high rate of land subdivisions, which has compromised farmers' ability to adequately engage in sustainable farming activities and maintain their livelihoods. A lack of sufficient land and fodder poses a major challenge to dairy farmers. For example, feed conservation, especially silage, is limited in Nyamira County because it requires an abundance of fodder. Farmers are unable to produce sufficient quantities of fodder for silage conservation (KIPPRA, 2017).

The county engages in unsustainable natural resource management, which compromises agricultural productivity. The most prevalent consequence of this situation is soil degradation, followed by water volume reduction, the drying of wells and rivers, and the disappearance of some indigenous plants and animals (ASDSP, 2014). Nyamira County's environmental degradation is compounded by unsustainable farming practices such as the improper use of inputs; the cultivation of land up to riverbanks, resulting in surface soil erosion; improper disposal of solid waste; massive tree felling for firewood and timber and to clear land; and agro-chemical pollution. These practices are linked to farmers' limited skills and inadequate access to agricultural extension and training services.

Nyamira County's low use of agricultural farm inputs like pesticides, certified seed, and fertilizers, and of services like AI, credit, extension, and farm inputs, constitutes a serious hindrance to its agricultural production (ASDSP, 2014). Livestock production inputs are minimal in Nyamira County in part because of high prices. The dairy value chain is affected when veterinary services are delayed, because this problem in turn can hinder and in some cases preclude effective vaccinations against such diseases as foot and mouth disease, lumpy skin disease, and anthrax. Use of crop production inputs is minimal due to high prices and the distance between farms and markets. Most households (59%) cannot fully access recommended farm inputs such as improved seed, planting fertilizer, and topdressing fertilizer. The reduced inputs results in reduced production and decreased economic competitiveness (ASDSP, 2014).

Nyamira County has huge irrigation potential, yet just ten small irrigation schemes are distributed across the county. Only 1.4% of farmers practice irrigation farming. Nyamira County thus depends mainly on rain-fed agriculture, which increases the farmers' vulnerability to climate changes and other risks that result in fluctuation and seasonality in food production (County Government of Nyamira, 2018).

The county's agricultural education system is characterized by diverse and uncoordinated sources of information and extension providers. Agricultural extension, training, and research services are still minimal due to inadequate expertise, limited funding, and poor coordination and collaboration among institutions.

Weak, poor, and inadequate farmers' organizations, associations, and cooperative societies are a major obstacle to agricultural marketing in Nyamira County. This situation deprives farmers of the bargaining power to facilitate efficient marketing. As a result, farmers sell their produce individually, which exposes them to exploitation by middlemen. The cooperatives that do exist are less attractive to farmers because they pay lower prices in order to cover their operation costs. If farmers are encouraged to organize, they may gain access to agricultural services and explore better markets for their produce.

Nyamira County's inadequacy of policy, coupled with a weak and inadequate institutional structures, hampers its agricultural production and marketing. The county has limited regulation and certification to ensure the quality and availability of inputs. Farmers have reported ineffective AI services that do not always produce the right breeds (County Government of Nyamira, 2018). The lack of agricultural marketing regulation has led to insufficient markets and the exploitation of farmers by middlemen. The county's values chains are also impeded from reaching their full potential by political influence and interference, and inadequate implementation of government initiatives and support.

Low investment in necessary infrastructure, along with poorly organized and institutionalized marketing strategies, hinders Nyamira County's agricultural sector's growth. Poor road infrastructure and networks, especially in rural areas, complicate the transportation of highly perishable produce. Limited access to modern technologies and facilities slow the value chains' development and growth. Nyamira County lacks modern chilling, storing, and processing facilities for the dairy value chain, proper packaging and transportation equipment for the banana value chain, and suitable storage and processing facilities for the chicken value chain. These challenges result in huge post-harvest losses and products that fetch poor prices at the farm level.

3. Climate Change and Agriculture-Related Risks and Vulnerabilities

To assess climate change and variability in Nyamira County, in this profile we analyzed past trends and future projections pertaining to precipitation- and temperature-related hazards, such as extreme hydrological events including flash floods, droughts, moisture stress, heat stress, and the start and length of the growing seasons. We defined the growing season as follows: the first, long rainy season is the 100-day wettest period from January to June, while the second season, short rainy season is the 100-day wettest period from July to December (KMD, 2020).

To assess droughts and dry spells, we focused on the maximum number of consecutive dry days (CDD), defined as days with rainfall totaling less than 1mm (precipitation < 1 mm day^{-1}). Heat stress was determined by measuring the total number of days with maximum temperatures greater than or equal to 35°C (NT35). We discerned the start of the growing season by the occurrence of 5 consecutive growing days, while the length of the growing period (LGP) refers to the total number of growing days. 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.

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

To assess the degree of adequacy of rainfall and soil moisture to meet the potential water requirements for agriculture, we focused on drought stress, represented by the number of consecutive days in each season when the ratio of actual to potential evapotranspiration fell below 0.5. For each pixel, we calculated this value per season per year by evaluating the soil's water capacity and evapotranspiration in order to define the number of days that met the requirements for drought stress.

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 Phase 5 (CMIP5) models (Taylor et al., 2012), using RCP 8.5 for two future periods, namely 2030 and 2050. [1]

3.1 Climate Change and Variability: Historic and Future Trends

Temperatures in Nyamira County vary between 15oC and 30°C (Figure 6 and 7). The county experiences two growing seasons: a long rainy season between February and June and a short rainy season between August and December. It sees relative dry spells with less than 100 mm of rainfall between January and February and in August. The month of April has the highest rainfall, around 250 mm. The average annual precipitation in Nyamira County falls between 1400 and 2000 mm. Its western region receives an average annual precipitation of more than 1800 mm. The annual average temperature falls between 19°C and 25°C. Historically, the annual average rainfall and temperature display a directional spatial trend, with less rainfall in the south.

The annual total rainfall did not significantly change for the period 1985-2015 for the long rainy season. It is however expected to decrease significantly up to 2040. The total annual rainfall was increasing and is expected to increase for the short rainy season (Figure 8). The annual mean temperature trends show an increase for both season and this is expected to continue in the future (Figure 9).

During the first rainy season, most of Nyamira County has historically experienced 10 or fewer CDDs. During the second rainy season, most of Nyamira County has historically experienced fewer than 14 CDDs. The number of CDDs serves as an effective measure of extremely low precipitation and seasonal droughts. During the first rainy season, the regions of Nyamira County that record higher precipitation have historically been more prone to 95th percentile rainfall intensity . The 95th percentile of daily precipitation for a season serves as an indicator of heavy rainfall or very wet days, and is linked with erosion risk. Estimated based on when the climatic conditions become suitable for crop

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

growth, the start of the growing season in Nyamira County occurs in February, with some variability. Temperatures greater than or equal to 35°C (NT35), an indicator of heat stress, have never occurred during the first rainy season.

Nyamira County's LGP during the long rainy season, the period when the climatic conditions are suitable for crop growth, has always lasted around five months. Comparison of historical and future trends indicates that moisture stress has been increasing significantly in the past across the county by up to 2 weeks but in the future there will be a significant decrease in moisture stress of up to three weeks throughout Nyamira County. Moisture stress serves as an indicator of the available soil moisture for plants. Higher values of moisture stress negatively affect the vegetative growth of crops during the growing season.

Future projections indicate that during the long rainy season, Nyamira County will witness an overall increase of up to five CDDs (Figure 11). This suggests a marginal increase in the occurrence of drought. During the second rainy season, Nyamira County will likely experience a decrease of 1 or 2 CDDs, suggesting a relatively unchanged pattern. Future projections also indicate that the 95th percentile intensity will remain about the same and follow the same spatial patterns as always, with an average change of 2 mm or less. There will be a general increase by 5 mm or more in the 95th percentile intensity during the second season (Figure 10). Projections suggest that the first growing season will start a week or more earlier across most of the county, while the second growing season will be delayed by 2 - 3 months. Farmers will therefore experience a shorter overall growing season. Climate advisory services will become critical to inform farmers about the optimum planting window. Research and extension services will also play a crucial role in advising farmers about appropriate crop varieties that can thrive in the new, briefer growing season. During the first growing season, the LGP is expected to shorten by up to two months. The second growing season is projected to shorten by 1 - 3 months. Quick-maturing crop varieties will help farmers adapt to these changes. Climate advisory services will also be important to alert farmers to the earliest possible planting opportunities.

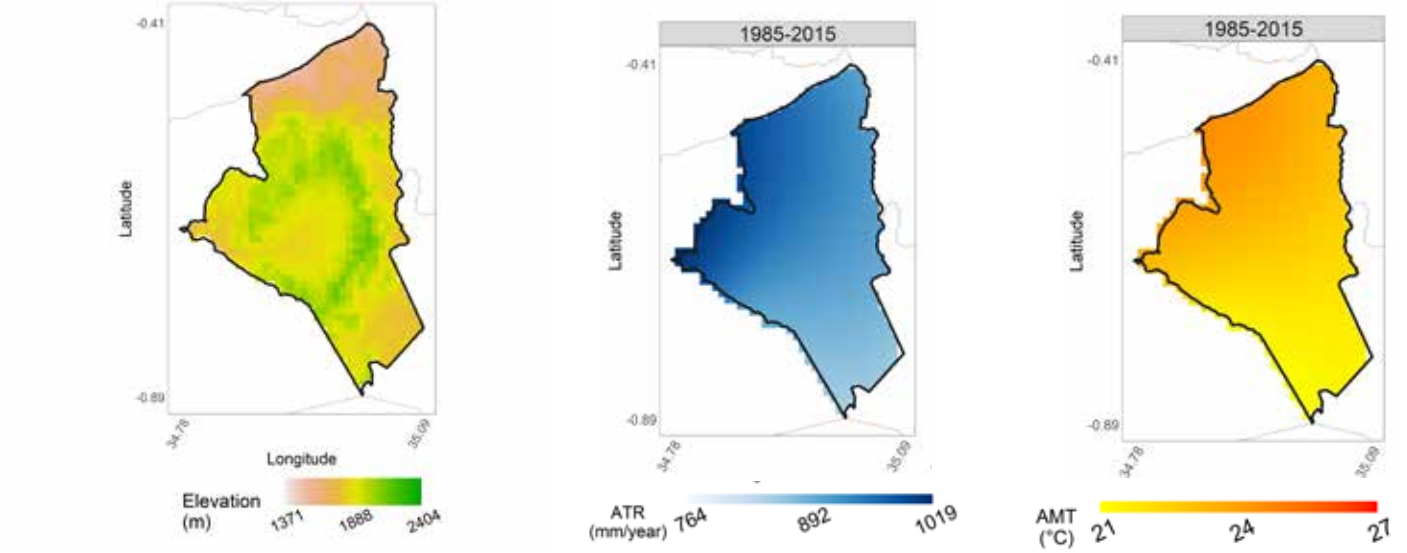

Figure 6: Elevation (left), historical annual mean precipitation in mm (center), and historical annual mean temperature in °C (right) for Nyamira County for the long rainy season

