Climate Vulnerability and Agricultural Value Chains for Laikipia, Isiolo and Samburu Counties

Review of Climate Change Impacts on Agricultural Value Chains and identification of adaptation strategies for priority crops

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Generating information and raising current knowledge of Climate Change and its implications on target LISTEN counties.

ACRONYMS

ACT	Act Change Transform
ACTED	Agency for Technical Cooperation and Development
AGRA	Alliance for a Green Revolution in Africa
ASAL	Arid and Semi Arid Lands
ASDSP	Agriculture Sector Development Support Program (Kenya)
CA	Conservation Agriculture
CFA	Community Forestry Associations
CBO	Community Based Organisation
CCAF	Climate Change Adaptation Funds
CDF	Constituency Development Fund
CeC	County Executive Council Member
CESVI	Cooperazione e Sviluppo
CETRAD	Center for Training and integreated Research in ASAL Development
CGL	County Government of Laikipia
CSO	Civil Society Organisation
DRSLP	Drought Resilience and Sustainable Livelihoods Programme
ENNDA	Ewaso Ng'iro North River Basin Development Authority
ENRM	Environment and natural Resources Management
FAO	Food and Agriculture Organization
FCDC	Frontier Counties Development Council
GAP	Good Agricultural Practice
ICRAF	World Agroforestry Centre
KALRO	Kenya Agricultural and Livestock Research Organisation
KEBS	Kenya Bureau Of Standards
KEPHIS	Kenya Plant Health Inspectorate
KEVEVAPI	Kenya Veterinary Vaccines Production Institute
KFS	Kenya Forest Services
KIRDI	Kenya Industrial Research and Development Institute
KLMC	Kenya Livestock Marketing Council
KVDA	Kerio valley Development Authority
KWS	Kenya Wildlife Services
KWTA	Kenya Water Towers Authority
LISTEN	Laikipia, Isiolo, Samburu Transforming the Environment through Nexus
LWF	Lutheran World Foundation
MKWEP	Mount Kenya Ewaso Water Partnership
MoU	Memorandum of Understanding
NARIGP	National Agricultural and Rural Inclusive Growth Project
NAWIRI	USAID Thrive program
NDMA	National Drought Management Authority
NEMA	National Environmental Management Authority
NRT	Northern Range Trust
NWWDA	Northern Water Works Development Agency
RPLRP	Regional Pastoral Livelihoods Resilience Project
RUAs	Rangeland Users Associations
SNV	Netherlands Development Organisation
VSF-Swiss	Vétérinaires Sans Frontières Suisse
WEF	Water Energy Food Nexus
WFP	World Food Programme
WRA	Water Resources Authority

CONTENTS

1. AGRICULTURE-LED ECONOMIC TRANSFORMATION FOR KENYA'S ARID LANDS

Approximately 17 million people, residing in the Arid and Semi-Arid Lands (ASALs) in Kenya earn their living principally through a mix of pastoralism and small-scale agriculture. Often marginalised, and with high rates of poverty, residents of ASALs are particularly susceptible to droughts and flooding. With increasing impacts from climate change, these areas are considered to be at risk of desertification.

Moreover, a large percentage of ASALs have been degraded from deforestation and overgrazing, which further reduces the productivity of these lands, threatening food security, livelihoods and biodiversity .

ASALs in Kenya are increasingly becoming key livelihood and economic zones that drive the country's development in line with Vision 2030 and the Big Four Agenda. According to the Kenya Climate-Smart Agriculture Strategy, 2017–2026, the livestock sector, which is a predominant activity through pastoralism, employs 50% of the agricultural workforce, providing a substantial source of income and livelihood to over 10 million Kenyans living in the ASALs. And contributing 12% of the national GDP and 43% of the agricultural GDP. Additionally, crop production is also practised in arable parts of the ASAL areas.

ASALs in Kenya face multiple challenges from the effects of climate change, problem further complicated by various other factors such as population expansion and competition for available resources such as land.

Recent research indicates that there has been a general decline in rainfall in 15 out of the 21 ASAL counties of Kenya (except Narok, Baringo, Laikipia, Turkana, West Pokot and Elgeyo Marakwet). Similarly, the average temperature in all the 21 ASAL counties has increased during the 1960 to 2014 period. Five counties that have surpassed the 1.5^{0}C increase are: **Laikipia (1.59^{0}C)**, Narok (1.75^{0}C), Turkana and Baringo (1.8^{0}C), and West Pokot and Elgeyo Marakwet (1.91^{0}C) . It is estimated that 16 counties in ASAL will have maximum temperatures increases greater than 1^{0}C. By 2050, in 17 counties, the temperature would have increased by more than 1.5^{0}C and by 2070, in all counties, temperature increases are expected to exceed 1.5^{0}C. Consultations with residents of the three counties reveal that most pastoralists experience severe decline and more unpredictable rains alongside changing temperatures.

The decline in rainfall and changes in temperature has led to a decrease in the number of livestock in the last few years . More frequent droughts continue to affect available livestock feeds, whilst increases in temperature limit livestock productivity, feed intake, reproduction and performance across the range of livestock species. An increase in animal pests and diseases and the emergence of invasive species have also been reported. In Isiolo County, invasive species Prosopis juliflora was specifically reported to outgrow the common (adapted) pasture, affecting the availability, quantity, and quality of available feeds.

It is projected that by the 2030s, 7 out of 21 counties will have over 50% of their cattle range experience temperatures above 30^{0}C. This will result in lower cattle production per unit area. These counties include Garissa, Tana River, Wajir, Mandera, **Isiolo**, Turkana and Marsabit. Another 5 Counties will have their cattle range moderately impacted, and these are Baringo, **Samburu**, Kitui, Elgeyo Marakwet and West Pokot. The counties of Lamu, Kajiado, Kilifi, Makueni, Kwale, Taita Taveta, Narok, and **Laikipia** will be affected minimally.

Thirteen out of 21 counties have a high potential of **rearing camel**. These are the counties of Kitui, Baringo, West Pokot, Marsabit, Mandera, Tana River, Wajir, Garissa, Taita Taveta, **Isiolo**, Turkana, **Samburu** and Makueni. Therefore, this presents an adaptation opportunity for the future.

'Releasing Our Full Potential', Sessional Paper No. 8 of 2012, on National Policy for the Sustainable Development of Northern Kenya and other Arid Lands seeks to reverse colonial policies perpetuated through the successive government policies prior to Constitution of Kenya 2010 that biased distribution of public investment towards high potential areas of crop production, overlooking the wealth of lowland livestock-based economies. Annual rainfall in arid areas ranges between 150mm and 550mm per year, and in semi-arid areas between 550mm and 850mm per year with high rates of evapotranspiration.

The main challenge is how to ensure food and nutrition security in a sustainable manner in ASAL environments that are prone to drought, with unpredictability is set to increase as climate change takes hold. The policy recognises that ASAL regions have hidden strengths and enormous resources that can be harnessed not only to sustain themselves but to contribute to national development, estimating the contribution of livestock as half of agricultural GDP.

2. ENHANCING CLIMATE RESILIENT AGRICULTURAL PRODUCTIVITY IN LAIKIPIA, ISIOLO AND SAMBURU COUNTIES

The partnership between Alliance for a Green Revolution in Africa (AGRA),SNV Netherlands Development Organisation, and the Frontier Counties Development Council (FCDC) in collaboration with the respective County Governments are implementing the Laikipia, Isiolo, Samburu Transforming the Environment through Nexus (LISTEN) initiative.

Funded by the Embassy of the Kingdom of the Netherlands, the 3.6 million Euros project seeks to contribute to enhance resilience by increasing food, nutrition and water security in the three selected Arid and Semi-Arid Lands (ASAL) counties of Laikipia, Isiolo and Samburu in Kenya using the WEF nexus programming in Kenya with four outcomes:

1. Improved institutional capacities and programming frameworks for inclusive climate resilience at the county level.
2. Improved water and livelihood resource management at Landscape level in the Ewaso Nyiro River Basin Ecosystem.
3. Increased production and income through adoption of Good Agricultural Practice (GAP), good management and efficient water practices, technologies and innovations in selected crop and livestock value chains, including fodder and forage.
4. Use of Knowledge and Innovation management increased in ASALs.

In this context, the objectives of the agricultural value chain assessment are:

- Identification of past and projected climate trends and hazards for the Kenya, with specific focus on the ASAL sites of Isiolo, Laikipia and Samburu counties.
- Assessment of climate risks, vulnerabilities and adaptation strategies for key (value chain) actors and underlying factors that contribute to high risk/vulnerability.
- Identification of suitable and contextualised climate-smart practices and adaptation strategies that will increase the adaptive capacity and overall resilience of the actors

- Inventory of current & recommendations for potential climate-smart inputs and services provided by value chain actors and government service providers.

