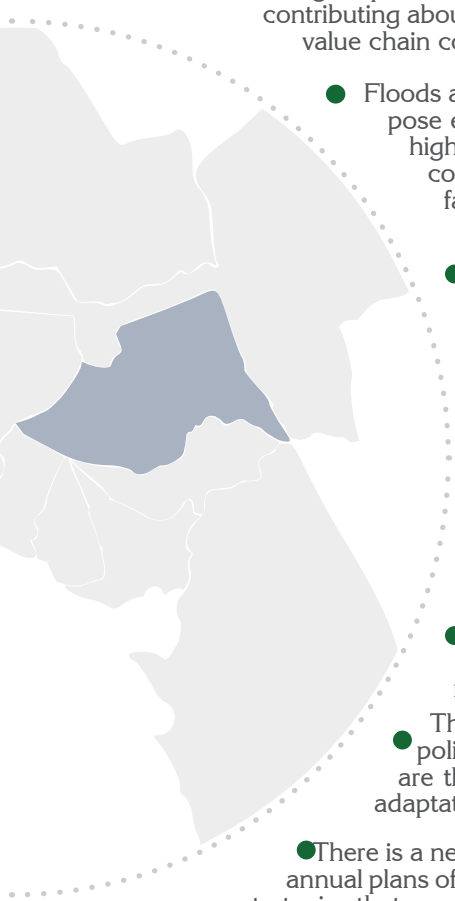
Climate Risk Profile
Meru County

Highlights

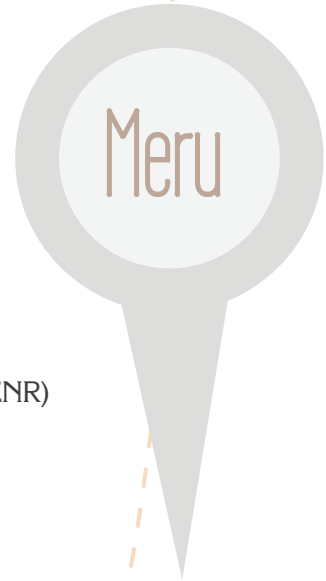


- Meru County is characterized by high agricultural productivity attributed to favourable climatic conditions and fertile lands. High-input, rain-fed agriculture complemented by irrigation is the main source of livelihood in the County, contributing about 80% to the average household income. Maize, bananas, potatoes and dairy cattle are the key value chain commodities that contribute to both household food security and livelihoods.
- Floods and heat stress compromise productivity and food security in Meru County and are expected to pose even greater challenges in coming years. Reduction of agricultural land, declining soil fertility, high input costs, lack of protection of catchment areas, environmental degradation, cross-border conflicts between pastoralists and crop farmers, and poor marketing systems are some of the key factors that exacerbate the impacts of climate change and variability and at the same time limit the ability of farmers and livestock keepers to cope with these impacts.
- Farmers employ a number of on-farm strategies to cope with climate risks and shocks including: conservation agriculture, tree planting, growing of drought-tolerant crop varieties, value addition, improving livestock breeds, animal feed conservation, water harvesting, farm inputs such as seeds and fertilisers, irrigation and water harvesting equipment, and forming of cooperatives for easier access to credit, markets and information. The main constraints to adoption of these strategies include; high costs of inputs, distance to input markets, counterfeit inputs (products) and technologies, and limited knowledge of new technologies.
- Off-farm services to increase the adaptive capacity of farmers include: agricultural extension and training, youth friendly technologies/engagement, credit and insurance schemes, early warning information and food security assessments. These services are provided by governmental, non-governmental, faith-based and private organizations.
- Engagement between actors is facilitated through a stakeholders' forum, however, there is a need to strengthen the framework for collaboration to maximize the use of resources and minimize duplication of effort.
- The absence of County-specific legislations on enforcing national climate change policies, lack of political goodwill, and a lack of mechanisms to coordinate, implement and monitor interventions are the most common institutional hindrances to disaster risk management and climate change adaptation.
- There is a need to fast track the drafting of policies on climate risk management to be mainstreamed in the annual plans of the County. This will facilitate the allocation of budgets to implement climate risk management strategies that are proactive.