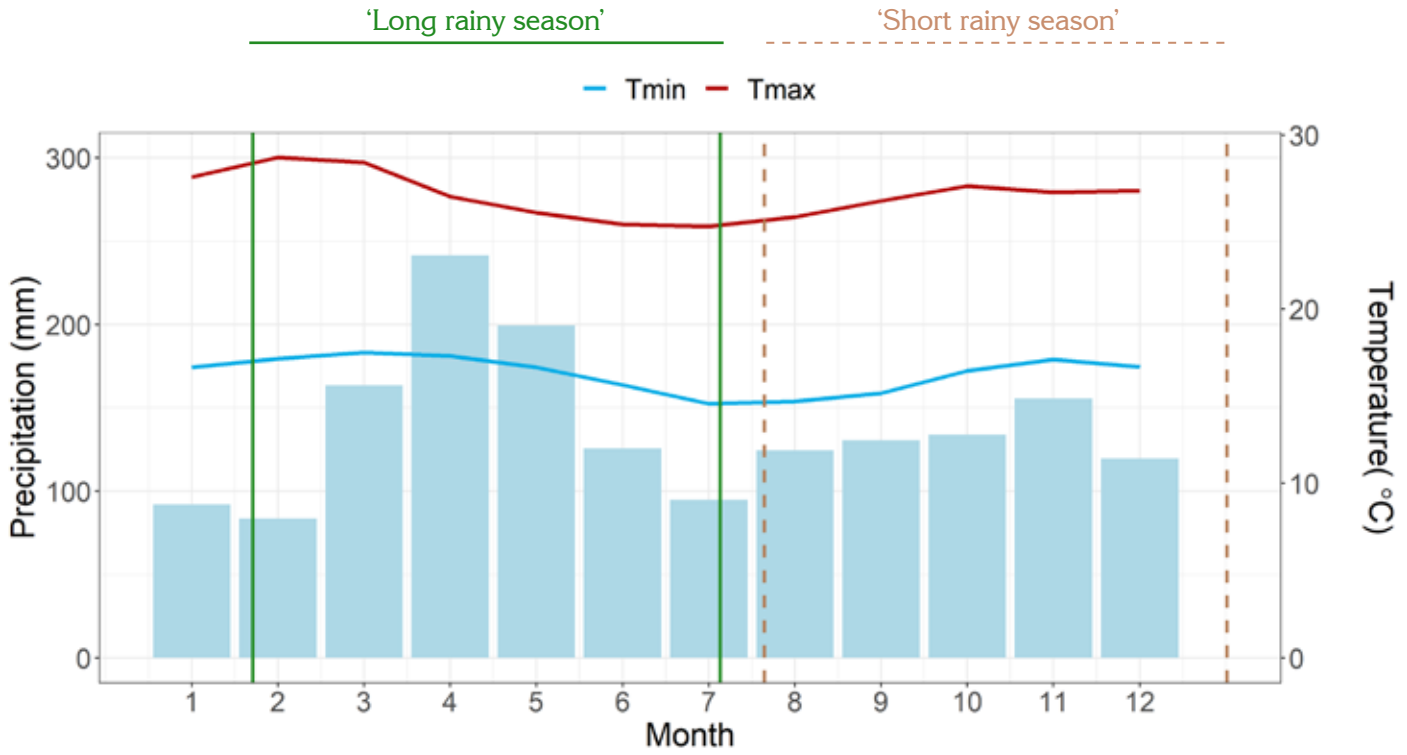

Figure 7: Historical monthly mean temperature and precipitation in the last 30 years in Nyamira County. The first long rainy season is the 100-day wettest period from January to June, while the second, the short rainy season is the 100-day wettest period from July to December. Bars represent total monthly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

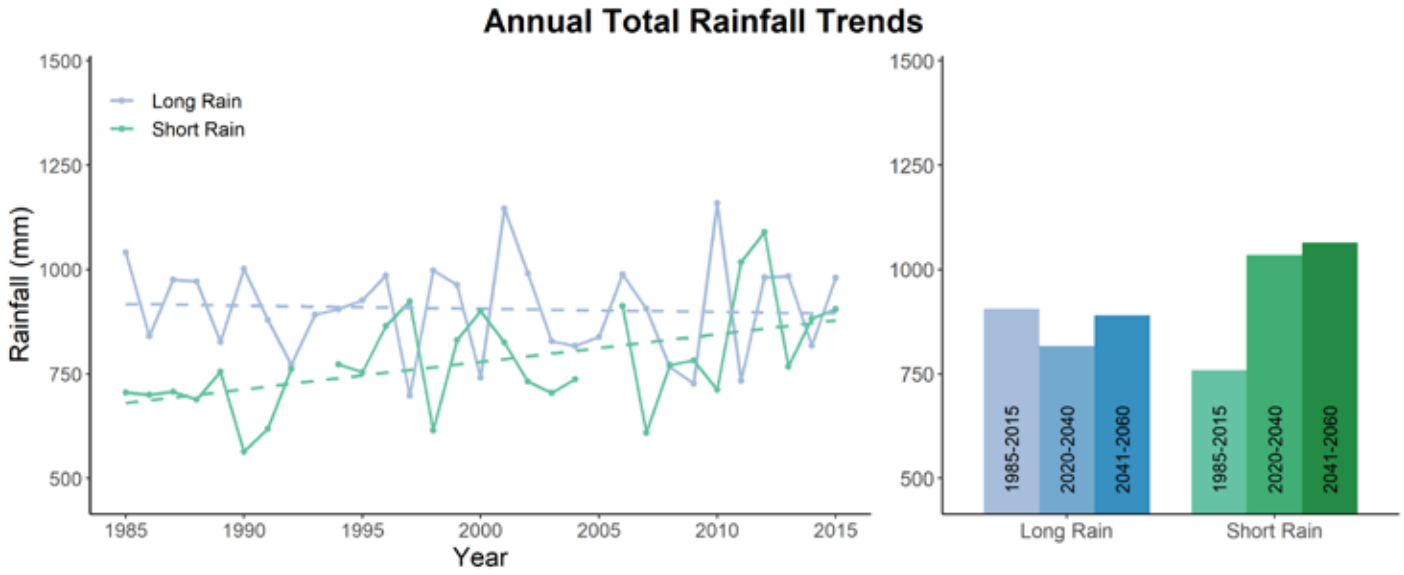

Figure 8: Annual total rainfall trends for the long rainy and short rainy seasons in the past (1985-2015) and in the future (2020-2040 and 2041-2060)

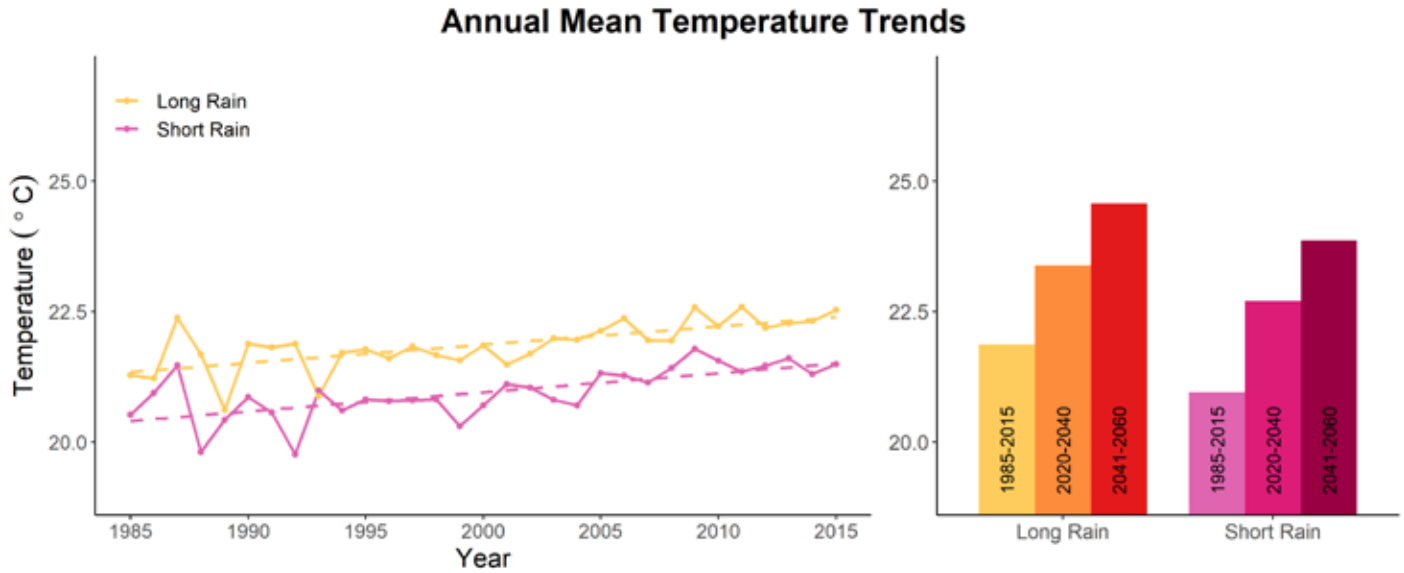

Figure 9: Annual mean temperature trends for the long rainy and short rainy seasons in the past (1985-2015) and in the future (2020-2040 and 2041-2060)