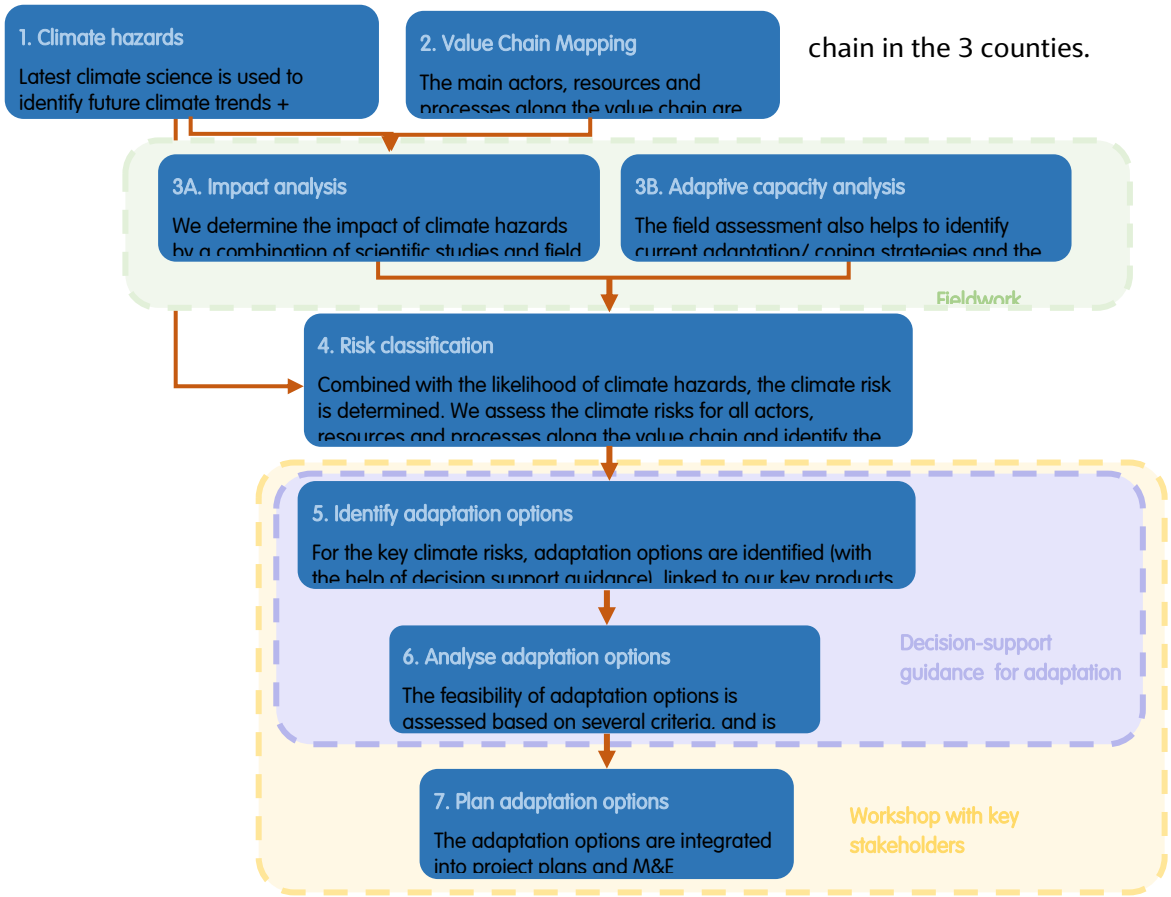
METHODOLOGY: SNV'S CLIMATE RISK ASSESSMENT TOOL

Utilising SNV's climate risk assessment tool (Fig. 1, below), a document review has been used to pinpoint the key risks to the agricultural sector in the three counties. Climate research is used to identify most likely climate hazards, trends and their future impact on farming systems, but often cannot provide sufficient detail on what impacts can be expected at the local level. To fill this gap, additional field assessment will be carried out, to get a better understanding of the value chain commodities, factors that determine the local impacts and vulnerabilities of the value chain actors, resources and processes, and the way in which they already respond to climatic stresses or shocks. Based on the fieldwork results as well as findings from literature, two tools (a climate risk matrix and resilience score card) are used to provide an overview of key risks and vulnerabilities.

Step 2. The key / representative Value Chain Commodities (VCCs) and main actors are derived from County Climate Risk Profiles for Isiolo and Laikipia, and from the Agriculture Sector Support Development Program (ASDSP), Min. of Agriculture for Samburu. It is worth noting that the County Climate Risk Profile are same as those listed in ADSP. As the Climate Risk Profile for Samburu has not been published, similar value chains grown under equivalent conditions have been adopted.

A comprehensive mapping of the main value chain actors will be during project implementation with a deep dive mapping consultancy survey to be undertaken next quarter alongside, Activity 2 under Output 3.2- Understanding the productivity, economics and soil fertility issues of the 4 main cropping value chains and irrigation systems and for livestock the fodder and meat value chain in the 3 counties.

Fig. 1: SNV's Climate Risk Assessment Tool



3. AGRICULTURAL VALUE CHAINS CHOSEN INFORMED BY A CLIMATE RISK PERSPECTIVE

The list of crop and livestock production and / or related products' value chain commodities for the LISTEN Counties is shown in Table 1. VCCs in RED are from prioritised list supported by the Ministry of Agriculture's Agriculture Sector Support Development Program (ASDSP). This is important to avoid creating conflicting information to smallholder farmers and pastoralists already facing critical challenges from climate variability particularly soil moisture and temperature changes.

Table 1: Value chains in the LISTEN Counties

	Isiolo	Laikipia	Samburu
Livestock	Cattle	Cattle (milk)	Cattle (beef)
	Goats (meat)	Sheep	Sheep
	Camel (milk)	indigenous chicken	Goats
	Indigenous chicken	Fish	Camels
			Donkeys
			Fish
Crops	Maize	Maize	Maize
	Green grams	Millet	Beans
	Sorghum	Sorghum	Wheat
	Beans	Sunflower	Barley
	Nerica Rice	Black beans (Dolichos)	Pyrethrum
	Cowpeas	Traditional Vegetables	Sorghum
	Black Beans (Dolichos)		Kales/Traditional vegetables
	Kales		
	Traditional Vegetables		
	Tomatoes		
	Onions A		
	Watermelons		
Forest products / other	Bees (Honey)	Bees (Honey)	Bees (honey)
	Furniture (wood)	Furniture (wood)	Pasture grass (Fodder)?
	Pasture grass (fodder)	Pasture grass (fodder)	

The prioritised VCCs are also referred to in the following climate vulnerability analysis.

4. ISIOLO CLIMATE VULNERABILITY

Isiolo's CIDP (2018-2023) indicates that the County is one of the most vulnerable counties to climate change in Kenya. Some of the key vulnerabilities emanating from climate change include drought and unpredictable rainfall, floods, the spread of water- and vector-borne diseases, intra and extra conflict among the agro-pastoralist and the pastoralist, wildlife-farmers conflict, loss of forests and wetland ecosystems, land degradation, desertification and scarcity of potable water. These factors negatively impact the County's economy, leading to reduced crop yield, low

livestock productivity, high livestock mortality, loss of income for farmers, famine, and malnutrition.

As of May 2021, almost half of the County's accessible grazing lands had poor pasture condition, attributed to poor regeneration of natural vegetation as an impact of the poor performance of the long rains season. The condition has also been worsened by the depletion of palatable grass species and accidental bush fires. The amount of pasture in traditional grazing areas is very poor so are left to sustain lactating herds though expected to last just less than three months. However, significant amounts of pasture are available in dry season grazing reserves such as Kom, Yamicha and neighbouring areas where most livestock have migrated to. During this same period, household milk production was low and expected to deteriorate further into the long dry spell. Further, there were increase conflicts in Kom, and the situation is expected to escalate further as the drought situation gets worse.

According to World Bank, analysis of temperature trends in the County over 25 years (1980 to 2005), showed an increase of about 0.5°C in the mean temperatures of both seasons. On the other hand, analysis of rainfall, measured over a 35-year period (1980-2015), showed little change in rainfall amount, with average first season rainfall remaining constant and average second season rainfall increasing only moderately (≤25mm). The combination of the moderate increase in temperatures and the relatively unchanged precipitation has resulted in an increase in the number of heat stress days in both seasons and an increase in drought risk for the first season.

Looking ahead to the period 2021-2065, climate projections based on two representative concentration pathways (RCP2.6 and RCP8.5) indicate that temperatures in both seasons are expected to continue to increase, increasing under the high emissions scenario. While heat and drought stress has been indicated as the main hazards for Isiolo, under both scenarios, the number of heat stress days , compared to the historical average, are expected to reduce, while the maximum number of consecutive dry days are expected to remain reasonably constant for both seasons. Under the high emissions scenario, rainfall is expected to reduce and moisture stress expected to increase, particularly in the second season. Under the conservative emissions scenario, a decrease in rainfall intensity for both seasons is expected, although both moisture stress and dry spell duration are also expected to reduce in the first and second season, respectively. An increase in season length is also expected for both seasons under the conservative GHG emissions scenario, although a reduction in length expected under the high emissions scenario.