KAPP
Kenya Agricultural Productivity Programme
Republic of Kenya
WORLD BANK GROUP

List of acronyms

AEZ	Agro ecological Zone
ASDSP	Agricultural Sector Development Support Programme
CFA	Community Forest Association
CRA	Commission on Revenue Allocation
FAO	Food and Agriculture Organization of the United Nations
GEF	Global Environmental Facility
KACCAL	Kenya Adaptation to Climate Change in Arid and Semi-Arid Lands
KALRO	Kenya Agricultural and Livestock Research Organization
KAPP	Kenya Agricultural Productivity Programme
KES	Kenya Shillings
KFS	Kenya Forestry Service
KMD	Kenya Meteorological Department
KNBS	Kenya National Bureau of Statistics
KPHC	Kenya Population and Housing Census
KRC	Kenya Red Cross
MDU	Meru Dairy Union
MoALF	Ministry of Agriculture, Livestock and Fisheries
MoENR	Ministry of Environment and Natural Resources (MoENR)
NCCRS	National Climate Change Response Strategy
NDMA	National Drought Management Authority
NEAP	National Environment Action Plan
NEMA	National Environmental Management Authority
PERIS	Plantation Establishment and Livelihood Improvement Scheme
SCCF	Special Climate Change Fund
VCC	Value Chain Commodity
WFP	World Food Programme
WV	World Vision
WB	World Bank



Foreword

Climate change is becoming one of the most serious challenges to Kenya's achievement of its sustainable development goals as described under Vision 2030. Kenya is already extremely susceptible to climate-related events, and projections indicate that the impacts are likely to affect the country even more in the future. In many areas, extreme events and variability of weather are now the norm: rainfall is irregular and unpredictable; some regions experience frequent droughts during the long rainy season, others severe floods during the short rains. The arid and semi-arid areas are particularly hard hit by these climate hazards thereby putting the lives of millions of households and their social and economic activities at risk.

In 2010, Kenya developed a National Climate Change Response Strategy (NCCRS) which recognized the importance of climate change impacts for Kenya's development. This was followed by the development of the National Climate Change Action Plan in 2012. The focus of these initiatives including the development of country climate profiles have been considered at national level. As the country shifts towards County governance and focus, there is a need to mainstream climate change perspectives into programmes and development plans at the County level.

To strengthen local capacities of stakeholders to reduce the near-, medium- and long-term vulnerability to current and future climate variability, the Kenyan Government, through the Ministry of Agriculture, Livestock and Fisheries (MoALF) is implementing the Kenya Adaptation to Climate Change in Arid and Semi-Arid Lands (KACCAL) project. The project is funded with a grant from the Global Environmental Facility (GEF)/ Special Climate Change Fund (SCCF) through the World Bank (WB). The present study is part of the KACCAL project and aims to inform the County Government and stakeholders on the climate change risks and opportunities for agriculture so that they are able to integrate these perspectives into their development plans and processes.

This document presents the Climate Risk Profile for Meru County, where climate variability is accompanied by a significant increase in attendant risks, as frequently reported in national and international news. Flooding related to El Niño phenomena in 2015 resulted in damages to farm land, homes, and infrastructure amounting to hundreds of millions of Shillings[1]. In November alone, more than 100 people were left homeless when flash floods swept away their houses and destroyed 988 acres crop land, while two of the County's major infrastructure projects (an underground drainage and irrigation project and a major mining quarry) collapsed[2]. Flash floods and landslides are exacerbated by interspersed periods of prolonged drought, as occurred in 2012, 2015, and again in 2016. In 2015, the withering of maize and bean crops and the drying of pastures that sustain 20,000 heads of cattle encouraged the state to introduce initiatives for the adoption of drought-resistant varieties and contingency plans for livestock care[3]. The disastrous nature of severe floods and drought makes the identification of impending climate risks an urgent matter: likewise, considering how practices that help citizens become more resilient in the face of imminent threats to their health, safety, and livelihoods becomes an exercise with the potential to affect hundreds of thousands of lives.

The Profile is organized into six main sections, each reflecting an essential analytical step in studying current and potential adaptation options in key local agricultural value chain commodities. The text first offers an overview of the County's main value chain commodities key to food security and livelihoods, as well as major challenges to agricultural sector development in Meru. In the next section, the main climate hazards are identified based on the analysis of historical climate data and climate projections, including scientific assessments of climate indicators for dry spells, flooding, heat stress, among other key hazards for agriculture. Then it continues with an analysis of the vulnerabilities and risks posed by the hazards deemed to be potentially most harmful to the respective value chains. Based on these vulnerabilities, current and potential on-farm adaptation options and off-farm services are discussed. The text also provides snapshots of the policy, institutional and governance context that can enable adoption of resilience-building strategies, and finally presents potential pathways for strengthening institutional capacity to address potential future climate risks.

1 As reported by the The Star online newspaper (Kirimi, 2015)

2 As reported by the Stanadard online newspaper (Mukui, 2015)

3 As reported by the Daily Nation online newspaper and Kenya Red Cross Society reports (Ikidii, 2015; KRCS, 2015)

Agricultural context

Economic relevance of farming

Meru County lies on the eastern slopes of Mt. Kenya covering a total area of 693,620 hectares (ha) out of which 177,610 ha is gazetted forest (GoK, 2013). The County shares borders with Tharaka/Nithi to the south, Isiolo to the north and east, Laikipia and Nyeri Counties to the west and Tana River to the southeast.