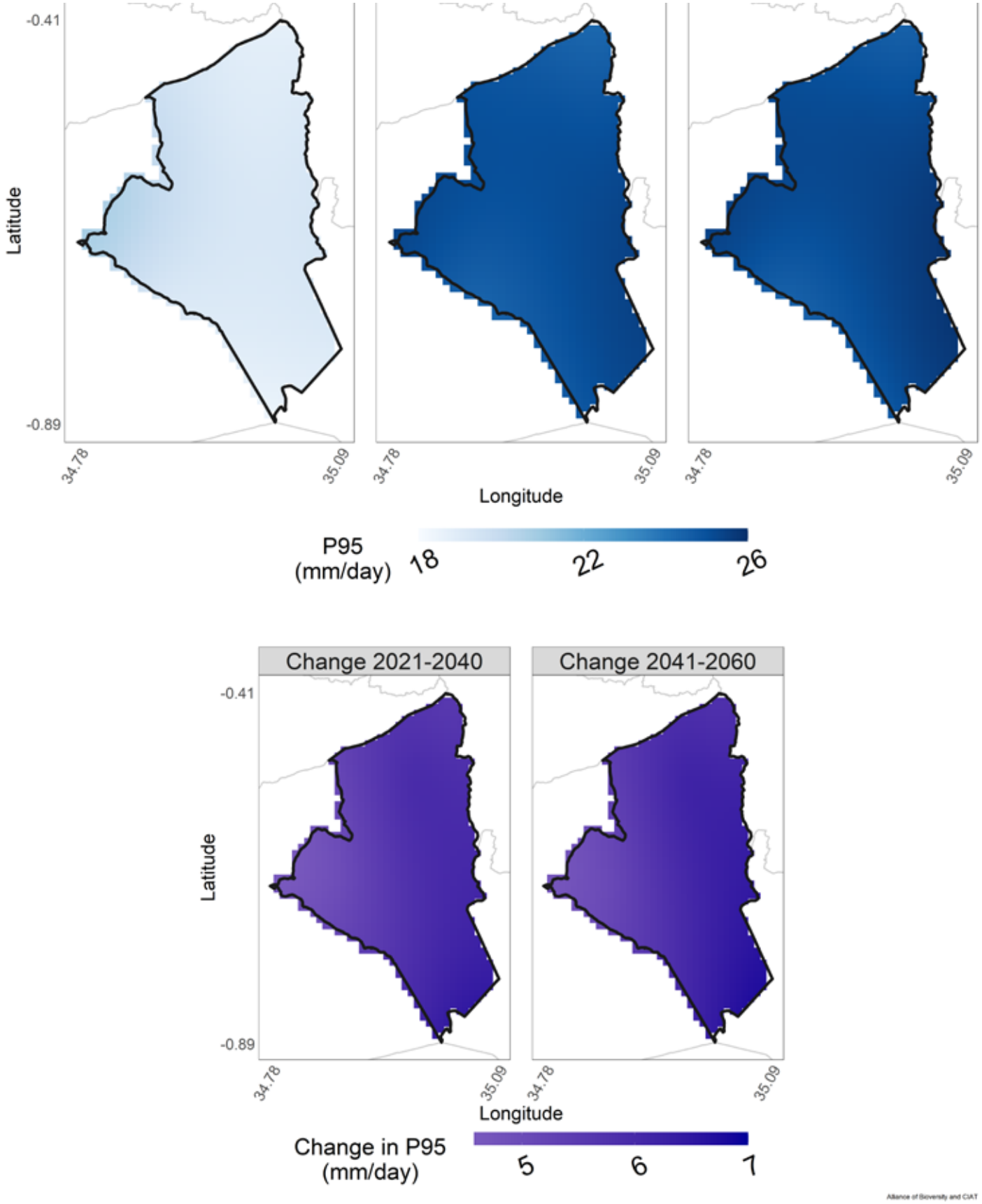

Figure 10: The 95th percentile of daily precipitation in mm for the short rainy season : historical (left), future projected (center), and projected change (right)

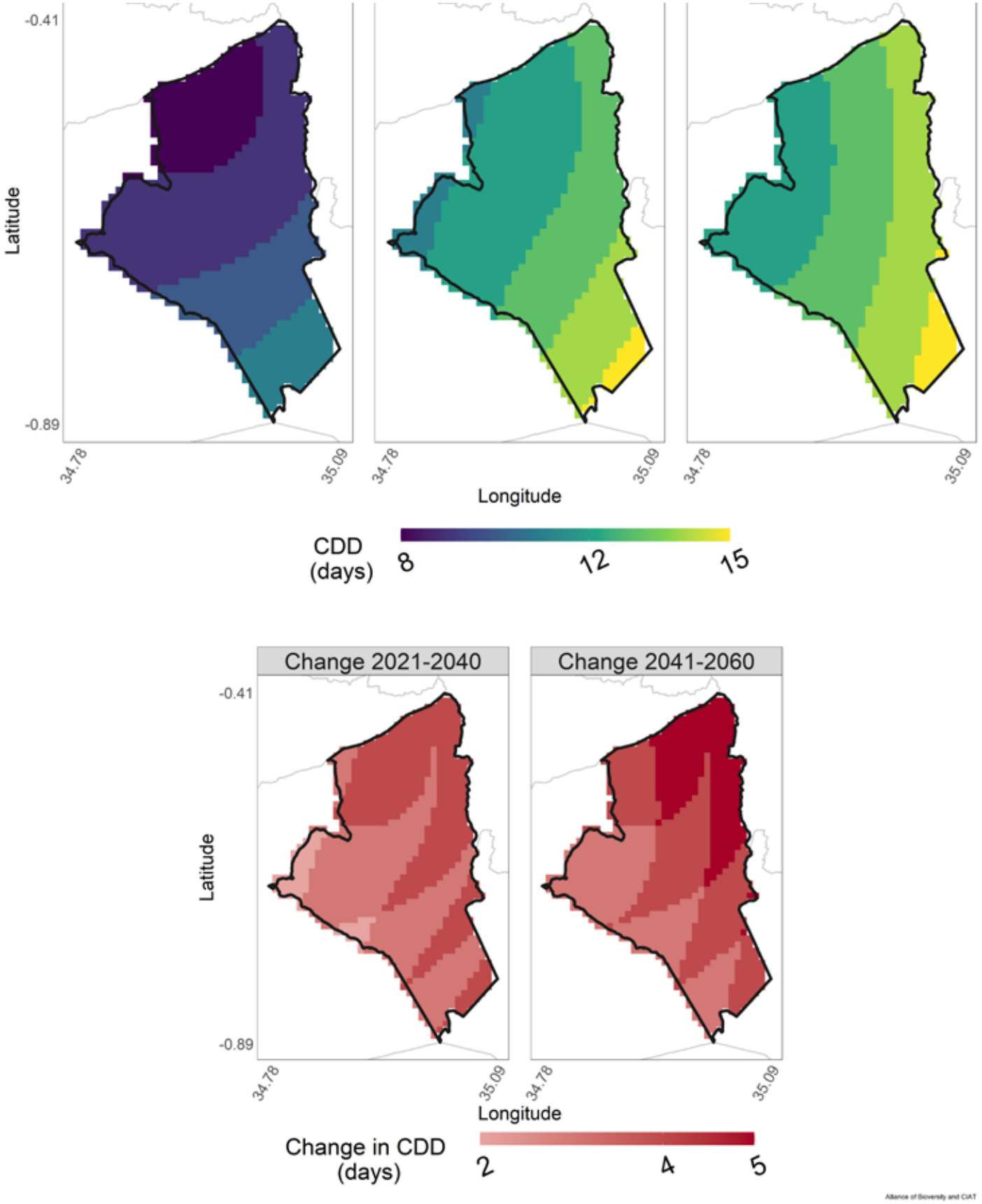

Figure 11: Average number of consecutive dry days for the long rainy season: historical (left), future projected (center), and projected change (right)

3.2 The Climate from Farmers´ Perspectives

Climate variability is a reality in Nyamira County, and farmers have reported a myriad of manifestations. The majority of both male-headed (93%) and female-headed households (97%) have noticed long-term environmental changes in average temperatures and rainfall during the last 20 years (ASDSP, 2014). These changes include unpredictable rainfall patterns characterized by unevenness and inconsistency in rainfall distribution. Farmers also reported an increase in seasonal rainfall variability, including delays or shifts in the onset and/or cessation of seasonal rainfall. This variability has affected the timing of key farming activities like land preparation and planting, which has resulted in poor harvests. Farmers stated that extreme rainfall has increased and that 2020 has been characterized by continuous, heavier-than-normal rains. This extreme rainfall has occasionally been accompanied by hailstones, which damage crops like vegetables, bananas, beans, coffee, and passion fruits. The excess rains have led to low banana production due to prolonged maturity and blockage of planting holes, which has hindered manure application. The extreme rains have led to soil erosion, which has resulted in the siltation of tributaries in the lowlands and decreased soil fertility due to soil-nutrient leaching.

Farmers have also reported that, while historically it has been quite unusual to experience one month without rain in Nyamira, lately there has been an increase in dry spells. Farmers recalled a distinct dry spell from November 2017 to May 2018, and from January to April 2019. These dry spells depleted water sources such as springs, wells, rivers like the Sondu and the Gucha, and swamps that once hosted migratory birds from Europe. The birds have since disappeared.

Farmers also noted that extreme low and high temperatures have been widespread throughout Nyamira County. They describe extremely high temperatures that last for few hours a day and affect crops like tea and maize. Farmers also report extremely low temperatures, especially in the months of July and August. Notably, Nyamira County recorded very low temperatures during these months of the year 2020.

Farmers agree that these climatic changes are exacerbated by the county's increasing environmental degradation. This degradation results from factors such as unsuitable farming methods; inappropriate solid waste management; inadequate sanitary facilities; the felling of massive trees for firewood, timber, and land clearing; quarrying; pollution; effluents from agro-chemicals; and alien and invasive species (County Government of Nyamira, 2018).

3.3 Climate Vulnerabilities across Agricultural Value Chain Commodities

As previously discussed, Nyamira County suffers from a number of climate-change related hazards. The most problematic hazards are dry spells, strong winds, heat stress, and extreme rainfall. These hazards affect each value chain differently, as described below.

3.3.1 Bananas

The banana value chain in Nyamira is most affected by dry spells and strong winds. Dry spells impact all stages of banana production. They pose a major threat to the water supply, with consequences for the growth and development of tissue cultures that can lead in turn to low production and a limited supply of bananas. Bananas are not planted during dry spells, which results in a lower income for the farmers and agro-dealers who supply manure and fertilizer.

Dry spells have a major-to-severe impact on banana production. They cause seedlings to die and necessitate supplementary irrigation, which increases costs and delays the establishment of banana orchards. The growth of the banana plants is retarded; the health of the plants may suffer, rendering them plant more susceptible to disease and pests; and the product diminishes in quality and yield. These problems may bring about the loss of key segments of the market which require specific quality grades. This situation, in turn, depresses incomes and revenue. Low productivity and poor quality pose challenges at both the post-harvest and marketing stages of the value chain, such as the heightened transport costs that come with low volumes. Poor product quality decreases prices, leading to low and unsteady incomes and job losses, which in turn can mean insecure livelihoods for farmers.

Strong winds have a major impact at the input stage due to the loss of topsoil and nutrients, which increases demand for manure and fertilizer. At the production stage, stakeholders' opinion was that strong winds (related to variety) have a major impact because more labor is required to create a bigger planting hole – which, in turn, demands a lot of manure and fertilizer. Thus, strong winds lead to higher labor costs and input requirements that drive up the cost of production. Strong winds push over trees and products, causing damage and premature harvests and lessening farmers' incomes. Poor harvests can bring about a banana shortage in a market with high demand, resulting in high prices. These high prices affect consumer purchasing power, which in turn may reduce nutrition and food security. Low production results in job losses for the men and youths who are involved in activities such as pruning, loading, and transportation.