3.1 CLIMATE VULNERABILITIES ACROSS AGRICULTURE VALUE CHAIN COMMODITIES IN ISIOLO

The County is generally an ASAL with low-lying plains on most parts of the region. 80% of the land is non-arable (22,000 km^2) and is used for grazing, while agro-pastoralism is practised in a few areas. Isiolo comprises of three agro-ecological zones (AEZs): semi-arid (5%), arid (30%), and very arid (65%) . Some of the characteristics of these AEZs are discussed below.

The semi-arid zone (Zone V) covers part of Wabera Ward, Bulla Pesa Ward, some parts of Burat Ward in Isiolo North Constituency, and the southern parts of Kinna Ward Isiolo South Constituency. This zone receives between 400 and 650 mm of rainfall annually, and the vegetation mostly consists of thorny bush with short grass. The main crops grown in this zone are **Maize, beans, cowpeas, green grams, onions, tomatoes, mango** and **pawpaw**.

The arid zone (Zone VI) covers Oldonyiro, Ngare Mara, some parts of Burat Wards in Isiolo North Constituency, the entire Garbatulla Ward, and northern parts of Kinna Ward in Isiolo South Constituency. Rainfall ranges between 300 and 350 mm annually and supports grassland and few shrubs. Crops grown in this zone are mainly **maize, beans, cowpeas** and **green grams**.

The severe arid zone (Zone VII) covers Chari, Cherab, parts of Oldonyiro Ward in Isiolo North Constituency, and Sericho Ward in Isiolo South Constituency. The area is barren, very hot, and dry most of the year, with annual rainfall averaging 150-250 mm. Such harsh climatic conditions do not favour crop growth in this zone.

Given the aridity of the County, 80% of the land is non-arable and used for grazing. The erratic and unreliable rainfall cannot support crop farming, which partly explains the high food insecurity and poverty levels among the population in the County. Approximately 12% of arable land was dedicated to subsistence crops and 15% to commercial crop production in 2013 . Agro-pastoralism is practised in a few areas, including Isiolo Central, Merti, Garbatulla, Kinna, and Sericho.

Food poverty rates are alarmingly high (77%), which has led to a high dependency of the population on relief food. Over the past three decades, drought hazards and high temperatures have increased significantly in the first season (January-June), while the second season (July-December) has been characterized by a lower increase in precipitations and higher mean temperatures. Short- and medium-term climate projections show that the County will remain highly susceptible to more frequent drought periods, increases in mean temperatures, and a decrease in intense rain in both seasons.

Climate change is bringing both opportunities and threats to the County. **The main opportunity is a possible increase in the resources that support crops/ livestock value chain, such as water and forage, which also allows some cultivation during the rainy seasons, resulting in increased production and productivity.** The main threats include the outbreak of pests and diseases, an increased risk of flooding resulting in damage to infrastructure and property, and prolonged drought with its impacts on crop failure and livestock mortality, degradation of rangeland resources, and morbidity. Expected future climate change and variation pose serious threats to the value chain commodities prioritized for analysis in this study. Drought and high temperatures were identified as key hazards, both currently and in the future. These hazards affect the prioritized value chain commodities differently.

CAMEL MILK

Camel milk is one of the most important value chains in Isiolo County. Camels are a key pastoral asset, given their ability to adapt to and survive harsh climatic conditions. However, the noted low and poorly distributed rainfall and higher temperatures have affected milk yields significantly due to lower quality fodder crops and reduced quantity of water for livestock, especially during dry spells. The major climate hazards affecting camel milk include drought and high temperatures. The vulnerable areas to drought and high temperatures are Isiolo central and the northern part of the County where camel milk value chain is a key economic activity. Prolonged drought and high temperatures lead to reduced pasture for the animals; hence milk production is reduced as the body condition of the animals deteriorates. Milk is more sensitive to high temperatures both at production and value addition (transportation) stages. The value chain characterization in Isiolo County shows that up to 20% of the population is engaged in the camel milk value chain.

GREEN GRAMS

Drought and high temperature affect every ward in Isiolo County where green grams are grown. Despite being a heat-resilient crop suitable for dryland farming, green gram can be adversely affected by drought and high temperatures. Green gram grown during the dry spell is normally of poor grades due to poor germination, flower abortion and withering. All genders are affected by these consequences since they all are engaged in the value chain.

INDIGENOUS CHICKEN

In as much as the local chicken value chain is rapidly being embraced as a cost-effective alternative livelihood and perceived to be resilient to climate hazards, drought and high temperatures affect the local chicken negatively throughout the County. The notable consequences of the drought and high temperatures range from an increase in poultry feed prices and drugs as a result of feed scarcity and households cannot afford to buy them; reduced extension service (households migrate to different places in search of pasture and water hence extension officers cannot locate them), reduced egg production due to high temperature; reduced egg shelf life due to reduced quality of eggs; low volumes in the market- (low turnout of buyers and traders); high prices (law of supply and demand); lack of water for cleaning, and increased incidences of pests and disease-causing organisms.

Service providers are also impacted because of infrastructure challenges rendering some areas inaccessible. At on-farm production, the key activities/ consequences include chicks having heat stress that leads to mortality. Women and youth remain highly vulnerable to climate impacts on poultry production, given their scarce resources to buy the feeds and limited access to input supplies.

GOAT (MEAT)

The demand for goat meat is predicted to rise dramatically in Isiolo, expanding the existing small ruminant value chain. Drought and high temperatures have been identified as the most problematic hazards in the goat meat value chain. The affected areas by these hazards include Isiolo town, Garbatullah, Sericho, Oldonyiro and Merti. These hazards cause water and pasture scarcity, which affects the availability of feeds and ultimately leads to lower productivity and animal susceptibility to diseases. In addition, increased temperatures and more frequent and prolonged droughts hinder pasture and herd recovery from previous climate hazards, encouraging herd migration to new, favourable territories.

3.2 ADAPTATION MEASURES TO CLIMATE VARIABILITIES IN ISIOLO COUNTY

Adaptation strategies Isiolo households are using to cope or mitigate against risks associated with agricultural production and food security are specific to certain value chains, whereas others cut across value chains.

For crop farmers, these include improved drought-resilient crop varieties; fast-growing and early maturing variety of crops; rainwater harvesting and conservation; conservation agriculture; crop rotation and intercropping; afforestation, and irrigation.

For livestock producers, they include **fodder production and conservation;** rearing improved breeds; breeding management; and livestock health management for livestock keepers.

Further, in the livestock and crops sub-sector, responses to climate hazards in the County have taken various adaption forms, including pasture establishment and conservation, disease control and surveillance, construction and maintenance of boreholes and watering points for livestock mass vaccination, destocking, and rearing of drought-tolerant livestock types. Crop farmers combine water and soil conservation practices, conservation agriculture, drought-tolerant and early-maturing crop varieties, agro-forestry, and post-harvest management and marketing.

To manage and lessen the effects of climate change, the County must step up efforts towards the adoption of renewable and alternative energy sources. Capacity building on improved crop varieties and livestock breed suitability can be emphasized to enhance the County's technology adoption.

Despite ongoing on-and off-farm efforts to increase climate resilience, farmers' adaptive capacity remains low and agricultural yields have decreased over the past years. In addition, limited access to water resources, farm inputs, and services, unaffordable productive technologies, and decline in the quality and quantity of natural resources (water, pastures) have led to inconsistent and uneven adoption of sustainable agricultural practices.

5. LAIKIPIA CLIMATE CHANGE AND VARIABILITY: HISTORIC AND FUTURE TRENDS

Laikipia has a cool climate with mean annual temperatures largely below 21°C in most parts of the County, with the western and southern parts of the county have cooler temperatures that only rise moderately in the eastern corner to between 22°C and 24°C. Annual average rainfall over most of the County ranges between 400mm to 750mm. However, there are areas with rainfall averages below or above these figures. Rainfall totals greater than 1000mm per year are recorded in some southwestern areas bordering the Aberdare Ranges and the slopes of Mt. Kenya. The drier northern pockets around Mukogodo and Rumuruti receive the least rainfall of between 250 and 500mm annually. Heat stress and drought are major agricultural risks for the county, often resulting in pasture deterioration, drying of water sources, livestock emaciation, natural resources-based conflict among pastoralists, crop losses and human-wildlife conflict over water. Flash floods also occur in the County, often impacting infrastructure and crop and livestock production.

Analysis of historical temperature trends in the County over 25 years (1981 to 2005) indicate a moderate increase in both first and second season mean temperatures by 0.2°C . On the other hand, rainfall trends over 35 years (1981-2015) showed that the first season rainfall average had not changed significantly, although the second season average rainfall has increased by over 50mm. Although average first season rainfall has not increased significantly, the slightly increasing temperatures have increased heat stress days. On the other hand, in the second season, the increase in precipitation has resulted in an increased risk of high-intensity rainfall, hence an associated increase in the risk of flash floods.