The County is parcelled into four agro ecological zones (AEZs) ranging from upper highlands-UH3 to lower midlands-LM6 (Jaetzold et.al., 2010).

- The Upper Highlands (UH) cover the majority of the County's area from Imenti South, Meru Central, Imenti North, Tigania East, Tigania West, Buuri, Igembe Central, Igembe North and Igembe South constituencies. The upper highlands have an average precipitation of 700 mm to 1000 mm per annum and mean annual temperature of between 14.90C-10.50C. The altitude ranges between 2230-2900 m above sea level.
- The Lower Highlands (LH) have an average precipitation of 800 mm to 2600 mm, temperatures of between 17.40C-14.90C. The altitude ranges between 1830- 2210 m above sea level.
- The Upper Midlands (UM) have an average precipitation of 500-2,400 mm, temperatures of between 20.60C-17.60C and an altitude range of 1280-1800 m above sea level.
- The Lower Midlands (LM) have an average precipitation of 580-1,600 mm of precipitation, temperatures 240C-20.90C and an altitude range of 750-1300 m above sea level; these include parts of Buuri and Tigania which borders Isiolo County.

The major economic activity in Meru County is agriculture (crop farming and livestock keeping). The total acreage under food and cash crops is 161,907 ha and 15,773 ha respectively which represents 23% and 2.3% of the total land area of Meru County (GoK, 2013). The mean value of the total household income for Meru County is 258,028 Kenyan Shilling (KES) The overall mean on-farm income is KES 97,740 per year while the overall mean non-farm and off-farm income is KES 86,576 per year (GoK, 2014).

The majority of the population in Meru County are employed in agriculture. The sector contributes about 80% to the household income. Wage employment and self-employment contribute the remaining 20% to the household income. Both men and women are engaged in agricultural activities right from production to marketing with men mainly engaging in market-oriented crops that are associated with expected higher income. Youth provide the largest share of both family and hired labour in crop production and women the least. In livestock production, however, adult women provide the largest share of labour whereas youth contribute the least (GoK, 2014).

People and livelihoods

According to the Kenya Population and Housing Census (KPHC) of 2009, the population in the County stood at 1,443,555 in 2012 with almost equal gender distribution (50.6% women, 49.4% men). Using the same annual growth rate of 2.1%, the population is expected to stand at 1,601,629 in 2017.

The great majority of the population resides in the rural areas while 60% of the total urban population is located in Meru town. The average population density in Meru County in 2012 was 282 persons per square kilometre (Km2), ranging from 544 persons per Km2 in the fertile lands of Igembe to 134 persons per Km2 in the semi-arid parts of Buuri.

The absolute poverty level in Meru County is 28.3% which is well above the national poverty line of 47.2% (CRA, 2011). This can be attributed to a wide array of income sources that are available to households in the County. Most adult male-headed households had between one to more than four income sources while youth-headed households had between one and four income sources (GoK, 2013).

The main sources of energy for cooking are fuel wood and charcoal accounting for 86.1% and 6.6% respectively (GoK, 2013). Agroforestry is widely practised in the County and provides a readily available source of firewood. The number of households connected to the electricity grid is 13.6% (GoK, 2013). The literacy rate in the County is 53% compared to the national rate of 72% in 2012 (GoK, 2013). The low literacy rate is partly attributed to a high incidence of child labour in the agricultural sector, especially in the miraa production and supply chain system.

Meru County is considered food secure except for the areas bordering Isiolo and Tharaka Nithi Counties. Cases of malnutrition are minimal and this can be attributed to the diversification of food sources consumed. Prevalence of stunting, wasting and underweight among children is relatively high. Children receive three meals per day during the lean season while other household members take only two (GoK, 2013; KNBS, 2014).

The main livelihood strategies are crop, livestock, and fish farming, forestry and agroforestry, tourism, and industry. The major food crops are maize, beans, bananas, potatoes, pigeon peas, cow peas while the major cash crops are tea, coffee, wheat, sorghum and horticultural crops.

Livestock in the upper highlands and upper midlands is kept under smallholder zero-grazing systems involving the "cut-and-carry" method of feed management characterized by ownership of one to two dairy animals. Cows are kept for dairy milk while bulls are used for traction. In the lower midlands of Tigania and Igembe, livestock is kept on group ranches where grazing animals are able to roam over large areas. This is characterized by large herds of predominantly indigenous cattle. The main livestock kept are goats, cattle, sheep, pigs, rabbits and poultry. Based on estimates from the livestock production office in the County, there were 180,000 dairy cattle (both pure and crosses), 250,000 beef cattle, 331,000 goats (dairy and local), 245,000 sheep, 60,000 broilers, 1,065,000 indigenous birds, 28,000 pigs, and 48,500 rabbits.