The climate hazards that affect the banana value chain impact people differently, depending on their roles in the value chain. Women and youths are likely to be affected more than male farmers, because they have limited access to financial services, resources, and adaptation strategies such as water harvesting and conservation measures. Female farmers are more likely to suffer from climate hazards due to sociocultural factors which limit their decision-making especially about matters of land. Bananas are a staple food in Nyamira County, and low production greatly impacts the county's food and nutrition security.

3.3.2 Local Chickens

The climatic hazards that effect the local chicken value chain in Nyamira County are dry spells and heat stress. Both hazards are associated with increasing temperature that arise from hot and humid weather conditions.

Dry spells impede the input supply stage because the associated high temperatures can kill chicks that were purchased from distant hatcheries. During dry spells, raw feed materials such as green vegetation, groundnuts, and sunflower seeds dry out, rendering them unusable. Reduced feed results in reduced egg production and higher rates of immature and unviable eggs. Farmers are consequently forced to use commercial feeds, which drives up their production costs. Feed shortages may compel farmers to sell their chickens at throwaway prices[2] in order to reduce stocks. Farmers may sometimes have to leave their birds to scavenge, which exposes the birds to predators. During dry spells, incidences of external parasites such as red mites and diseases such as Newcastle disease, fowl pox, fowl cholera, and Gumboro increase. These diseases and parasites may have severe consequences for chickens, including death. Vaccinations against these diseases elevate production costs. During the post-harvest stage of production, the high temperatures that are associated with dry spells result in decreased quality and shelf life of chicken products. The post-production risks associated with high temperatures are exacerbated by poor infrastructure, like inaccessible roads and poor packaging facilities.

Although the magnitude of the impact of heat stress on the value chain, was rated as severe, this may vary based on the exposure of the value chain or the frequency of the hazard. The possibility of heat stress underscores the need to provide housing with good ventilation; sourcing for heatproof materials may raise production costs. Heat stress makes chickens pant more in order to keep cool, which causes them to lose water. Dehydration can be fatal for chickens, and therefore heat can reduce a flock and result in losses. Heat can also cause chickens to suffocate; this affects their growth, egg production, and hatching. During egg formation calcium plays an important role of hardening the eggs, and thus underfed chickens may produce smaller, more fragile eggs of overall poor quality (Ebeid et al., 2012). High temperatures result in smaller chickens which fetch low prices in the market, meaning a loss of incomes for the producers. Dry spells also severely affect the market forces of supply and demand: they cause high demand for chicken products like chicks, eggs, and meat, coupled with low supply.

Youths and women are most likely to be affected by these climate hazards, not only because they are the value chain's major players, but also because of inadequate access to knowledge and financial resources to help themselves adapt. Youth are primarily impacted due to their limited access to land and their inability to make decisions. Vulnerable groups like the disabled are also at risk, because they do not have sufficient capability to adapt to climatic hazards.

3.3.3 Dairy Cows

The climatic hazards that affect the dairy value chain in Nyamira County are extreme rainfall and dry spells. Women are more likely to suffer from these climatic hazards because they are more involved in the dairy value chain and lack the financial capacity and access to cope.

Dry spells are a major hindrance to dairy production. Water scarcity due to dry spells decreases the quality and quantity of fodder crops. Due to fodder shortages, farmers are compelled to use more commercial feeds and supplements as well as hay and silage as alternative sources of feed. These sources are sometimes expensive, low-quality, and unavailable in the market due to ineffective distribution systems (Auma, 2018). Due to high feed costs, farmers may underfeed cows, which results in smaller quantities of lower-quality milk. Decreased production may bring about milk shortages, which drive up market prices. Higher prices benefit producers but negatively affect consumers - especially low income earners. The high temperatures associated with dry spells hamper breeding by lowering rates of conception. This situation results in long calving intervals and lower milk production. Often there is also an upsurge in disease outbreaks during dry spells, like East Coast Fever, which heightens the demand for clinical services, vaccinations, and drugs. Because most farmers lack cold storage, milk expires quickly in the heat. Although milk fetches higher prices during dry spells, profit margins remain low due to elevated production costs from sourcing for alternative feeds and veterinary services.

Extreme rainfall is also a major problem, because excess moisture predisposes livestock to contract diseases like foot and mouth disease, which in turn necessitates increased veterinary services like vaccination and drugs. Extreme rainfall can destroy infrastructure such as roads, which makes it difficult for clinical and veterinary service providers to access

[2]Used to describe price that is very low

farms and for farmers to access agrovets. Unusable infrastructure renders livestock inputs or veterinary care unavailable at the required time. Blocked roads also impede farmers from bringing their milk to collection centers, which results in spoilage. Excess rainfall leads to more green matter, which, when fed to cows, lowers milk fat content, thus diminishing milk quality. The maturity of forage influences the milk fat percentage (Alstrup et al., 2015).

3.3.4 Indigenous Vegetables: African Nightshade and Spider Plant

The climatic hazards that affect the indigenous vegetable value chain in Nyamira County are dry spells and extreme rainfall. A dry spell in local vegetable farming is defined as a period of more than a month with no rain. During dry spells, farmers delay acquiring planting material like seedlings and seed, which leads to delayed planting. In this scenario, the manure and fertilizer used during planting is stored for a prolonged time, and this results in delayed nutrient release. This situation, in turn, impacts the soil's fertility, which affects crop growth and development. Dry spells, however, also create positive opportunities to aerate soil properly and suppress soil pests with the heat of the sun.

Dry spells delay land preparation; a hard pan forms in the earth, which is labor-intensive and expensive to break. The high temperatures associated with dry spells invite an influx of pests, especially aphids, caterpillars, and scales, which reduce crop yields and increase pesticide usage. Insufficient moisture retards the maturity of local vegetables, especially the spider plant. Dry spells also bring about crop wilting, which likewise results in reduced crop yields and so affects farmers' livelihood and incomes. However, during the post-harvest stage of production, dry spells have more positive consequences: reduced sorting and packing labor costs, ease in transportation, and value addition in the form of solar drying and preservation. However, farmers reported that extremely hot temperatures increase the rate of spoilage and rotting - especially during post-harvest transportation - which means a lower volume of product. A diminished supply of vegetables in the face of high demand at the market undercuts farmers' livelihoods.

During extreme rainfall or hailstorms, roads are destroyed. This is a major threat to the input stage of production since it affects farmers' ability to access inputs, raising costs and creating an input shortage. Waterlogging leads to poor seed germination, erosion, and the washing away of seed; farmers must therefore buy more seed for replanting. Waterlogging also makes planting difficult. Additionally, extreme rainfall can bring about delayed land preparation, nutrient leaching, increased outbreaks of diseases such as blight and black rot, and higher demand for pesticides. In hilly areas, excessive rainfall means mudslides and soil erosion; in lowlands, farms risk flooding, which makes weeding and harvesting difficult.

Excessive rainfall damages vegetables while they are still at the farm, reducing their quality, shelf life, and quantity. However, excess rainfall also sometimes results in an unusually bountiful harvest, which results in an influx of vegetables at the market, leading to low prices. Impassable; flooded roads delay delivery and drive up transportation costs.

4. Adaptation to Climate Change and Variability

4.1 Factors Determining Future Vulnerability and Climate Change Impacts

Climate change is affecting Nyamira County more and more, and the need to adapt is urgent. The county government, non-governmental organizations (NGOs), and private-sector players are able to provide farmers with safety nets (ASDSP, 2014). However, farmers' ability to adapt to climate change is impaired by the wider social, institutional, and geographical contexts in which they live. Due to population growth, pressure on Nyamira County's natural resources, especially land, has increased. This situation, coupled with land and water loss, has complicated farmers' traditional strategies of coping with climate hazards. Other factors that have undermined their adaptive capacity and exacerbated their vulnerability include the following: sociocultural realities like beliefs, practices, and values; constrained access to important natural resources such as land and water and to basic social services; a lack of markets; poor infrastructure, including roads and storage facilities; inadequate availability of information, including skills, knowledge, and data; insufficient credit services; weak institutional arrangements; a lack of empowerment to participate in political processes; environmental degradation; and the loss of employment opportunities.

4.2. Options to Adapt to Climate Change

4.2.1 Ongoing Adaptation Practices

In an effort to adapt to climate hazards, farmers have embraced various strategies that are relevant to specific value chains (Figure 11).

Bananas

To combat dry spells, banana farmers have begun growing drought-tolerant, disease-resistant, early-maturing species, such as the purple banana. Banana farmers have also embraced other income-generating activities like chicken farming. They have begun using extension and advisory services in order to learn the best strategies. In an effort to retain soil moisture, farmers have embraced the use of climate-smart

agriculture (CSA) practices such as proper orchard establishment by digging deeper and bigger holes, which allow for water collection and retention. They have also embraced conservation agriculture practices such as zero tillage, cover crops, mulching, and de-suckering, which helps to regulate evapotranspiration. Farmers have established soil and water-conservation strategies such as zai pits, terraces like *fanya juu* and *fanya chini*, and stone bunds. To protect against hailstone damage, farmers have also begun bagging banana fruits. They also employ strategies like de-suckering, thinning to remove excess buds and plantlets, and ripening bananas using avocado fruits. In order to minimize post-harvest losses that result from hot temperatures due to quick ripening and rotting, farmers cover the harvest with dry banana leaves and place it in the shade to protect the bunches from sun scorching and moisture stress. Upgraded collection centers with cold storage facilities and appropriate transportation facilities play a critical role in reducing post-harvest losses.

To overcome the challenges that strong winds pose to banana production, farmers have adopted varietal selection: they choose banana varieties that are not susceptible to lodging, such as "N*usu Ng'ombe*." To ensure that there is adequate manure during planting, farmers have begun making compost on-farm and stockpiling manure. These processes help ensure that the banana stalk is strong enough to withstand strong wind. Farmers have also been practicing deep planting, which facilitates adequate anchorage of the banana plants, and propping and staking the plants with Y-sticks to support them. Agroforestry has gained popularity in banana-growing areas; trees such as grevilleas are planted around the farm to protecting the bananas against strong winds.

Local Chickens

Farmers have devised several strategies to adapt to the climactic hazards that affect the chicken value chain. Due to limited and expensive feeds, they have begun formulating their own feeds using locally available resources such as maize cobs, Omena fish, and di-calcium phosphate. To source more feed, farmers have created Common Interest Groups (CIGs), which enable them to purchase feeds in bulk, then share amongst the members. Farmers have begun activities for incubation and brooding chicks. They are also adopting livelihood diversification by incorporating vegetable farming into their enterprises, which has diversified their income. To manage diseases effectively, farmers are using vaccinations and biosecurity measures such as disinfection troughs at the entrances of chicken houses. To reduce post-harvest losses, farmers have also embraced the use of carton trays for packaging; they utilize sawdust as cushioning to minimize egg breakage. Online and social media marketing is also gaining popularity, especially among youth farmers.