Looking ahead to the future, climate projections based on two representative concentration pathways (RCPs) indicate that there is expected to be a continued increase in mean temperatures under both scenarios. Under both scenarios, moisture stress is expected to increase; however, the increase is more pronounced for the first season, which is projected to experience an increase of over 60% in moisture stress days. In terms of precipitation, mean first season rainfall is expected to remain fairly constant in the first season regardless of the emissions scenario. However the second season is expected to rise by up to 20% under the high emission scenario. Flood risk is

projected to increase under both scenarios and for both seasons, with the maximum 5-day running precipitation average expected to increase by at least 25% regardless of the emissions pathway taken. In terms of season onset and duration, both seasons are expected to start earlier under the low emissions scenario; however, under the high emission scenarios, the season onset is expected to recede. As a result, season length under both scenarios and for both growing periods is expected to decrease moderately. The projections under the two GHG emissions scenarios show some differences. However, both indicate the likelihood of increasingly variable rainfall, shifts in season onset and duration, and continued rises in temperatures and these result in an increased risk of both heat stress and flood risk.

4.1 CLIMATE VULNERABILITIES ACROSS AGRICULTURE VALUE CHAIN COMMODITIES IN LAIKIPIA

Expected future climate change and variation pose serious threats to the prioritised value chain commodities in Laikipia County. Hazards include moisture stress, uncertainty in the onset of the growing season, drought and intense rainfall. In this section, we discuss some key value chains in Laikipia County.

MAIZE

The two hazards identified as the most problematic in the maize value chain are uncertainty in the onset and duration of the growing seasons and moisture stress. Areas most prone to uncertainty in the onset and duration of rains include Sosian, Ol-Moran, Githiga, Mochongoi, Marmanet, Rumuruti, Igwamiti, Kiriita, Gatimu and Gathanji. Salama ward, Leshau/Pondo ward and parts of Sosian ward. Uncertainty in the rain season imposes several challenges on the value chain. Farmers are not sure exactly when to prepare the land and when to plant. Post-harvest losses through aflatoxins, moulds and rots may occur if the rains come during harvest time. Marketing is also affected since farmers may be forced to sell immediately after harvesting at low prices.

Moisture stress affects all activities along the value chain. Farmers use less fertilizer when there is less moisture hence low yields and incomes. The post-harvest stage is likely to be affected negatively as there will be low volumes to be bulked and transported. Shelling and storage costs are likely to go up for farmers with reduced yields. As a result, there will be reduced linkage to buyers, and price will also go up as demand will be high with low supply.

CATTLE (MILK)

The hazards identified most catastrophic to the value chain were uncertainty in the onset and duration of the growing season and moisture stress. Areas identified to be more prone to uncertainty in the onset of the rainy season include Ol-Moran, Githiga, Mochongoi, Marmanet, Rumuruti and Tigithi wards. Parts of Salama, Ngobit, Mwiyogo/ Endarasha, Thingithu and Umande were identified to be more prone to moisture stress. The dairy value chain depends on hay and fodder inputs that solely rely on rain-fed agriculture. Uncertainty at the onset of the growing season will affect the input supply stage negatively as supplementary feeding will be in high demand as fodder production will below. Extension services will also be in high demand thus expensive. There will be high costs in the maintenance of dairy cattle at the on-farm stage as the production of feeds will be reduced. There will be an increase in the cost of transport with reduced volumes, storage and bulking costs in the post-harvest stage will also rise with reduced volumes

of milk. At the output market stage, promotion would be hindered, and pricing will also be affected by uncertainty at the growing season's onset.

The effects of moisture stress include reduced fodder supply, thus increased demand and higher costs of supplementary feeds, the higher cost in maintenance of dairy animals, reduced quality and quantity of milk, higher cost of bulking, storage and processing related to low volumes and reduced quality milk.

BLACK BEANS

Dolichos Lablab is a fast growing bean that flowers between 65-75 days, with purple flowers and matures between 80-90 days. The grain is black with a white hilum. It is recommended for cultivation in the lower and more marginal areas of Machakos, Kitui, Makueni, Tharaka-Nithi and Laikipia counties.

Dolichos has a yield potential of 3000-4000kg/ha or 1200-1600kg/acre (double that of normal beans), and can be ratooned- harvesting a monocot crop by cutting most of the above-ground portion but leaving the roots and the growing shoot apices intact so as to allow the plants to recover and produce a fresh crop in the next season to give a second crop that is 80% more grain than the first crop. It is mainly a grain type but at higher elevation it can also be used as fodder. It is attacked by pod boreres, but the diseases are of little economic importance.

Dolichos seeds take longer than common beans or cowpea to germinate and emerge, and thus should be planted earlier than other crops, before the onset of the rains.

Low crop yields in the Poor soil fertility in semi arid areas of Kenya is one of the key factors in low crop yields. A study undertaken by researchers from the University of Nairobi in semi-arid Machakos in 2008 and 2009 demonstrated that despite low rainfall of 500 mm, intercropping of maize with dolichos produced upto 20% higher yields of maize, improved soil physical and chemical properties including soil moisture content, organic carbon, total nitrogen, penetration resistance and the bulk density. Subsoiling (conservation tilling) increased water infiltration, legume biomass and showed some further improvements differences in maize performance.

Under similar conditions, separate research in Tanzania covering 58 years (1960-2018) demonstrated that when rainfall was below normal, production of dolichos was high, implying that Dolichos lablab is the best crop to plant during drought conditions, due to its capacity to tolerate droughts. It was established that during excessive rainfall, lablab plant grew well, but provided low yield than during low to moderate rainfall[1].

TRADITIONAL VEGETABLES

Kenya's most popular indigenous vegetables include Amaranthus (Terere), African nightshade (Managu), spider plant (Chisaga), cowpeas (kunde), and Jute mallow (Mrenda). Before the advent of county governments, production of these local vegetables was mainly on a subsistence basis, often by intercropping with other crops. However, some farmers have seen the economic benefits of local vegetables due to availability of markets and have started allocating substantial portions of their land for production. This has also changed the formerly rain-fed local vegetable farming

[1] *Bakari, A.E.* and *N.M. Pauline*; Institute of Resource Assessment, University of Dar es Salaam; **Tanzania Journal of Agricultural Sciences (2020)** Vol. 19 No. 2, 188-202

to include planting along riverbanks and/or supplementary watering in some areas during dry seasons. Most farmers still adopt traditional management practices where seeds are broadcast and end up being closely spaced in the field. This provides good ground cover, which reduces the impact of rainwater on the soil.

During land preparation, the un-harvested parts are ploughed back into the soil, thus adding to the soil organic matter content.

Farmers are involved in land preparation, buying seeds, planting, weeding, harvesting, and marketing. Local vegetables are produced on a semi- commercial and small-scale basis . Seed companies, agro-dealers, KALRO, and NGOs such as ACTED provide seeds and other inputs.

The popularity of local vegetables arises from their high nutritive and medicinal value as well as the large market demand and adaptability to the local environment. Some vegetables like grain Amaranth are currently being incorporated by milling companies into making composite flours due to their nutritive value. However, the fact that most species are open pollinated and their seeds are therefore easily saved by farmers over many seasons has discouraged commercial investment in their seed systems.

Most of the vegetables have a bitter taste and a strong smell, so they repel some pests.

Post-harvest handling, solar drying and processing technologies to prolong shelf life to maintain quality of local vegetables are being promoted by County extension workers and NGOs.

SHEEP

The hazards identified to be most problematic in the sheep value chain were drought and moisture stress. All areas in the northern parts of Laikipia were identified to be prone to drought, while Ngobit, Central, Tigithi, Naromoru and Mwiyogo/Endarasha wards were identified to be more prone to moisture stress. Moisture stress causes both water and pasture scarcity. As a result, livestock are poorly fed and become sick and emaciated. This leads to low livestock productivity, which also affects the availability of breeding stock. Livestock keepers also need to spend more money on disease control and surveillance. Reduced quality and quantity of stock will also affect the post-harvest stages, such as selection and grading as well as transportation.

Farmers with low financial capacity and low literacy levels are more likely to suffer from the consequences of these hazards. Youth and women are the most affected because they lack the knowledge and finance to adapt to these extreme events. Farmers/pastoralists who are always on the move to look for water and pasture are more likely to be affected as extension workers cannot keep track and monitor their stock.