The County has over 2,000 fish ponds evenly distributed throughout the County and an estimated 2,500 small-scale farmers engaging in fish farming.

Agricultural activities

Land is unequally distributed within the County: a minority of large-scale farmers hold most of the land while the majority of households own small parcels of land. The average land holding size is 1.8 ha while for the large scale it is 18.25 ha (GoK, 2013). Large-scale farming, mainly wheat production, is carried out by individuals and private companies in the Timau area of Buuri constituency.

Roughly 50% of the farmers in the County have title deeds. The highest number of farmers without title deeds are found in Meru North region. Lack of title deeds affects investments on land negatively.

Farmers in Meru County use a variety of agricultural inputs, such as planting fertiliser, storage pesticides, organic manure, and top dressing fertiliser. Up to 80% of farmers are using improved seed varieties (GoK, 2014). The high usage of inputs in crop production coupled with favourable climatic conditions in the County contributes to high productivity levels compared to other counties in Kenya. Nevertheless, households experience constraints in acquiring inputs such as seed, planting and top dressing fertiliser. This is attributed to high prices, distance to markets, and lack of access to inputs at the right time (GOK, 2014).

Meru County has a huge untapped irrigation potential with 11 permanent rivers. However, only about 14% of the households use irrigation water as an input (GoK, 2014). According to County water experts, the area under irrigation in Meru County is 15,000 ha with a potential of 80,000 ha. Harnessing this potential would ensure all-year-round crop production and contribute to increased productivity.

Agricultural value chain commodities

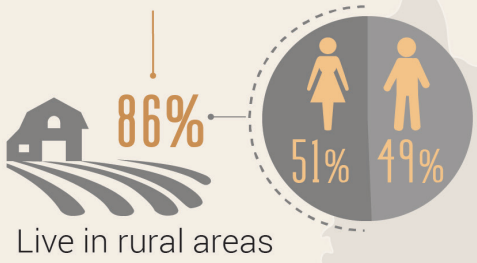
Meru County is endowed with a wide array of food and cash crops produced in the varied agro ecological zones. Various value chains have been prioritized for development interventions by different government organizations and programmes, such as the Agricultural Sector Development Support Programme (ASDSP), the Kenya Agricultural and Livestock Research Organization (KALRO) and University of Nairobi survey, and the Kenya Agricultural Productivity Programme (KAPP). For the development of this County Climate Risk Profile, four major agricultural value chain commodities (VCCs) were selected for in-depth analysis, based on their contribution to food security, productivity characteristics and importance to the economy. These VCCs have been selected from a list compiled from the above-mentioned documents, using the following prioritization indicators: harvested area (hectares), production (90 kg bags), variation in production (in the past five years), value of production (US$/bag), dietary energy consumption (Kcal/ capita/ day), protein content (gr of protein/ 100 gr of product), iron content (mg of iron / 100 gr of product), zinc content (mg of zinc / 100 gr of product), and Vitamin A content (IU Vitamin A / 100 gr of product). The VCCs selected for further analysis in this study are: maize, potato, banana, and dairy cattle.

Livelihoods and agriculture in Meru

Demographics

3.5% Of Kenya´s population

1,443,555 inhabitants



Live in rural areas

Access to basic needs

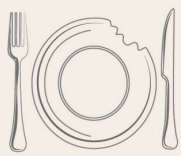
ND of the population lives in **absolute poverty**

Potable water	2%
Electricity for cooking	0.4%
Electricity for lighting	14%
Education (youth literacy rate)	53%

Food security

28% of the population suffers from **food poverty**

ND of household **income spent on food**



ND People **undernourished**

33% Children **stunted**

7% Children **wasted**

ND: No data

Infographic based on data from the County Integrated Development Plan (GoK, 2013), the Agricultural Sector Development Support Program (GoK, 2014), and Kenya National Bureau of Statistics (KNBS, 2015)

Farming

County´s farming area

ND

ND% of the population employed in agriculture production

50% of farmers have title deeds

ND% are women

Farming activities

Food crops

Cash crops

Of county´s agricultural land

Livestock

4 Group ranches

4 Company ranches

Farming inputs

Water uses

ND ND ND

Fertiliser types (% of households)

54% Organic manure

45% Basal fertiliser

37% Top dress fertiliser

Pesticide types (% of households)

35% Field pesticides

39% Storage Pesticides

18% Herbicide

Maize

Maize is a key staple food for the population of Meru County, contributing to food security. It is grown on 14.5% of the County's total agricultural land. In 2015, a total of 65,740 metric tonnes of maize was harvested in the County with a value of KES 1,730 million. Maize is grown in all the AEZ of the County. However it is not regarded highly in terms of economic value as opposed to other crops such as potatoes, bananas and miraa.