Dairy Cows

Dairy and cattle farming in Nyamira County is under threat from extreme rainfall and dry spells. To better utilize the available land, most farmers are rearing their cattle with zero grazing units that minimize land needs and intensify production. To overcome the challenges these climate hazards pose to fodder production, which include stunted growth and reduced production, farmers have adopted on-farm adaptation strategies such as water conservation using dam liners, feed formulation like maize germ, and cooperatives and farmers' groups. Farmers are also using chaff cutters to better utilize available fodder such as Napier grass. They are practicing crop rotation involving Napier grass and other crops such as potatoes and sweet potatoes. Hay and silage are growing in popularity across the county as forms of fodder and feed conservation. About 13% of farmers have adapted to climate change using feed conservation and diversification (ASDSP, 2014). Farmers have diversified their fodder to include varieties like Bracharia; Boma Rhodes grass, which is drought-tolerant; and Lucerne, which is very palatable and has a high feeding value. They also use by-products and crop residue. To improve animal fertility and production, 10% of farmers have embraced the use of AI services to enhance their Zebu cattle. To manage animal diseases, the county government has enhanced disease surveillance for better prevention and management of communicable diseases. In addition to treatment options such as deworming, routing spraying and vaccination, farmers have embraced use of good husbandry practices, and use of local herbs such as Bracharia grass and Desmodium for medication. During marketing, farmers have started using coolers to increase the shelf life of dairy products. Farmers are conducting collective bulk marketing through cooperatives; they receive benefits in return such as bargaining power and sustainable milk prices.

Indigenous Vegetables: African Nightshade and Spider Plant

In local vegetable production systems, farmers establish nurseries using their own seeds. These seeds mostly come from the farmers' previous crops. As drought increases, Nyamira County has begun to recommend that farmers adopt the use of certified seed varieties which are drought-tolerant as well as pest- and disease-resistant. Farmers now use compost manure and well-decomposed farmyard manure alongside inorganic fertilizers. Manure is recommended over inorganic fertilizers. Farmers have adopted the use of organic pesticides and traditional herbs made from Mexican marigolds (*Tagetes minuta*), black-jack (*Bidens pilosa)*, and pepper (*Capsicum annum*). These herbs have proven to be effective in managing pests. To conserve soil moisture during dry spells, farmers use mulch and double digging to aerate soil.

4.2.2 Potential Adaptation Practices

Despite the practices that farmers are already utilizing on their farms, other adaptation options were proposed, which if implemented would aid in averting the climate hazards identified in the selected value chains (Figure 10).

Bananas

Establishing more nurseries with varieties suitable for Nyamira County's climatic conditions could help prevent shortages of banana plantlets during dry spells. Since manure is an important input during banana establishment, farmers could build up manure and fertilizers stocks for use at the onset of rainfall. Farmers might embrace diversification to other agro-enterprises which can supplement banana production. Upscaling weather advisory services would support better planning for input acquisition and orchard establishment, and upscaling water harvesting and storage during periods of rain could supplement crop-water requirements during dry spells. The construction of cold storage facilities at banana collection centers for banana preservation could minimize post-harvest losses. More farmers could grow varieties that are less susceptible to lodging, agroforestry could be upscaled, and collective sourcing of farmyard manure and fertilizers could minimize costs. Extension services could be expanded in Nyamira County through the integration of field-based farmer schools and the use of mass media through local radio and television stations. Augmented extension services will build farmers' capacity for good agricultural practices such as wrapping banana bunches, de-handing to reduce losses from mechanical damage, and the use of appropriate transportation.

Local Chickens

To avert the climate hazards affecting the local chicken value chain, several adaptation strategies were proposed to support what farmers are already practicing. Farmers could construct climate-smart modern houses and well-aerated structures in brooding areas with automated incubators and standby generators for manual incubators. To minimize disease outbreaks, farmers can establish biosecurity measures, proper sanitation, and routine vaccination using conventional drugs. Farmers' capacities for the use of emerging feeds and feeding systems, on-farm ration feed formulation, and supplementation could be enhanced. To minimize losses at the post-harvest stage, farmers might embrace use of a battery cage system that will ease egg collection; they could also use crates or plastic boxes for egg collection. Other innovations might also increase efficiency, such as the use of on-line marketing platforms and the establishment of a one-stop shop where farmers can source all necessary inputs including feeds, vaccines, and drugs and can also market their products.

Dairy Cows

To mitigate the effects of dry spells and extreme rainfall hazards in the dairy cow value chain, extension services in Nyamira County could be upscaled by increasing the ratio of qualified and certified vet officers to farmers. Farmers could also increase their adoption of good husbandry practices such as proper housing and vaccination schedules, their use of irrigation-based production systems, their cultivation of drought tolerant fodder varieties such as Bracharia, and their use of fodder conservation such as hay and silage and of mineral supplementation. To ensure the availability of feeds, during seasons of extreme rainfall, farmers can construct hay bans for the storage of excess feeds to use during dry spells. To check for milk quality before marketing, the use of alcoholic guns and lactometers should be embraced by both farmers and cooperatives along with the use of digital milk recording systems to maintain proper production records. At the marketing stage of the value chain, the use of coolers and deep freezers could be upscaled to increase the dairy products' shelf life.

Indigenous Vegetables: African Nightshade and Spider Plant

The proposed adaptation strategies along the indigenous vegetable value chain include the enforcement of regulations governing agro-inputs like certified seed and fertilizers, and the restructuring of the government fertilizer subsidy program. A number of climate-smart production practices could be upscaled: water conservation measures like the use of double digging and sunken pits; the adoption of multi-storey gardens, greenhouses, and shade net production technologies; the use of integrated pest management (IPM); and farmers' seed selection. Several post-harvest management practices could also be enhanced, such as value addition, the use of solar drying techniques, and the construction of cold storage and refrigeration facilities. The promotion of e-marketing and contractual and collective marketing could prevent exploitation by middlemen.

Adaptation strategies used in selected value chains in Nyamira County

Banana	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Dry spell Consequences	Seedling scarcity, because nursery operators find it difficult to create nurseries; limited access and increased prices of planting materials; low demand for manures and fertilizers; this leads to loss of income for farmers and agro dealers; decreased demand for extension and advisory services.	Delayed establishment of the orchards and loss of seedlings due to moisture stress lead to increased replacement costs; low yields and retarded growth lead to high cost of management; pest and disease attack; reduced production in terms of size, quality, and quantity of bunches - leading to loss of income.	Loss of key market segments that require specific grades of quality; decreased quantities; underutilization of packaging, due to limited products; redundancies of transportation capacity, leading to diseconomies of scale.	Job losses due to limited products; unpredictable price fluctuations, leading to unsteady incomes; idle marketers and surveyors leading to unemployment and low income.
Magnitude of Impact	Minor-Major	Major-Severe	Minor-Moderate	Minor-Moderate
Farmers' Current Coping Strategies	Adoption of early and fast-maturing varieties; farmers engage in other income-generating activities; government addresses other enterprises and provides advisory services on other enterprises like drought tolerant crops	Proper orchard establishment (digging deep and bigger holes, retention of unfilled spaces for water collection); application of manure and fertilizers for water retention and nutrient supply; mulching, planting cover crops, desuckering to regulate evapotranspiration.	Shading harvested banana bunches; cushioning banana fingers.; diversification to other businesses (avocado, cane, and potato transportation)	Diversification to other products or businesses (avocados and sweet potatoes)
Potential Adaption Options	Establishing more banana-hardening nurseries; stocking manures and fertilizers for use during the rainy season; raising awareness about other drought-tolerant crops.	Use of weather advisory services in planning input acquisition and orchard establishment; continued use of mulch and cover crops for moisture retention; encouraging water harvesting and storage; drilling boreholes; promoting other management practices such as pruning (removal of the male bud).	Setting up cold storage facilities at collection centers; wrapping banana bunches during harvesting; promoting use of appropriate transportation and holding facilities; diversification to other businesses	Diversification to other sectors; entering into new contracts and diversifying enterprises; acquiring multiple set of skills in different fields.
Underlying Factors	Non-adherence to regulations and input standards; laboratory and nursery production; meddling in the name of personal economic and political interest; supply-driven markets instead of demand-driven markets; institutional corruption.	Bureaucratic processes which lead to delays in release of resources; inappropriate messaging from various service providers, which makes the farmer deliberate on the best choice	Not investing in cold storage facilities leading to farmers selling at throw away prices; inappropriate packaging and transportation equipment, leading to losses during handling, packaging, and transportation; bad road networks lead to perishing and waste.	Non-synchronized inter-county fiscal policies and taxes, leading to multiple taxation across counties, which lowers farmer's profit margins.
Strong Winds Consequences	Strong winds do not affect seedlings - they affect mature banana plants; increased demand for manure and fertilizers, which leads to increased production costs; demand for extension and advisory services increases, thus increasing cost of production.	Increased cost, as more manure is needed to fill bigger holes; lodging banana plants; premature harvests and damages to mature banana fingers leading to losses.	Sorting and grading becomes costly and tedious; underutilization of packaging materials/containers; redundancies in transportation and carriage capacity, diseconomies of scale, and loss of revenues and profits.	Loss of jobs and earnings, as a result of limited products; increased prices due to high demand and reduced supply; redundancies in marketers and researchers.
Magnitude of Impact	Minor-Major	Major	Minor-Moderate	Minor-Severe
Farmers' Current Coping Strategies	Variety selection, e.g. Nusu Ng'ombe; on-farm compost making and stock piling of manures; use of mainstream government extension services; use of PPPs in extension and advisory service provision.	Propping and staking to support trees; deep planting for proper anchoring; practicing agroforestry to break the speed of the wind.	Rudimentary sorting and grading skills; using the locally available materials for packaging; venturing into other transport businesses.	Diversification into other income-generating activities; outsourcing of bananas from other markets/ counties.
Potential Adaption Options	Select varieties which are not susceptible to lodging; joint sourcing/procuring of bulky manures and fertilizers to reduce cost; establishing and operationalizing farmer field schools; using of other forms of extension approaches like extension, mass media, and local FM stations.	Establishing pockets of woodlands on the farm; continuous agroforestry.	Training farmers on sorting and grading; using of appropriate packaging and transporting materials; diversifying to other businesses.	Diversifying into other income-generating activities; venturing into cold storage to help suppliers during times of shortage; using value addition to increase product shelf life; diversifying skills and competencies to fit into other sectors.
Underlying Factors	Farmer's lack of technical knowledge of variety selection, leading to the use of unsuitable varieties.	On-farm production often disregards professional advice and ignores agronomical practices that can minimize the effects of strong winds; economic constraints	Lack of cohesive policy guidelines on post-harvest management of farm produce.	Lack of cohesive policy on marketing and trade of bananas.