INDIGENOUS CHICKEN

The most problematic climatic hazards identified for the local chicken value chain were intense rainfall and moisture stress. Areas more prone to intense rainfall included Githiga, Igwamiti, Gatimu, Ngobit, Thingithu, parts of Marmanet, Umande and Tigithi wards. Parts of Rumuruti, Salama, Central, Ngobit, Tigithi, Naromoru, Thingithu and Mugogodo East are some of the wards identified to be more prone to moisture stress. Intense rainfall has a major impact on all stages of the local chicken value chain. Intense rain has been associated with scarcity in chicken feed, reduced production of feeds, outbreaks of respiratory diseases, parasites and reduced quality and weight of chicken meat. It will also affect grading due to low quality and with low volumes; transport costs are likely to go higher, destruction of chicken house structures, sudden deaths and reduced breeding stock. In addition, impassable roads hamper transportation and lead to high

transport costs. Intense rainfall also negatively affects the marketing of chicken products since prices increase because of low production/high demand.

4.2 ADAPTATION MEASURES TO CLIMATE VARIABILITIES IN LAIKIPIA

Overdependence on rain-fed agriculture makes farmers in Laikipia County vulnerable to climate change and variability. According to Water Resource Management Authority (WARMA), water supply fell by more than half in recent years, and this is worse in the current dry spell. Farmers are now being encouraged to practice rainwater harvesting through rooftop gutters, water pans and dams to mitigate against moisture stress and to be able to sustain their crops and livestock production. This is because major rivers are drying up, for example, Nanyuki, Timau, Tehesoni, Naromoru and Ewaso Nyiro. The drilling of boreholes and water vendors have increased to satisfy the water shortages as rainwater is no longer adequate. Women nowadays spend less time on the farm as they have to search for water. In extreme situations, gender roles have been reversed, with men taking up few household chores like feeding the children when the women are looking for water.

Diversification is also encouraged where farmers are encouraged to grow early maturing, drought-tolerant, pest, and disease-resistant varieties of maize. Maize varieties series like 520, 517 and 516 are examples of short-term varieties promoted by the Ministry of Agriculture (MoA) to ensure that farmers have a crop even during shorter planting seasons. In addition, the County has begun acquisition of drought-resistant livestock breeds such as the Galla Buck breed for goats and Dorper Ram for sheep. These breeds also have a fast growth rate and are resilient to climate variability. Drought resistant crops are also encouraged as an adaptation measure. For example, hay is continuously being grown and promoted in different parts of the County.

Livestock in Laikipia County is facing challenges as a result of climate change and vulnerability. This is further aggravated by the fact that land parcels are now smaller and not enough to include fodder. In the highlands, priority is given to cash crops, while in the lowlands, there are no major cultivation activities, and pasture is left to emerge during the rainy periods. Nevertheless, fodder conservation is now being promoted across the whole County in hay and silage. The county government distributed hayseeds to farmers, and they were able to feed their livestock and even export to other counties like Garissa and Mandera. This shows the potential that fodder has in the County, not only as a feed to the livestock but as a cash crop.

On-farm adaptation strategies include conservation agriculture, rainwater harvesting, fodder conservation, planting early maturing and drought-tolerant crops, and drought-resistant livestock and hybrid breeds. Off-farm adaptation strategies include education and research on smart climate practices, farmer/pastoralist field schools, early warning systems, sub-county specific climate-based advisories, extension services, insurance, afforestation and re-afforestation.

However, poor coordination between different departments and institutions within the County has undermined the adaptive capacity of communities. There is little harmony and involvement of all the key players at the county level to have clear-cut roles and enhance coordination. Conflicting programmes and policies, overlapping mandates between sectors also cripple adaptation efforts. To improve the resilience of communities in climate risk management, collaboration and coordination by institutions are key.

4.2 ADAPTATION MEASURES TO CLIMATE VARIABILITIES IN LAIKIPIA COUNTY

Farmers are now embracing drought-tolerant maize varieties to reduce the consequences of moisture stress. Farmers can also adapt to these hazards through accessing timely information and extension services. Water harvesting through rooftop gutters, water pans and dams will go a long way in irrigation, especially during moisture stress periods. Small-scale, resource-poor farmers, are the most vulnerable as they are not able to diversify or purchase the high-cost inputs when these hazards strike. Farmers located far from extension workers are also more vulnerable as they are not able to receive updated information in time. Illiterate farmers who cannot decipher and understand information are also more vulnerable.

Although these hazards affect all farmers in the County, the most vulnerable will be the less educated, the resource-poor farmers, women and youth. This is because they have little access to the resources and information required to cope with climatic hazards. Farmers practice fodder conservation in the form of silage, hay and Boma Rhodes to ensure that their animals have food during such calamities. The volumes are, however still low and must be increased. To further cope with the hazards, farmers should harvest rainwater and use irrigation systems to cope with periods of drought.

Timely surveillance and disease control are also on the rise. Disease resistant varieties are also being introduced, e.g. Dorper Ram. Farmers can conserve pasture as an adaptive measure. Water harvesting to ensure the stock has water during drought and moisture stress periods is also an important adaptation strategy in the County.

To cope with this climatic hazard, farmers build stronger housing structures for their birds, vaccinate them against emerging diseases, and preserve feed for their birds. The most vulnerable people are the farmers with low financial capacity and low literacy level and women and the youth because they lack the know-how and finance to adapt to these climate risks.

6. SAMBURU CLIMATE CHANGE AND VARIABILITY: HISTORIC AND FUTURE TRENDS

The County's driest months are January and February. The long rainy season falls in the months of March, April and May. The elevation and orientation of the major topographic features such as Mathew ranges and Ndoto hills influence rainfall distribution. Apart from South Horr and Wamba areas, short rains occur during July and August, sometimes extending into September. At Wamba and South Horr areas, the short rainy season is usually delayed and occurs in October and November and sometimes extends into December. The southwest plains and the Lorroki Plateau receive between 500 mm and 700 mm of rain annually. The Nyiro and Ndoto Mountains and Matthews range receive the highest amount of rainfall between 750 mm and 1250 mm per annum. The central basin and the plains east of the Matthews Range are the driest parts of the County, with an annual rainfall of between 250 mm and 500mm.

The County has an annual mean temperature of 290C, with the maximum range being 330c and a minimum of 240C. The central plains and the east of the Matthews Range have the highest temperatures, while the highland belts in the North-Eastern side of Lorroki Plateau are cooler. Like other ASALs, In Samburu County, rainfall is highly variable, with high spatial and temporal variability. Future projections of total annual precipitation suggest increases by approximately 0.2-0.4% per year, with regional variations in precipitation. A key observation is that rainfall has become irregular and unpredictable, with more intense downpours . Wet extremes/high-rainfall events that occur once every 10 years are projected to increase, while dry extremes are projected

to be less severe, at least in the northern parts of the country . Parry et al. notes that, at the subnational level, greater rainfall has occurred during the short rains of October to December, and the long rains of March and April have become increasingly unreliable. .

Climate trends in Samburu have been marked by increases in both the minimum and the maximum temperature. It is reported that the minimum temperature has risen by 0.7-2.0°C and the maximum by 0.2- 1.3°C, depending on the season and the region. A trend of increasing mean maximum temperature has been observed (1960-2002) in Samburu County.

5.1 CLIMATE VULNERABILITIES ACROSS AGRICULTURE VALUE CHAIN COMMODITIES

Climate change in the County has manifested itself through the increase in variability of rainfall patterns, with increasingly shorter and unpredictable rainy seasons in areas that used to receive adequate downpours. Climate change impacts include the outbreak of livestock diseases, increasing malaria incidences, prolonged droughts, poor crop yields, famine, and migration and displacements. Expected future climate change and variation pose serious threats to the key-value chain commodities in Samburu County.

MILK (GOATS, CATTLE AND CAMEL)

Pastoralism is the main economic activity in Samburu, with about 80% of the households keeping livestock. Milk production from a range of livestock species, including camels, goats, sheep and cattle, and general livestock activities, provided households with most of their farm-related income. Overall, households do not have formal savings and hold on to livestock as a living bank. The most important livestock species are goats, sheep, cattle, and camels. Cash for buying maize—the main staple food—is derived from livestock sales, but wage labour (mainly from livestock herding) is a frequent supplement to household income.

Rainfall variability in intensity and seasonality of rainfall has resulted in prolonged drought and severe weather events in recent years. Droughts in Samburu County very often lead to livestock mortality and smaller herd size. While some evidence shows that droughts and occasional flooding are the most severe risks facing pastoralists (Ouma, Mude, & van de Steeg, 2011), other studies identified additional risks for pastoral households, including disease, risks of market exclusion, and deteriorating terms of trade (livestock products relative to grains).

MAIZE

Rain-fed maize cropping is the most common practice in our study region. However, agricultural production in the County is low relative to its potential. The County has a total of 139,892 ha arable land, which is mainly concentrated in Samburu Central highland. Main food crops grown include maize, beans and wheat. Maise is grown under small-scale farming in the highlands of Poro in Kirisia division. This is due to its fertile soils and adequate rainfall sufficient for rain-fed agriculture. In addition, there exist numerous mountain springs in the northern parts of the County covering parts of Nyiro division, such as south Horr and Tuum. The potential for these areas could be exploited through irrigation. A government-funded irrigation scheme is already underway at Tuum, which is expected to boost food production in the area.