Over 80% of the County's population, predominantly small-scale farmers, are engaged in the maize value chain. Suppliers of inputs are mainly small-scale traders found primarily in the rural trading centres as well as medium-scale traders operating in the major urban centres of the County. The feeder roads that serve the agricultural areas are in poor state especially during the rainy season. This hinders access to markets and increases the cost of transportation. There are both retailers and wholesalers of maize in the County with small-scale buyers purchasing at farm gate, while medium-scale buyers aggregate volumes for onward transmission to markets and processors. Small-scale processors convert maize into flour and animal feeds.

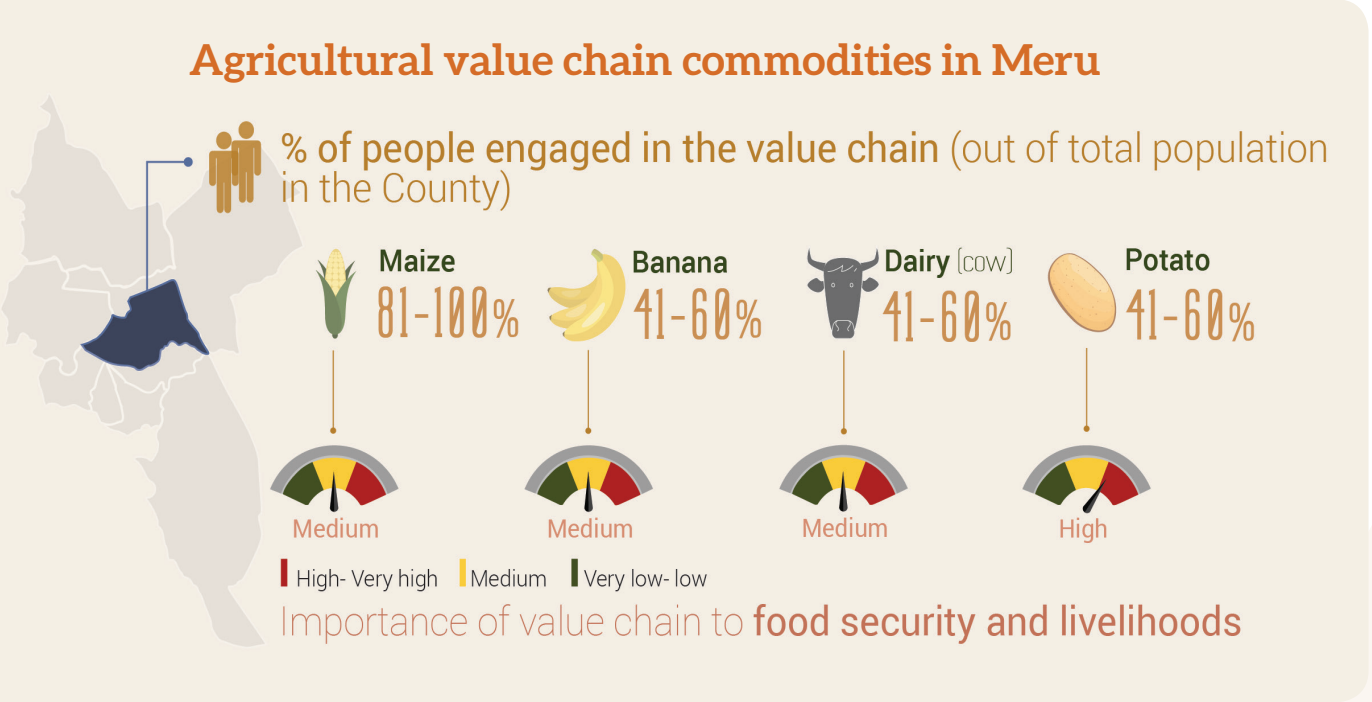
Irish potato

Meru County is among the leading potato producers in Kenya. Potato is grown for both commercial and household consumption purposes and takes up 3.3% of the County's total agricultural land. Potato growers constitute between 40% - 60% of the total population of the County. Most potato farmers are small-scale with average farm sizes of 1.8 ha. Potatoes are grown in Buuri, Imenti Central, Imenti North, Imenti South, Igembe Central and Igembe South Sub Counties which are found in the upper highlands AEZ. In 2015, a total of 124,420 metric tonnes was harvested worth KES 3,884 million.