Chicken (Local)

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Heat Stress Consequences	High cost of labor and inputs due to needing additional materials for temperature regulation; increased chicken mortality which results in losses and low income; increased feed prices due to inadequate raw materials and limited resources.	Low quality and immature eggs, leading to low profits and high cost of production; increased mortality due to unpredictable climate conditions, pests, and diseases, leading to high cost of production; underfed chickens, leading to low quality eggs, chicks, and profits.	Low production of eggs leading to losses; immature and unviable eggs which make hatching difficult to get quality eggs for hatching, -may cause deformed chicks.	High demand and low production, leading to over or under-supply of chicks; breakages due to poor handling, poor roads, and poor package design.
Magnitude of Impact	**Severe**	**Severe**	**Severe**	**Severe**
Farmers' Current Coping Strategies	Chicken coexist with human beings in the house, especially the kitchen; chickens allowed table scraps and free movement.	Raising chickens free range, with kitchen left overs and feed substitutes; using ash, herbal concoctions, paraffins, and tyres for disinfection and pests; natural hatching.	Physical picking and sorting using natural light, feeling, and bare hands.	Physical market surveys and sourcing; use of saw dust as cushioning; physical delivery to the target population.
Potential Adaption Options	Use of smart-climate modern houses; online chick sourcing/ phone calls, media, adverts; use of standardized feed ration and feed supplementation.	Using of automatic incubators and standby generators; using biosecurity, conventional drugs, and vaccines; formulating on-farm feed ration according to standards.	Introducing of battery cage system for easy egg collection; candling, using torches, using of digital scales.	Online survey promotions, adverts, phone calls, and media; using pastors and flyers for advertisement; using egg trays; making "one stop shops" for all inputs.
Underlying Factors	Feeding is done by women and youth, but women and youth do not have the power to source feed and chicks.	Disease control and vaccinations are done using improperly-measured herbs, which leads to poisoning; heat stress compels farmers to use non-researched methods of treatment and vaccinations leading to higher mortality rates.	Most farmers do not want to use a hatchery for brooding, which lead to low hatchability and many embryo deaths; most farmers cannot access or afford incubators or backup generators, leading to low production.	Women are perceived to be immoral and not are allowed to do market surveys, and youth are not taken seriously; little regulation of taxes and enforcement of quality control; farmers will opt to sell their product at home rather than taking them to the market.
Dry Spell Consequences	Increased temperatures necessitate heat proof housing materials; high temperatures increase maturity rate, thus increasing costs; inadequate feeds cause increased competition and prices.	Decreased hatching due to high temperatures; emerging pests and diseases which lead to high loss of chicks and cost of drugs; inadequate feeds and increase feed prices, leading to high cost of raising chicks and low-quality chicks.	Reduced number of eggs; cost of production increases, leading to low profits/ income; difficulty sorting;. lots of immature eggs and few viable eggs; increased breakages and deformities.	High demand and low supply; improper packaging, poor roads, and poor handling causes breakage and thus reduces sales and increases transport costs.
Magnitude of Impact	**Major-Severe**	**Major-Severe**	**Major-Severe**	**Severe**
Farmers' Current Coping Strategies	Cushioning the rooftop and the house using locally available materials like sacks and boxes; natural hatching and brooding; using the mother chicken and brooder jikos; using non-standardized feeds; using kitchen left overs and the free range system.	Natural hatching and brooding; using herbal remedies like ash for disinfectant; using non-standardized feed like kitchen left-overs, formulations, and weeds; using the free range system.	Using saw dust to prevent breakage; using of natural light; physically observing by, feeling and shaking.	Engaging in physical market surveying and after sale services; using baskets, cartons, and buckets; physically delivering chicks and eggs.
Potential Adaption Options	Using smart-climate modern structures like backup generator for manual incubators and automatic incubators with standby generators; formulating feed rations, systems, and demonstrations at the farm level.	Using automatic incubators; using of biosecurity measures; using timely vaccinations; standardizing feed formula ratios on-farm.	Using crates and plastic boxes as cushioning; using candles and torches; learning how to egg sort in different ways; learning how to grade better.	Performing online market surveys, advertisements, and promotions; using after-sale services; using egg trays; creating "one stop shops" for input.
Underlying Factors	Women and youth are mostly affected because land is owned by men; women and youth lack collateral to access credit because title deeds are held by men.	Using of herbal treatments to control diseases that can be treated with drugs and vaccines, leading poisoning, and high mortality; some pests, parasites, and pathogens develop resistance to drugs, leading to increased mortality rates.	Culturally, women and female youth are assigned to collect eggs (not men); normally, men control the income after sales; women and youth do activities like feeding, cleaning, and selling, but decision-making falls to men.	Culturally, women are not allowed to source for the market as it is perceived to be immoral; money that's meant for market survey packaging and transportation is fully controlled by men.

Dairy (Cow)

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Extreme Rainfall and Hail Consequences	Affects the implementation of extension packages, leading to reduced level of production; makes the house inhabitable, leading to reduced milk yields; reduces fodder production; reduced milk trade.	Reduced heat signs leading to reduced milk production, because of fewer calves; inadequate fodder production; destruction of feed; increasing rates of disease; reduced milk production.	Poor quality milk; reduced volumes of milk.	Damaged roads, leading to delay in milk transportation and spoilage; reduced and low-quality fodder for conservation; inadequate quality and quantity of product.
Magnitude of Impact	Minor-Severe	Major-Severe	Moderate	Moderate
Farmers' Current Coping Strategies	Using online extension services, which are very limited; using service provider-based extension services; using substandard housing units; using banana stems and maize left overs.	Training farmers on proper heat detection; using local herbs.	Using organoleptic techniques to test the quality of milk; using senses such as smelling; using water, wheat flour, blue band to adulterate milk; recording milk stock with pen and paper.	Fermenting excess milk; using local preservation methods like cold water; using low quality fodder for conservation, like banana stems and black jacks; sourcing from other farms.
Potential Adaption Options	Enhancing online extension services; providing standard housing for dairy cows with the right specifications and construction; establishing hay bans.	Improving nutrition and proper housing for the dairy cows; establishing fodder specifically for conservation; enhancing use of mineral supplements; using qualified and certified veterinary officers to advice on disease control and management.	Using alcoholic guns and lactometers; using dry matter to increase milk production; embracing digital milk recording and management systems.	Using of deep freezers and milk coolers; constructing more hay bans to store feeds pricing milk properly to attract increased production.
Underlying Factors	Hilly areas such as the Kiaboyoru hills, Manga, and the Masaba hills are more effected by hailstones than the rest of the county; extension services are affected because of poor roads.; fodder production and quality is reduced.	High cost of treatment and A.I services; poor quality/adulteration of drugs and A.I services; using herbs instead of medicine; unimplemented policy and misinformation.	Famers are not free to expose their production records due to cultural beliefs; some farmers want to run their own accounts separately; farmers do not trust the milk-bulking societies because they fear losing their product.	Poor road networks that impede transportation of inputs and products; high cost of processing equipment; poor policy implementation like Kenya Dairy Board issuing licenses but being unable to control hawkers.
Dry Spell Consequences	Hinders implementation of production activities, leading to low yield; housing units can be restructured and renovated to minimize leakages and provide quality manure; leads to reduced yields, leading to reduced fodder production.	Extreme heat hinders breeding by lowering rates of conception; prolonged dry spells lead to poor quality feed materials; vaccinations control expected diseases.	Easy transportation and timely delivery of milk, leading to reduced milk spoilage; quality feeds due to favorable temperatures and conditions; low-quality raw materials in value-added products	Easy transportation and timely delivery of milk leading to reduced milk spoilage; quality feeds due to favorable temperatures and conditions; low-quality raw materials in value-added products
Magnitude of Impact	Moderate	Moderate	Moderate	Moderate
Farmers' Current Coping Strategies	Reliance on rain -fed farming; using extension packages; using substandard housing in response to heat stress; using banana stems and maize left overs.	Training farmers on proper heat detection techniques; using poor-quality raw materials due to scarcity of good quality fodder; using local methods to treat cows (e.g., using salt to control Foot and Mouth Disease and giving animals local alcohol).	Tasting and smelling milk; milk adulteration with what flour, etc. ; recording milk stock manually.	Using boda boda to transport milk; fermenting excess milk; using standing hay and feed directly from the farm; sourcing from other farms.
Potential Adaption Options	Using irrigation-based production; standardizing housing according to specifications and construction; establishing of hay bans.	Improving nutrition and proper housing to control extreme temperatures; establishing fodder farms using drought tolerant varieties (e.g. Brachiaria) for fodder conservation; using qualified and certified veterinary services for disease control.	Using alcohol guns and lactometer; increasing milk production through dry matter feeding; embracing digital milk recording and management systems.	Using of deep freezers and bulk coolers; constructing more hay bans for storing excess fodder; pricing milk properly to attract production.
Underlying Factors	Reduced production of milk and fodder; some parts of the County could be recording higher rainfall than others.	Reduced production of raw materials for feed formulation; extreme temperatures hinder onset of heat periods.	N/A	N/A

Vegetables (Local)