The average farm size is 0.4 ha per household. Crop production is constrained by water scarcity, limited access to agricultural inputs (fertilizer, seeds, chemicals, and machinery), lack of credit facilities, and inappropriate farming practices. Samburu County is thus classified as the 5th

poorest County in Kenya, with 77% of the households considered poor (Kenya National Bureau of Statistics, 2013).

HONEY (BEEKEEPING)

Droughts in Samburu County very often lead to livestock mortality and smaller herd size. In a county where the majority rely on livestock, climate change has resulted in the loss of livelihoods. Therefore, one of the recommendations was to support Beekeeping and Honey processing as a priority project as one of the alternative livelihood options.

Climate change and climate variability have negative impacts on the productivity of honeybees; altering plant flowering time, increasing water stress, especially in situations of drought, thus reducing pollen and nectar availability, inhibiting movement, affecting bee communications, causing physical damage of hives, colony starvation and retarding bee forage activities. In response to climate change, beekeepers have adapted to reduce impacts by shifting to pollen-rich areas, providing food for bees, providing water, changing hive types, changing apiary location, putting hives in tree shadows, use of over-dimensioned wooden hive and changing harvesting methods and time.

5.2 ADAPTATION MEASURES TO CLIMATE VARIABILITIES IN SAMBURU COUNTY

Some County-specific issues affecting Samburu as major impediment to development include insecurity due to frequent cattle rustling between communities, and community conflicts over pasture and watering points during dry periods. Insecurity has completely paralyzed farming activities around Look, Amaiya and Poro areas. Human-Elephant Conflict (HEC) is also afflicts the County, as are people continually encroaching into wildlife habitat in search of settlement pasture for livestock. It is expected that if areas designated for Wildlife conservation are affected negatively by climate change, the intensity of conflicts will increase.

The Samburu people are trying to cope with the impacts of climate change using a variety of strategies. The strategies they have put in place are; rearing of camels, embracing agro-pastoralism and small scales business ventures like poultry, brick making, beading and charcoal burning.

7. PRIORITY CROP VALUE CHAINS AND PROPOSED ADAPTIVE STRATEGIES FOR LAIKIPIA ISIOLO AND SAMBURU COUNTIES

As a result of the above analysis, priority cops for Laikipia, Isiolo and Samburu counties have been further elaborated with respect to adapting to changes and variabilities in climate, with a focus on strategies across major value chains in the tables below

1. Isiolo: Green Grams, Black beans, Kales, Traditional Vegetables
2. Samburu: Maize, Beans, Sorghum, Kales/Traditional Vegetables
3. Laikipia: Maize, Black Beans, Traditional vegetables

MAIZE	Provision of seeds and other inputs	On farm production	Harvesting storage and processing	Product marketing
Uncertainty in start and duration of growing season	Uncertain extension services; uncertainty in variety selection Low supply of seed; uncertainty of timely supply of the right fertilizers; low supply of fertilizers; late purchase of herbicides	Uncertainty in planting time, high input costs; incur extra costs on machinery, equipment and labour	Great losses in post harvesting through aflatoxins, molds and rot; uncertainty in store preparation leading to post harvest losses; poor quality maize; low prices	Fluctuation of prices which affects buyers and sellers; uncertainty in supply and volumes leading to low prices; poor quality produce on the market
Magnitude of impact	**Major**	**Major**	**Major**	**Major**
Farmers' current strategies to cope with the risks	Use of Indigenous Technical Knowledge (ITK);use of internet; use of trails and guesswork; use of previous records; trails and guess work, use of farmyard and composted manure; use of previous years records; use of local varieties	Use of traditional methods; trials and guess work; Conservation Agriculture (cover crops, slashing, herbicides and rotation); use of good agricultural practices; soil sampling and testing; crop insurance	Use of motor shellers; sorting and grading; use of moisture meters; use of hermetic bags and metallic silos; use of aflatoxin detectors; construction of warehouses/aggregation centers; certification of warehouses/aggregation centers by EAGC;	G-soko/e-soko/internet; millers; sourcing market information through local radio stations/internets/local dailies; formation of marketing groups through EAGC and FAO, ASDSP; banks for warehouse receipt system financing
Other potential options to increase farmers' adaptive capacity	Conduct trainer of trainers (TOT) and capacity building on timing of planting; frequent weather advisories; private extension services; research on improved seed varieties; provision of subsidized seed by government; credit facilities	Early planting; increased ca equipment and machines to farmers; timely weather advisories; access to ca equipment and machineries; upscale ca capacity building/adoption to farmers; upscale ca weeding equipment and	Upscale shelling equipment; increased moisture meters to organized farmer groups' use of hermetic bags; access to drying machines and equipment; warehousing; aggregation centers; farmers access to aflatoxin kits and	Create more market linkages; improve access to market information to farmers; support farmer groups; warehouse receipt system; G-soko/e-soko; government to support farmers on linkages; upscale local radio station programs; increased support

	for traders; support farmer groups access seed; increased soil sampling; support organized farmer groups access fertilizers	training to farmer; crop cover; mulching	moisture meters; construction of warehouses; improve on infrastructure (roads)	to agro processing industries; training farmers on farm agro processing.
Moisture stress	Reduced extension services; giving alternative choice of enterprise; low supply of seeds and change in varieties of seeds; low supply of fertilizers	Uncertainty in planting time leading to loss of inputs and reduced yield; Less costs and low yields	Greater cost for shelling and storage as compared to yields; low volumes of bulking leading to reduced income	Low quality, volume and less income; Poor linkage and low income; Poor quality, less volumes, less income, high costs in the market
Magnitude of impact	**Severe**	**Moderate**	**Major**	**Severe**
Farmers' current strategies to cope with the risks	Supply short rain seeds e.g. 5 series; early maturing varieties; use of manure; subsistence fertilisers; soil sampling and testing	Early planting; Conservation Agriculture; water harvesting; conservation agriculture; early land preparation; shallow weeding; herbicides; cover crops; mulching	No significant impact	Source of manure. Mulching; On farm feed conservation
Other potential options to increase farmers' adaptive capacity	Training of TOTs; more research on adaptable moisture stress seed varieties; access to affordable credit facilities; upscale use of compost and farm yard manure; upscale soil sampling and testing; access to affordable subsidized fertilizers	Early harvesting; water harvesting technologies e.g. ponds, dams; upscale use of conservation agriculture; early land preparation; access to ca land preparation equipment; increase shallow weeding equipment; crop cover/mulching; subsidized herbicides to farmers	Increase shelling equipment, sorting and grading equipment; build more warehouses; increase access to hermetic bags; capacity build farmers on postharvest handling; support more aggregation centres; support capacity building for farmers on agro processing; introduce cottage industries	Create more market linkages/networks; use of internet, marketing i.e. G-soko, radio stations and mobile networks; create more linkages to millers/processors through county government and organizations; promote agro-processing on farm by products; capacity building on farmers

GREEN GRAMS	Provision of inputs	On-Farm production	Harvesting, storage and processing	Product marketing
Drought	Farmers migrate to different places in search of pasture; reduced field demonstrations due to crop failure; no water for demonstration plots; reduced procurement for seeds and planting materials due to low purchasing power	Reduced land preparation; reduced acreage for planting; low production; reduced weeding due to crop failure and low production	Food insecure at household level, high commodities price; in-flow from other counties; high transportation cost; reduced collection due to crop failure	High commodity prices due to law of supply and demand; low market linkage; poor grades due to low quality of grains
Magnitude of impact	**Severe**	**Severe**	**Severe- Major**	**Moderate**
Farmers' current strategies to cope with the risks	Time of operation adjusted; accessing of relief seed; provision of farm inputs by NGOs and government	Conservation agriculture; use of drought resilient varieties; Diversification of crops and livelihoods	Training on appropriate technology; outsource of better and affordable price	Group marketing; bulking, training in marketing, use of ICT (text, WhatsApp, e-agriculture platform)
Other potential options to increase farmers' adaptive capacity	Use of ICT e.g. mass media, mobile phones; continuous use of appropriate technologies; exchange tours; continue encourage saving culture; formation of groups; revised policy focused on ASAL areas	Scaling up of conservation agriculture; use of drought resilient varieties; use of certified seeds; use IPM; use early maturing crops	Introduction of treated sacks instead of direct application of storage chemical; skills development through training; farmers forming groups to cut down transportation cost, government provide transport subsidy	Policy formulation to control essential commodity price; enhance networking and linkages through training; encourage use of machines during
High temperature	Reduce number of training; drying of seedlings due to high temperature or withering	Low production hence low income; reduced number of land operations; poor germination; withering of crops; Low labour productivity	Difficulty in storage; pest infestation during storage; low transport volumes; mechanical breakdown of equipment due to high	High prices for the commodity due to low production; reduced market linkages; reduced grading due to low productivity

			temperatures; reduced produce to be collected	
Magnitude of impact	**Major**	**Severe**	**Moderate**	**Moderate**
Farmers' current strategies to cope with the risks	Group procurement of inputs - Farmers group leaders/representatives given enough time to mobilize; provision of seeds by agriculture department/ organisations	Communal land preparation; selection of varieties that survive at low moisture content; shorten irrigation intensity; increase frequency of irrigation and use of waste water; decrease land under crop	Spraying with pesticides and use of improved seeds; adjust time of operation (late evening and early in the morning); adjust time of operation (late evening and early in the morning)	Group marketing; Change sales times to coincide with better prices and market demand
Other potential options to increase farmers' adaptive capacity	Conduct trainings in the morning and evening; use of ICT for sharing extension and weather information (mobile phones, ICT platforms); agricultural input subsidies	Promotion of conservation agriculture; capacity building on Integrated Pest and Disease Management (IPDM); Promotion of efficient irrigation	Use of modem harvesting and processing equipment; opening of cottage processing industries in rural areas; plan collection timing with farmers	Formation of ICT platforms for market information; establishment of decentralized market centres