Inputs are provided by small- and medium-scale suppliers found in major market and urban centres. Meru Potato cooperative society has organized farmers into farmer groups and offers extension services, trainings and farm demonstrations. In addition, the society buys potatoes from farmers for aggregation. Middlemen also play a major role in potato marketing since most of them buy the produce at farm gate for bulking and onward transmission to traders who take the produce to Nairobi and markets further afield. Since potatoes are perishable, farmers and traders are highly dependent on road network condition and are likely to incur heavy losses during periods of rain, when roads become inaccessible. A small portion of the potatoes is sold in local markets, mostly by women traders. The larger share is transported to Nairobi to fast food outlets selling chips. Small-scale processors in the County consist of hotels and fast food outlets.

Banana

Banana is a key livelihood source for Meru's population and is grown on 2.2% of the County's total agricultural land. In 2015, a total of 382,390 metric tonnes were



produced earning the farmers approximately KES 3,700 million. Bananas are grown in Imenti South, Imenti Central, Imenti North, Tigania East, Tigania West, Igembe South Sub Counties which are found in the upper highlands AEZ.
Banana is grown for both subsistence and commercial purposes. Between 40% - 60% of the total population of the County is engaged in the banana value chain. The main value chain actors are small-scale farmers who grow the bananas, small-scale input suppliers and the traders. Farmers sell their produce to small-scale retailers (middlemen) who aggregate and sell to wholesalers who transport and sell the produce in Nairobi – the main banana market in the country. Women traders sell the produce at local markets. Processing facilities in the County are limited. Some banana farmers have formed a cooperative union to produce banana wine and flour which is sold in various supermarkets.

Dairy cow

Meru County is one of the leading milk producing areas in Kenya. Dairy farming is practised in all AEZs of the County. In 2015, an estimated 120,000,000 litres of milk was produced earning the farmers about KES 4.56 billion.
More than half the population (40% - 60%) of the County is involved in dairy farming with the majority of households keeping an average of two animals. Milk is consumed on a daily basis, hence the importance of dairy farming for food security. Although dairy farming is widespread, productivity is considered to be medium. For the exotic cattle, the productivity per animal is about 6.7 litres/cow/day during the dry season and 8.6 litres/cow/day during the wet season (GoK, 2014).
Dairy is an income earner for many households with farmers being paid an average of KES 38 per litre by the Meru Dairy Union, a large-scale processor in the County. In 2015, the processor was handling an average of 110,000 litres per day. Even though most of the milk is taken to the Meru Dairy Union, raw milk is still sold in local shops, local markets and pasteurized milk in the supermarkets. The actors in this value chain include the farmers (or milk producers), the inputs providers (who distribute the various inputs used in dairy production), and the processors (such as the Meru Dairy Union, who buy the milk from the farmers, add value and sell to consumers).

Agricultural sector challenges

Agriculture is the economic mainstay of Meru County contributing to food security, household income and providing employment. Even though the County is agriculturally rich, it is facing a myriad of challenges that prevents it from attaining sustainable growth, to increase incomes and provide more employment opportunities.

Farmers in Meru County experience constraints in acquiring quality potato seed which hinders their production capability resulting in lower yields. This is mainly due to the high cost and limited availability of certified seed and because stockists sell low quality seed that is not certified.

Poor quality planting materials as in the case of banana and potato and changing weather patterns have led to an increase in pests and diseases. Most of the pests and diseases are developing resistance to the commonly used pesticides thus posing a challenge to agricultural and livestock productivity.

Despite the County's potential for irrigation, most farmers are still dependent on rain-fed agriculture and thus vulnerable to weather variability. In this sense, households are expected to adopt water-saving irrigation technologies such as drip irrigation and rainwater harvesting in order to make maximum use of rainfall for both domestic and agricultural activities.

Meru County has eleven permanent rivers that traverse the County and drain their water into Tana and Uaso Nyiro rivers. Due to human activities upstream, some of the rivers are polluted while others are silt-laden reducing their water levels. The hilly terrain of the County and continuous cropping practised in the high potential areas has exacerbated soil erosion and reduced soil fertility. Environmental degradation caused by human activities such as overstocking of livestock especially in the lowlands has also been a major cause of degradation. There is therefore a need to protect the water catchment areas and prevent soil erosion through protective measures such as tree planting, training farmers on contour farming, terracing of farm lands and adjusting livestock numbers to carrying capacity.

Farm activities are mainly undertaken by women but income goes to men. Men tend to gravitate towards activities that generate higher incomes leaving women with the not-so-lucrative activities. Productive resources

such as land and capital are largely controlled by men. This limits the ability of women to take appropriate actions which is unfortunate since they are the major players on farm.

Most of the commodities produced in the County are sold in raw form, without any value addition, fetching low prices. Poor market organization leads to exploitation of farmers by middlemen who dominate the marketing of agricultural produce. This acts as a disincentive to farmers and affects returns in the agricultural sector. This can be addressed by increasing the formation of marketing cooperatives and strengthening of the management of the existing facilities in addition to construction of fresh produce markets in areas where there are none but are a necessity.