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Drought Consequences	Delays acquisition and lower quality of planting materials, especially seedlings; delays acquisition and lowers quality of fertilizer due to extended storage.	Enhances land preparations and delays planting; increased pest population (especially mites), leading to increased costs; lower quality and quantity of produce, and lowered profits; reduced quality, quantity, and shelf life of the vegetables.	Less labor required; easier packaging; low volumes of vegetables transported; possible dust contamination, especially if transporting via boda boda; reduced shelf life, higher post-harvest losses.	Fewer market actors; reduced product supply; increase in prices due to reduced supply; reduced shelf life and increased post-harvest losses; reduced income due to low volumes.
Magnitude of Impact	Minor-Major	Moderate-Major	Minor-Moderate	Minor-Major
Farmers' Current Coping Strategies	Farmers have their own farm and seasonal nurseries; farmers use their own local seed; farmers use fertilizer subsidy programs and homemade manure; farmers access fertilizer from uncertified services like the market center; using of mulching/compost manure; using of traditional pesticides or pesticide from uncertified sources.	Minimum tillage using herbicides; mulching; bucket irrigation and using branches for shading; using traditional pesticides; farmers access pesticide from uncertified sources; proper timing of vegetable harvest (early morning and late evening, when temperatures are low).	Value addition through drying and blanching; perforating nylon bags to use for transportation; storing product in the shade and spraying it with water.	Verbal promotion/marketing; hawking; middlemen moving from farm to farm; farmers avoiding middlemen to maximize on profit; sprinkling water on vegetables to maintain freshness and steady supply; using temporary shade.
Potential Adaption Options	Use certified seeds; setting up and promoting group nurseries of certified seedlings; using seed trays; restructuring fertilizer subsidy programs; enforcing regulations governing agro-inputs; teaching farmers about proper compost making promoting foliar feeding of crops; teaching farmers about IPM and safe use of local pesticides.	Using shade nets; adopting water harvesting and irrigation technology like drip irrigation; adopting water conservation measures like double digging and sunken pits; adopting of multi-story technology; training farmers in IPPM; enforcing regulation governing pesticide use; training farmers on safe use of pesticides; adopting technologies like green houses and shade nets; using foliar feeding after harvesting intervals to boost leaf growth; promoting appropriate technology like charcoal coolers; training farmers in seed selection.	Using of solar drivers, structure, and equipment; promoting appropriate transportation baskets and facilities like refrigerated tracks; establishing cold storage warehouses/stores.	Using E-marketing, collective marketing, and contractual marketing; using a marketing forum; using trade fairs and exhibitions; enhancing links between farmers and buyers; value addition; setting up an appropriate market with infrastructure such as shades, stalls, and cold rooms.
Underlying Factors	High levels of poverty during extended dry spells; farmers divert resources meant for inputs to other pressing issues; the vulnerability of socially marginalized groups like widows and single mothers aggravates the situation; inadequate access to climate information services; inadequate storage facilities for input, and limited access to agrovets.	High levels of poverty; most producers lack enough capital to employ alternative technologies (such as water harvesting, double digging, and irrigation) to overcome the consequences of extended dry spells and plant on time; inadequate skills in and knowledge of alternative technologies; male capital owners have a low opinion of the vegetable value chain, and do not allow the female chain actors technology, land, or resources.	Lack of appropriate storage facilities and transportation facilities; lack of appropriate, and expensive post-harvest handling facilities like pack houses and solar driers; nmarket actors don' have access to affordable credit facilities; inadequate knowledge about and skills in local vegetable processing	Lack of organized market structure (shades, stalls, cold rooms) for the local vegetables; market actors have negative attitudes towards collective marketing Inadequate knowledge about and skills in marketing and pricing; lack of marketing policy and regulations.
Extreme Rainfall and Hail Consequences	Reduced availability of seeds and seedlings due to hailstone destruction; difficulty in acquiring and transporting organic and inorganic fertilizers; increased transportation cost due to poor road networks.	Delayed land preparation; soil erosion; poor germination; increased costs of land preparation and planting; increased cost of pest control due to more pest sand diseases; reduced quality and quantity due to pest attacks and hailstone damage; increased perishability.	Increased labor due to high levels of damage; increased cost of transport due to poor roads; delayed transportation. Increased post-harvest losses/ increased perishability, as damaged leaves are prone to color change and rotting.	Reduced supply to market; reduced quality due to damages and mud; reduced prices and increased post-harvest losses.
Magnitude of Impact	Moderate-Major	Major	Major	Minor-Major
Farmers' Current Coping Strategies	Using litter to construct shades that protect seedlings from hail; establishing nurseries under trees; fertilizer subsidy programs; using compost manure; using stickers to improve herbicides' efficacy; using traditional pesticides; farmers access pesticides from uncertified sources.	Minimum tillage using herbicides; mulching; using tree branches to shade local vegetables; planting; using trash line to control erosion; using traditional pesticides; farmers access pesticides form uncertified sources; using stocks to increase efficacy; putting herbicides under shade to drain; proper harvesting timing.	Value addition through blanching and drying; using perforated bags during transport; storing in shade for draining	Verbal promotion/marketing; middlemen moving farm to farm/ Farmers use middlemen to get prices; using temporary shed and marketing stalls
Potential Adaption Options	Promoting crop insurance; adopting appropriate technology like shade nets and greenhouses; using growth/propagation hormones; using seed trays; restructuring subsidy programs to make them more responsive to farmers' needs; comprehensive crop insurance; educating farmers on appropriate manure making and storage processes; educating famers on IPM and safe use of chemicals; enforcing regulations on farm input supply.	Using agroforestry trees for shade; using shade nets, greenhouses, and vertical bags; proper soil and water management structures; adopting water harvesting technology like dams; using vailed nursery beds; training famers in IPM; enforcing regulations governing pesticide sale and use; training farmers in safe use of pesticides; adopting technologies such as greenhouses and shade nets; spraying product with fungicides after each harvesting interval.	Promoting appropriate transportation facilities like vegetable transportation bags; periodic road maintenance; promotion of appropriate local vegetables; creating storage structures to ensure that vegetables drain well.	Using of E-Marketing and collective marketing; contractual farming; using trade fairs/exhibition; enhancing e-marketing; enhancing farmer-to-buyer links; value addition; selling and procuring vegetables contractually; setting up appropriate market structure with sheds, stalls, etc.
Underlying Factors	Poor road network and inadequate storage facilities; high poverty levels; most nursery operators are unable to afford alternative technologies such as shade nets and greenhouses; lack of certified commercial vegetable nurseries; inadequate knowledge and skills about local vegetable seed processing at the household level.	Farmers do not have the capital to invest in alternative technologies such as shade nets, vertical bags, and tools./machinery; inadequate knowledge of safe and effective pesticide use and disposal; inadequate knowledge about and skills in sustainable land management intervention.	Poor road networks; lack of appropriate storage and transport facilities; inadequate knowledge and skills in post-harvest technology, like solar driers.	Lack of appropriate market facilities like shades, stalls, and cold rooms; lack of organized marketing structure for local vegetables; local vegetable markets actors reluctant to market collectively

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

5. Policies and Strategies on Climate Change

The development of policies and programs and their effective implementation play a key role in decision-making, since they affect actions and outcomes related to climate risk management and resource use. Several policies have been developed and implemented in Nyamira County in response to climate variability and change, with a focus on adaptation and mitigation (Table 1).

Table 1: Policies and programs relevant to climate change adaptation in Nyamira County

Policy	Year	Policy objective(s) achieved at the county level	Interventions for climate change adaptation and mitigation	Challenges and policy gaps
National Climate Finance Policy	2018	Establishment of mechanisms to mobilize climate finance	Development of Climate Change Fund Regulations and Climate Change Finance Policy	The county lacks appropriate climate change policies, budgeting, and political and economic will. Non-state actors are more active than state actors on environmental issues.
NCCAP	2013-2017; 2018-2022	Increase forest cover to 10% Rehabilitation of degraded lands including rangelands Heightened resilience in the wildlife and tourism sector	- A draft policy has been developed on reclamation of riparian land through removal eucalyptus trees - Awareness campaigns on benefits of bamboo farming as an alternative to eucalyptus along rivers and on hilltops - Provision of seedlings and trainings by the Department of Environment - Promotion of agroforestry to increase tree cover from 15% to 35% by planting Grevillea trees to replace eucalyptus or blue gum trees (CIDP, 2018)	
		Increased food and nutrition security through enhanced productivity and resilience of the agricultural sector in a low carbon manner	Strengthening the environmental resilience and social inclusion of value chains, and promoting the viable and equitable commercialization of the agricultural sector through value chain development. Provision of support to smallholder farmers by allowing them to adopt better agronomic practices and improve their incomes.	
		Reduced risks to communities and infrastructure from climate-related disasters such as droughts and floods	The KMD has been conducting participatory scenario planning (PSP) programs that aid in planning for climate risk interventions	
		Enhanced resilience of the Blue Economy and water sector through access to and efficient use of water for agriculture, manufacturing, domestic purposes, wildlife, and other uses	- Promotion and commercialization of fish farming; in the years 2019-2020 - Construction and stocking by farmers of167 fishponds with 187,000 fingerlings	
National Climate Change Framework Policy	Sessional Paper No. 3 of 2016	Enhanced adaptive capacity and resilience to climate variability and change Promotion of a low-carbon development pathway	- Formulation of the first County Climate Change Policy (2020) - Development of a County Climate Change Strategic Plan - Planned establishment of a county climate change unit	

Policy	Year	Policy objective(s) achieved at the county level	Interventions for climate change adaptation and mitigation	Challenges and policy gaps
Kenya Climate-Smart Agriculture Strategy (KCSAS)	2017-2026	Enhance adaptive capacity and resilience for farmers, pastoralists, and fisher-folk to the adverse impacts of climate change	- Provision of education and inputs like fodder seed to CIGs for bulking -Promotion of aquaculture development, enforcement of legislation, quality assurance through safe handling of fish and fishery products and management and conservation of fishery resources.	Weak institutional structures, collaboration and engagement to address climate-change issues Inadequate human resources and technical capacity to handle climate change issues
		Development of mechanisms that minimize greenhouse gas emissions from agricultural production systems	- Promotion of stand-alone solar systems and energy saving jikos in homes - Training about solar vegetable driers across the 20 Nyamira County wards	
		Creation of an enabling regulatory and institutional framework	- Development of County Crop Agriculture Bill (2019), which aims to provide a comprehensive, harmonized, efficient, and effective legal and regulatory framework for the development and regulation of crop agriculture in Nyamira County	
		Response to cross-cutting issues that adversely impact or enhance CSA	County Department of Agriculture has proposed an Agricultural Resource & Technology Transfer Center. The Centre will house various technologies (biotechnology laboratory, seed multiplication sites, a modern fish multiplication and training center, and crop and livestock-based technologies) and promote climate-smart technologies.	
The National Adaptation Plan	2015-2030	Consolidation of the country's vision for adaptation supported by macro-level actions that enhance long term resilience and adaptive capacity	- Development of County Climate Change Action Plan -Establishment of the department of climate change which is domiciled in the Department of Environment, Water, Energy and Natural Resources	
Agriculture Sector Development Strategy(ASDS)	2010-2020	Revolutionization of agriculture and its re-orientation towards the establishment of economic and commercial enterprises that can provide employment to youths and improve livelihoods	- Establishment of Nyamira County Agricultural Development Fund Bill (2019) which aims to finance the County's agricultural growth by supporting strategic farming interventions with a high potential for enhancing productivity, value, quality, and marketing - Creation of a processing plant in Nyamira by the county government to enhance and promote value addition in the banana value chain - Support from the county government for "Youth in Agriculture" programs through provision of inputs like seed, fertilizer, pesticides and spray pumps	

6. Institutional Capacity for 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. To enhance climate change mitigation and adaptation in Nyamira County, several organizations have endeavored to offer off-farm services and interventions to farmers and communities. These interventions include research and extension services, early warning services, capacity building, the provision of technology and technology transfer, enhancement of market linkages, financial and credit services, non-financial services like agro-inputs and insurance, and disease surveillance (Table 2).