Kale	Provision of seeds and other inputs	On-farm production	Harvesting storage and processing	Product marketing
Drought	Reduction in stocks of suppliers due to low demand; reduced extension service delivery	Insufficient water for irrigation; Low affordability of labour services; reduced and weak family labour; low aquifer yield; high concentration of pests	High moisture loss after harvesting; accelerated perishability; low harvest per unit area; high transport cost	Consumers demand is high due to limited supply; reduced income by cooperatives
Magnitude of impact	**Severe**	**Moderate**	**Moderate**	**Major**
Farmers' current strategies to cope with the risks	Purchase from stockists; information through mass media and mobile phones; purchase from input suppliers	Start early before the season and early in the day; using of harvested water from micro-catchment; use of traditional IPM methods for pest control	Harvesting in the early morning and late evening; soak in water after harvest; transported in plastic bags on wheel barrows, motor cycles, bicycles and other informal vehicles	Use of mobile phones to make orders; use of word of mouth during selling; sale as individuals and small groups
Other potential options to increase farmers' adaptive capacity	Promote saving and seed sourcing through cooperatives; capacity building of stockists; establishment of farmer field schools; savings and sourcing through cooperatives	Subsidized vegetable production equipment and services; construction of mega water harvesting structure; support capacity building on IPM	Capacity building on post-harvest handling; establish cold rooms at bulking sites; road infrastructure development and maintenance	Use mass media to share market information; promotion on utilization and value addition; formation of large marketing groups (cooperatives); training on commercial village model
Increased temperature	Reduced seed viability; Reduced mobility of extension services	High temperatures affect working hours; increases in irrigation water loss and plant transpiration; high concentration of pests in the few existing and productive areas	High moisture loss leading to reduced quality; increased field heat during bulking; high moisture loss during transportation; reduced stability of leaves	High cost of promotion; low production and contribution of providers; reduced income
Magnitude of impact	**Moderate**	**Major**	**Major**	**Moderate**

Farmers' current strategies to cope with the risks	Preservation of local seed varieties; use of mass media and phones to share weather information; individual procurement from input suppliers	Working early in the morning and only for a few hours per day; reduced watering intervals, mulching and watering during cool hours; use of cultural methods to control pests and diseases	Harvesting done during cool hours and water sprinkled during hot hours; use of plastic bags for storage; transport to market using informal transport	Use of mobile phones to get market information; use of word of mouth to promote their products; sale as individuals and small groups
Other potential options to increase farmers' adaptive capacity	Encourage seed conservation. Promote collective procurement of seed and other inputs (particularly during droughts).Scale up farmer field schools	Working early in the morning and only for a few hours per day; reduced watering intervals, mulching and watering during cool hours; use of cultural methods to control pests and diseases Support subsidized mechanized vegetable production (land tilling); support use of water efficient technologies e.g. shade nets, greenhouses, drip irrigation; support capacity building on solarisation of soil and IPM	Capacity building on post-harvest handling; support purchase of equipment for drying of vegetables; support establishment of cold chains in established production sites; training on kale value addition technologies like solar drying	Invest in use of mass media for marketing information (local dialect); support formation and capacity building of new and existing marketing associations; support feeder road construction and maintenance

Traditional Vegetables	Provision of seeds and other inputs	On-farm production	Harvesting storage and processing	Product marketing
Drought/Moisture stress	Wilting and death of some seedlings. Reduced availability of seeds. Reduction in manure availability	Poor seedling germination rates. Results in formation of hardpans that make land difficult to till. Increased water requirements resulting in increased labour. Increased cases of pests and diseases (aphids, termites)	Reduced quantity and quality of harvest. Reduced shelf life and increased perishability of harvested vegetables. Spoilage during transportation	Increased prices for consumers due to lower supply
Magnitude of impact	**Moderate**	**Major**	**Moderate**	**Moderate**
Farmers' current strategies to cope with the risks	Obtaining seeds and seedlings from government facilities or research organisations	Early land preparation/ dry planting. Use of minimum tillage practices. Irrigation using buckets. Use of leaves as mulch	Harvesting small quantities at a time. Farm gate sales in small quantities	Use of middlemen to link the producer to the market. Farm gate sales to reduce chances of spoilage before sales. Home consumption of produce
Other potential options to increase farmers' adaptive capacity	Promotion of drought and pest tolerant varieties. Introduction of high yielding varieties	Use of mechanical tilling equipment. Investment in water harvesting and small scale irrigation. Promotion of efficient water use technologies (e.g. drip irrigation). Capacity building on manure management and use	Developing cooperatives for vegetables. Capacity building on value addition	Improvement of access roads to reduce transport times. Establishment of contract marketing

Change in seasons (onset and duration)	Wilting of seedlings while awaiting rains	Poor seedling growth. Delayed recharge of soil moisture. Difficulty in planning farm operations	Poor quality produce. Greater storage and transportation costs. Difficulty in timing harvests. Difficulty in aggregation	Missed marketing opportunities. Irregular supply to markets. Difficulty in meeting market demand. Unstable prices
Magnitude of impact	**Moderate**	**Moderate**	**Moderate**	**Moderate**
Farmers' current strategies to cope with the risks	Use of mulching and irrigation to protect seedlings. Delayed seed procurement. Delayed manure application	Delayed land preparation. Mulching and irrigation with buckets. Compost production using leaves of various plants. Extension advice on planting dates	Extension advice on harvest times. Home consumption	Farm gate sales. Use of middlemen to link the produce to the market
Other potential options to increase farmers' adaptive capacity	Promotion of early maturing varieties. Local seed bulking. Local seedling production	Promote water harvesting and drip irrigation. Capacity building on integrated pest and disease management. Improvement in access to agro weather advisories for planning of vegetable production operations	Training on vegetable storage and value addition	Capacity building of vegetable marketing cooperatives. Contract growing of vegetables

Beans	Provision of seeds and other inputs	On-farm production	Harvesting storage and processing	Product marketing
Moisture stress	Low seed viability leading to poor germination	Reduced spraying due to poor stand establishment; delayed weeding; stunted growth and poor crop vigour (wilting)	Low yields (poor quantity and quality); lack of labour opportunities from poor grain harvests; household qrain scarcity from crop failure	Reduced market activities leading to low household incomes; high market prices (grain scarcity and high demand)
Magnitude of impact	**Minor**	**Major**	**Severe- Major**	**Severe**
Farmers' current strategies to cope with the risks	Planting of drought-resistant seed varieties	Soil and water conservation through mulching, cover crops, agroforesty, intercropping, conservation agriculture; planting of early-maturing bean varieties; diversification to other crop varieties (root crops)	Application of storage pesticides	Local produce marketing at low farm gate prices
Other potential options to increase farmers' adaptive capacity	Improved access to irrigation facilities for continous cropping; shifting from inorganic to organic farming	Capacity building on conservation agriculture; breeding bean varieties tolerant to moisture stress; land leasing to more commerially-viable enterprises	Construction of improved storage facilities; establishment of community- and county-based strategic grain reserves	Training and empowering vulnerable groups on entrepreneurship and post-harvest opportunities
Droughts	Poor quality seeds leading to poor stand establishment; limited seed accesibility due to high costs; seed scarcity	Reduced agronomic performance through applied agrochemicals; hard pans increase labor costs	Poor yields (low quantity and quality) caused by crop failure; Lost labor opportunities in post harvest grain handling (winnowing and grading); household grain scarcity; increased incidence of storage pests	Reduced market activities resulting to low household incomes; High market prices driven by fruit scarcity and high demand