Climate change-related risks and vulnerabilities

Climate change and variability: historic and future trends

Meru County has a range of climates within the county ranging from relatively hot and dry in the north and east portions (<750 mm precipitation and >23°C) to cooler and moist in the central and western parts of the county (>1500 mm precipitation and <15°C). Due to this strong gradient in climate throughout the county, flooding, dry spells, and heat stress, are all hazards that contribute to agricultural risk in the county.

Historic analysis of weather in Meru county shows that both dry spells and extreme precipitation are hazards in the county. Dry spells are longer during the second wet season averaging around 65 consecutive days of moisture stress, but ranging between 60 and 80 in any given year. The first wet season only experienced approximately 45 consecutive days of moisture stress, ranging from 30-60 in any given year. Extreme precipitation and flood risks[4] are quite high on average in both seasons. The first season consistently experienced high single day precipitation, with more than 70% of years experiencing greater than 20 mm of precipitation in a single day. However the second wet season was more highly variable from year to year, and had multiple years with very high precipitation events greater than 50 mm in a single day.

Climate has already been observed to change in the county. Since 1981, the first wet season has experienced a moderate (1°C) increase in mean temperature and associated reduction in crop cycle, a significant increase in heat stress days, and no detectable change in precipitation. The second wet season experienced a mild (~0.5°C) increase in temperature, and no change in precipitation.

Looking to the future in the years of 2021-2065, both extreme precipitation and prolonged moisture stress are projected to occur, but the changes are quite different during different seasons. Within 30 years (by the early 2040's) temperature is projected to increase by 0.3 °C, with the first wet season projected to experience even greater changes. And by this time, precipitation is projected to decrease by 0.4% in the first wet season, and increase of 25% in the second wet season. Consecutive days of moisture stress is projected to substantially increase in the first wet season from approximately 45 days to over 75 days (more than 50% increase). However, moisture stress is projected to decrease in the second wet season, with the number of consecutive moisture stressed days decreasing from more than 60 days to less than 25 days. Extreme precipitation is projected to remain approximately unchanged during the first wet season, but increase by 40-60% in the second wet season, depending on the level of greenhouse gas emissions (greater emissions resulting in greater change). These projections of future climate change under the two climate scenarios[5] - RCP 2.6 and RCP 8.5 - show some differences, but generally show the same trends in future projections. In general, the greater the greenhouse gas emissions, the greater the increase in moisture stress during the first season and increase in intense precipitation during the second season.

Climate vulnerabilities across agriculture value chain commodities

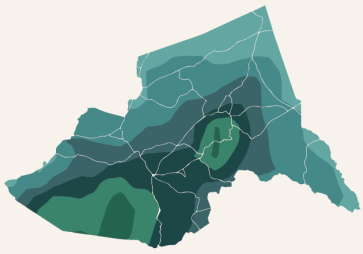
Expected future climate change and variation pose serious threats to value chain commodities prioritized for analysis in this study. Hazards affecting the agricultural sector include floods, drought, landslides, increased temperatures and increased incidences of pests and diseases. Floods and heat stress were identified as the most problematic hazards both currently and in future. These hazards affect the prioritized value chain commodities differently as explained below.

4 Refers to the wettest 1-day event (mm/day) indicator in the infographic.

5 The two RCPs, RCP2.6 and RCP8.5, are named after a possible range of radiative forcing values in the year 2100 relative to pre-industrial values (+2.6 and +8.5 W/m2, respectively). The pathways are used for climate modelling and research. They describe two possible climate futures, considered possible depending on how much greenhouse gases are emitted in the years to come. RCP 2.6 assumes that global annual GHG emissions (measured in CO2-equivalents) peak between 2010 and 2020, with emissions declining substantially thereafter. In RCP 8.5, emissions continue to rise throughout the 21st century.

Past and future impacts of climate hazards in Meru

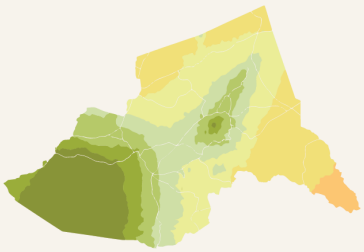
Historical annual mean precipitation (mm/year)



Legend
- Road
- <250
- 250-500
- 500-750
- 750-1000
- 1000-1250
- 1250-1500
- 1500-1750
- >1750

Data sourses
Precipitation: CHIRPS (1981-2015)
Roads: Digital Chart of the World

Historical annual mean temperature (°C)