Table 2: List of institutions that support the implementation of agricultural interventions in Nyamira County

Off-farm services	Institutions	Specific interventions in Nyamira County	Challenges
Agricultural research and extension services	Nyamira County Department of Agriculture, Livestock and Fisheries	On-farm demonstrations on new crop and livestock technologies, innovations, and management practices Promotion of good agricultural practices (GAPs), use of artificial insemination and other modern breeding technologies	Inadequate expertise (extension and research officers) leading to limited access to farmer extension services to facilitate demand-driven research and increased use of improved technologies Poor coordination and collaboration among institutions leads to duplication and overlap of roles Limited funding which affects efficiency of extension services Restrained institutional capacity especially on research and training – the county depends on Kisii County
	KALRO-Kisii Centre	Research and development related to the suitability of various AEZs to different crop varieties and livestock breeds	
	Kisii Agriculture Training Center (ATC-Kisii)	Trainings on GAPs	
	Kenya Dairy Board (KDB)	Training and technology transfer	
	Kenya Animal Genetic Resource Centre	Provision of AI and extension services relevant to animal breeding, including breeding technologies	
	Kisii University	On-farm research trials and technology transfer	
	Department of Environment, Water, Mining and Natural Resources	Rehabilitation of community water schemes Providing households with piped water drilling of boreholes Construction of additional water harvesting structures like tanks	
	Kenya Forestry Service Kenya Forest Research Institute	Promotion of conservation Protection of water catchment areas Farm and dry land management Monitoring programs in biodiversity conservation	
	National Environment Management Authority	Environmental awareness raising and education about the importance of planting trees Coordination of various environmental management activities and promotion of environmental considerations into policy, plans, programs, and projects	

Off-farm services	Institutions	Specific interventions in Nyamira County	Challenges
Regulatory services	Kenya Plant Health Inspectorate Service	Provision of inspectorate services on all matters related to plant health and quality control of agricultural inputs and produce, such as certification of the quality of seeds and fertilizers	Limited regulatory expertise results to inadequate surveillance and certification of agricultural inputs thus exposing farmers/ consumers to counterfeits High cost of key inputs such as seed, pesticides, fertilizer, drugs and for resource-poor farmers
	Pest Control Products Board	Regulation and approval of pest control products Quality monitoring for pest control products already in the market	
	KDB	Inspection and licensing of milk handling premises and surveillance of the quality and safety of milk and milk products	
	Kenya Bureau of Standards	Development of quality standards Provision of facilities for the examination and testing of commodities and any production and processing materials	
Climate information services and agro-weather advisories	KMD	Weather forecasts and advisory services through weekly bulletins Seasonal weather forecasts in the local language via media channels such as local radio and television stations, social media platforms like WhatsApp, and short message services through phones.	Inadequate synergies between the weather advisory providers and decision makers Technical format and language of the climate and weather forecasts which not easily understood by decision makers Limited technical capacity to interpret and use probabilistic forecasts in decision making.
	Christian Aid	Support for farmers to act on climate change issues	
	Team Kenya Environment,	Awareness creation on climate change and environmental conservation	
Climate risk management (Adaptation planning, Early warning systems-EWS) and participatory scenario planning-PSP	KMD in collaboration with experts from county departments and the ASDSP	Warnings about disasters like mudslides and landslides Support for the planning of farm activities and cropping calendars	Limited farmers' knowledge on weather and climate issues. Inadequate funding for climate change adaptation and climate risk management
	ADA (Adaptation) Consortium (Partners include: National Drought Management Authority, National Treasury, Climate Change Directorate, NEMA, Ministry of Devolution and ASALs and the Council of Governors.	Support county government to mainstream climate change into development and planning through the County Climate Change Fund Mechanism	

Off-farm services	Institutions	Specific interventions in Nyamira County	Challenges
Non-financial subsidies for inputs like fertilizers, pesticides, seeds, and trainings	Nyamira County government	Subsidies for farm inputs like AI services and certified seeds and fertilizers	Inadequate linkages between technical knowledge support and access to finance
	One Hen Campaign	Trainings for women and youths in entrepreneurship, agribusiness, and poultry management Provision of one hen that participants are required to rear according to their training	
	Insurance companies like Jubilee Insurance	Provision of cushion for crops and animals	
	Cooperative societies, including Borabu, Gesima, Keroke, the Peri-urban Farmers' Cooperative Society, and Hobanapo Cooperative Society	Support for in the production, post-harvest, and marketing processes	
	UNGA Feeds, BIDCO, Ultravetis, Vital Animal Health, East Africa Seeds Co. Ltd., Kenya Seeds Co. Ltd., Osho Chemicals, Murphy Chemicals Ltd., Bayer East Africa, and Baraka Fertilizers Ltd.	Distribution and sale of agro-inputs Trainings and demonstrations on the use of these inputs	
	Aberdare Technologies Ltd. Private nursery operators Jomo Kenyatta University	Provision of certified and clean planting materials	
	Development partners like Christian Aid	Capacity building initiatives on climate change action issues	
	Team Kenya Environment	Awareness creation on climate change and environmental conservation	
Financial services such as rural credit schemes	National and county governments	Project financing	High interest rates from banks that limit access to finance to small and medium enterprises Stringent institutional and evaluation criteria Inadequate financial products and services well-designed for farmers Limited long-term sustainable impacts from donor-funded projects
	Development partners including the European Union, the United States Agency for International Development (USAID), JICA, IFAD, World Bank, the United Nations Development Program, and the Food and Agriculture Organization of the United Nations	Project financing for technical capacity and value chain development	
	Micro-finance institutions such as Musoni	Support for farmers to access credit at lower interest rates	
	One Acre Fund	Financing to support on-farm and input supply	
	Savings and Credit Cooperative Societies and other cooperative societies	Support for farmers to access credit and loans at low interest	
	Mobile service providers like Safaricom, Airtel, and Telcom	Mobile banking services	
	Banks like Kenya Commercial Bank, the Agriculture Finance Corporation, the Cooperative Bank of Kenya, and Equity	Provision of financial and credit services	

Off-farm services	Institutions	Specific interventions in Nyamira County	Challenges
Market Services, infrastructure, and linkages	New KCC	Procurement of high-quality raw milk for processing, packaging, and marketing	Limited agriculture marketing policy and regulations Weak, poor, and inadequate farmers' organizations, associations, and cooperative societies Inadequate product markets and marketing infrastructure Poor rural infrastructure Low investment in storage and processing facilities Inadequate market information system
	KDB	Various activities to promote domestic, regional, and international markets for Kenyan milk and milk products	
	Kenya Meat Commission	Meat value addition Provision of ready markets Increased productivity and competitiveness	
	World Vision	Support for value addition in the banana value chain through the provision of banana-processing machines	
	Africa Harvest	Promotion of sustainable farming practices in the banana value chain	
	Processors like Highland Creamers and Food Ltd, Brookside Dairy, Stawi Foods and Fruits Limited	Processing, marketing, and distribution of Nyamira County's agricultural products	
	Producer associations like the Banana Growers Association of Kenya (which are largely absent in Nyamira County)	Protection for farmers against exploitation by middlemen	
	Mobile service providers like Safaricom and Airtel	Provision of online marketing platforms	

7. Synthesis and Outlook

This profile analyzes four key agriculture value chains in Nyamira County: dairy milk, bananas, local chickens, indigenous vegetables. These VCCs were chosen for their contribution to the county's economy, their resilience to the current and future effects of climate change, and their involvement of economically and socially vulnerable groups. However, these VCCs are at risk due to climatic hazards like dry spells, extreme rainfall, heat stress, and strong winds.

In the face of climate hazards, Nyamira County could improve the productivity, profitability, and competitiveness of agriculture by unlocking some of the constraints identified in this analysis. Some possible solutions towards the rejuvenation of the agricultural sector include investing in strategies that promote the use of non-rainfed agriculture, in improved infrastructure, in technology development and support, and in the promotion of effective extension and credit services.

Despite the limited ability of the county government to support climate risk management strategies, it is in the process of instituting structures such as the County Climate Change Policy, which is in its beginning stages. A Climate Change Unit is also under development. In order to allow socially vulnerable groups like women, youths, and disabled people better access to extension, veterinary, and credit services, among others, the Nyamira County government could institute relevant policies that unlock productivity constraints and promote access to services. The government can educate extension service providers about new technologies and strengthen the capacities of its institutions to provide services and information to farmers.

In order to support effective and sustainable agricultural marketing systems, collective marketing structures like cooperatives and producer federations could be established. These structures will aid and support farmers and safeguard them from exploitation.

To enhance resilience and to cushion farming systems against the detrimental effects of climate change, CSA production technologies could be integrated into county policies. The county could then promote the wide-scale adoption of these technologies. CSA involves, among other things, upscaling organic farming, sequestering organic carbon, improving soil structure and fertility, and supporting water harvesting and conservation facilities and structures.

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10. Annexes

10.1 Glossary

Absolute poverty: "Absolute poverty" measures poverty in relation to the amount of income necessary to meet the basic needs of a household, such as food, clothing, and shelter (KNBS, 2018).

Adaptation: Adjustment in agro-ecosystems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Adaptive capacity: The ability of a system to adjust its characteristics in order to expand its range under existing climate variability and future climate change.

Climate change: A change in the state of the climate that can be identified, for example 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 forces such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2018).

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

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

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

Climate-smart agriculture: Agriculture that sustainably increases productivity and resilience, reduces or removes greenhouse gases, and enhances the achievement of national food security and development goals.

Dependency ratio: The ratio of individuals in a population who are in the dependent age group under age 15 or over age 65, to those in the economically productive age group aged 15 to 64. For instance, a child dependency ratio of 0.45 means there are 45 children for every 100 working-age adults (PRB, 2019).

Food poverty: The inability to acquire or consume an adequate quantity of food in socially acceptable ways: households and individuals whose monthly adult equivalent food consumption expenditure per person is less than KfzSh 1,954 in rural and peri-urban areas and less than KSh 2,551 in core-urban areas, respectively, are considered to be food poor or live in "food poverty" (KNBS, 2018).

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

Heat stress: A negative relationship between the net amount of energy flowing from an animal's body to its surrounding environment and the amount of heat energy produced by the animal. This imbalance may be caused by many environmental factors, like sunlight, thermal irradiation, air temperature, humidity, and movement, as well as animal characteristics like species, metabolism, and thermoregulatory mechanisms (Ebeid et., 2012).

Mitigation: In the context of climate change, human interventions to reduce the sources or enhance the sinks of greenhouse gases, such as the following: using fossil fuels more efficiently for electricity generation, switching to solar energy or wind power from fossil fuels for industrial processes, and expanding forests and other "sinks" to remove greater amounts of carbon dioxide from the atmosphere.

Perception: The process by which we receive information or stimuli from our environment and transform them into psychological awareness.

The Representative Concentration Pathways (RCPs): Four greenhouse gas concentration trajectories adopted by the IPCC for its 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.

Resilience: The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner.

Vulnerability: The degree to which a geophysical, biological, and socioeconomic system are susceptible to and unable to cope with adverse effects of climate change, including variability and extremes.

Zai pits: Zai are holes usually excavated with a diameter of 0.3-0.6 m and 0.3 m deep". The holes harvest rain water at farm level and have the potential to boost soil water holding capacity by up to 5 times while collecting up to 25% of the runoff in the immediate area surrounding the hole.

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