Magnitude of impact	**Moderate**	**Major**	**Major**	**Severe**
Farmers' current strategies to cope with the risks	Use of drought-resistant, short-maturing seed varieties; seed bulking; access to credit facilities for acquisition of farm inputs	Delayed land preparation and planting; increased incidence of weed, pest and diseases; diversification to alternative crops (legume) and enterprises (fish farming); water harvesting and small-scale irrigation; conservation agriculture; agroforestry; crop rotation; intercropping; crop loss protection through crop insurance	Application of storage pesticides	Establishment of strategic grain reserves at community and County level
Other potential options to increase farmers' adaptive capacity	Research on drought-resistant seed varieties; wide-scale bulking for seed multiplication; improved access to affordable credit schemes; use of organic manures	New intercropping strategies with newly-emerging food crops; soil and water conservation (harvesting and irrigation); greenhouses; tree planting	Training women and youth on post-harvest value addition activities	Capacity building on grain marketing strategies and marketing opportunities

SORGHUM	Provision of seeds and other inputs	On-farm production	Harvesting, storage and processing	Product marketing
Increased moisture stress	Labour scarcity, high labour costs, limited access to certified seed/inputs (low demand)	Soil degradation (reduced soil cover, organic matter and microbial activity); poor germination; seed loss (pest/diseases damage); reduced fertilizer efficiency; delayed agronomic activities (planting, weeding); increased labour costs	Low quality and quantity of harvested grain; increased postharvest losses (pest/rodent damage); high transport costs; labour scarcity (harvest/ threshing/ packaging); reduced labour efficiency	Reduced seed density (mass per unit volume) increased producer losses; reduced market/marketing activities; increased demand for shelter/shade in markets
Magnitude of impact	**Major –Moderate**	**Severe – Major**	**Minor**	**Moderate**
Farmers' current strategies to cope with the risks	Participation in awareness creation campaigns (certified inputs/ fertilisers); local seed acquisition (farmers exchange); acquire seed from research institutions (KALRO); use of low-quality manure; access to poor quality agrochemicals	Use of mechanical and animal draught (ploughs); hand weed control; early land preparation; intercropping; tree planting; crop rotations; staggered cropping; use of manual/household labour	Household /hired help (winnowing/sorting/threshing); storage (gunny bags, home silos and granaries); farm gate sales (avoid postharvest sales)	Product hoarding (market speculation); market value addition (flour); local marketing (brokers/word of mouth/local markets/institutions; build temporary shades (in markets)
Other potential options to increased farmers' adaptive capacity	Promote soil and water conservation on farms/fields; improve land management (agroforestry); drought resistant- varieties; access to Early warning System;	Regulate use of rotary tillers; promote efficient weed control practices; access to weather advisories (EWS); access to efficient mechanized equipment (tractors); promote widespread FYM use	Access to mechanized threshers (minimize harvest losses); introduce and train producers on specialized equipment (grain sorting, winnowing and grading); use of moisture free	Regulated cereal pricing; contracting cereal production; county support for external markets; access to crop insurance schemes (prevent production/market

	County support for input access (seeds/inputs)		oxygen bags; construct county-wide storage facilities (NCPB)	insurance); construct modern markets (improved infrastructure)
Increased soil erosion	Loss of planted seeds; reduced fertilizer efficiency/efficacy	Soil/land degradation (loss of soil cover, soil nutrients, water holding capacity); seed loss (damage by pest/insects); low stand counts; increased weed prevalence; crop nutrient competition with weeds; loss of crop vigour	Limited transportation; high transport costs; increased damage to storage structures; increased postharvest losses (rotting/pre-germination); increased seed losses at winnowing; increased cost of structural maintenance	Poor quality and low quantity of marketed produce; limited access to market (damaged roads); damage to market structures; reduced market linkages/marketing opportunities
Magnitude of impact	**Major**	**Major- Moderate**	**Moderate –Minor**	**Moderate –Minor**
Facrmers' current strategies to cope with the risks		Staggered planting; terracing; agroforestry; depth planting (prevent seed loss); covering manure/fertilizer (aftter application); timely planting; enterprise diversification (tree seeding/bee keeping(; intercropping with legume; conservation agriculture	Gender (women) based labour use (winnining, sorting and grading); use of local transport means (bikes); use of local materials for storage structures (wood, nylon, bricks); use of gunny bags; drying produce using local sheds/dryers	Local grain sales (farm gate/long maize corridors); public media (radio) and local market channels (word of mouth); sell to external marketers (through external middlemen/broker)
other potential options to increase farmers' adaptive capacity		Promote agroforestry and afforestation; efficient extension services (visit/information); explore strategies for curbing seed loss (after planting); training on manure compositing; agriculture in hilly areas; promote weather advisories	Establish community based grain processors; county support at community organized grain collection and transport systems; introduce postharvest grain inspection program; capacity building (postharvest storage, value addition and packaging)	Inspection of grain weighing equipment (scales); introduce mechanical sorting/packaging equipment (improve produce market quality); county support to form organized farmer groups at village levels (collective marketings)

Add Final section on recommendations & Way Forward : On farm and Off-farm adaptation Options for Priority Crop Value Chains, either a table or a narrative summary of the profiles- on farm and off -farm adaptation section.

8. CONCLUSION AND RECOMMENDATIONS

Laikipia, Isiolo and Samburu counties lie in the arid and semi-arid part of Kenya, with between 80-90% of their land receiving below 500 mm of rainfall a year. To make this worse, climate change has increased the uncertainty of rainfall, increased the intensity and duration of droughts, while increased temperatures have aggravated evaporation, which was already more than 5 times higher than average rainfall.

The consequence is that Normalized Difference Vegetation Index (NDVI) has been falling below normal when compared to their respective long-term dekadal NDVI values. Rivers, dams, pans and other sources of water have been decreasing in flow and volume, creating increased conflicts between upstream, downstream and competing water users, while the amount available for supplementary irrigation has been reducing.

As a result, the mainstay for the majority of the population, livestock, have been repeatedly malnourished, reducing their productivity of beef and milk, as well as their value as household assets.

According to the UN FAO (1996) definition, "Food security, at the individual, household, national, regional and global levels is achieved when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and **food preferences** for an active and healthy life." In terms of food preferences, Kenyans have overwhelmingly preferred maize in their diet, despite its proven vulnerability to delayed and reduced rains that are worsened by climate change.

Recommended adaptation strategies to reduce production risk include the planting of crop varieties with a shorter growing period, changing planting times as dictated by rainfall, collection of water in furrows near plants and increasing use of irrigation.

To enhance nutrition, and provide fodder for to supplement rangeland grazing, the LISTEN program will support Laikipia, Isiolo and Samburu Counties accelerate their support to farmers in the production of their priority value chains reflected in the County Integrated Development Plans (CIDP) and the Agricultural Sector Development Plans.

Despite the vulnerability and low productivity of maize, due to the overwhelming demand and role of maize in household diet, the program will support the maize value chain. However, the other crops prioritised reflect best practice in terms of drought tolerance that is so critical in the dryland counties; multiple utility function, higher yield per unit of water, shorter growing period and beneficial impact on soil fertility. These include

- Dolicho (black beans) which not only have the highest impact on increasing maize production by fixing nitrogen and increasing soil-carbon, but also thrive under semiarid conditions, providing shade and enabling water infiltration, thus simultaneously increasing soil moisture availability and reducing evaporation by providing shade, and reducing weeds that compete for water and nutrients. Additionally, the dolicho have double the productivity of normal beans, high value in the market, and have no economically important pests that would require heavy expenditure by farmers, provide a second yield when rooted, and the leaves/stems nutritious fooder for livestock
- Traditional vegetables. Indigenous, African vegetables are on the rise after a long period of stagnation due to highly profligate modern vegetables that came to dominate the market. These traditional vegetables are not only more nutritious and even medicinal, but have higher tolerance to drought, pests and have great value improving soil fertility when ploughed back into the soil

- Green grams: For the arid lands, Kenya Agricultire and Livestock Research Organisation (KALRO) has developed K26, a green gram variety that easily doubles the yield and has larger sized beans than the traditional mung bean. Green grams have a good market price, are hardy, and grow in areas where other crops would fail due to heat and water scarcity, thus ideally suited for the marginal lands
- Kales: Though kales require significant amounts of water per unit of production, they are very easily grown in very convenient locations like kitchen gardens or even in sacks. They are similar to maize in terms of high market demand
- Beans: Due to continuous deficit and enormous demand for beans that is second only to maize, Kenya with support of international research institutions has developed and promoted the use of drought-resistant, short-maturing seed varieties; seed bulking; access to credit facilities for acquisition of farm inputs to expand bean production. Beans are also nitrogen fixing which is critical in arid lands that frequently subject to nitrogen depletion
- Sorghum: This is the fifth most produced cereal crop in the world, with high drought tolerance, can be grown in wide variety of soils, and has excellent nutritional value with a combination of trace minerals, vitamins and unlike wheat, is gluten-free. It has the advantage of being amenable to large scale growing like wheat or maize, thus providing for economies of scale (industrial, mechanised production) not possible with other popular drought tolerant crops like the ones mentioned above.

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