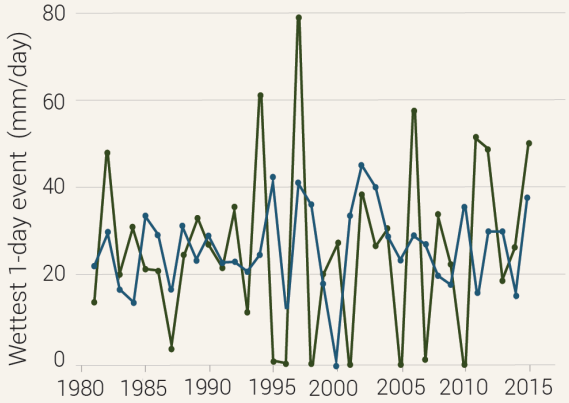
Legend
- Road
- < 15
- 15 - 17
- 17 - 19
- 19 - 21
- 21 - 23
- 23 - 25
- 25 - 27

Data sourses
Precipitation: WordClim (1970-2000)
Roads: Digital Chart of the World

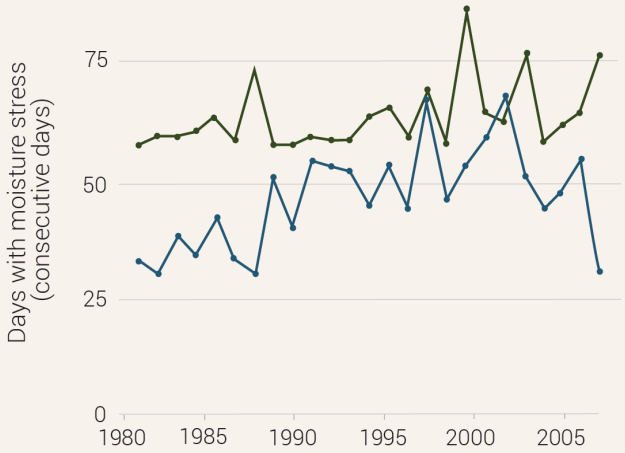
Flood hazards

Drought hazards

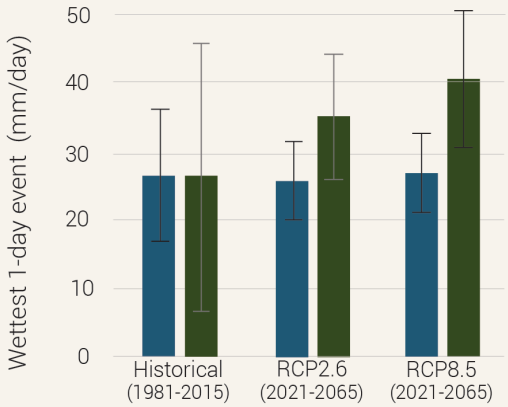
Historical extreme flood events



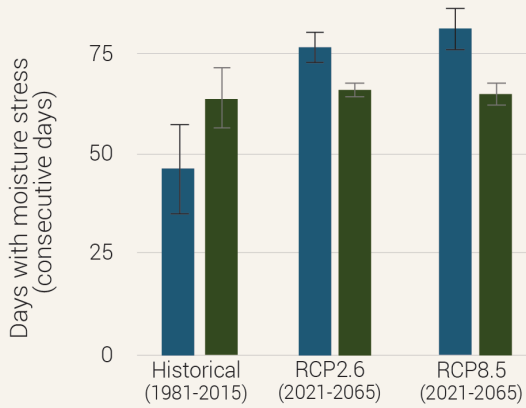
Historical drought stress events



Historical and expected extreme flood events



Historical and expected drought stress events



January - June July - December

Maize

Maize production is mainly affected by floods and heat stress. Floods occur mainly in Buuri, Maua and in the areas near Isiolo in Tigania East which are characterized by black cotton soils that have poor drainage. Floods reduce the germination rates and growth of maize. During floods, post harvesting is affected causing aflatoxin contamination due to excessive moisture and poor drying conditions. The heat stress occurs in some parts of Meru North, Tigania East and West, Igembe North, Igembe Central and Igembe South which are lowland areas thus susceptible to high temperatures. Heat stress causes poor germination rates, wilting of the maize crop and poor productivity since the crop cycle is shortened.

In response to these threats, farmers have started planting maize varieties that have short maturity and require less rain. Flooding is addressed by the construction of terraces on the farms to drain excess water. Farmers have also been trained on how to dry and store the maize to reduce the probability of aflatoxin incidences especially in cases where there is excess rain during harvesting. Hermetic bags are being used to store the grains and avoid infestation by pests. Farmers in Giakii have formed a cooperative society of maize farmers to increase bargaining power to secure better prices. The cooperative society also helps to source inputs at subsidized prices due to economies of scale.

Potato

Potato production is affected by floods and heat stress. Floods causes rotting of potato seed when planted and makes land preparation and planting difficult. On-farm activities such as weeding and fertiliser application are also very difficult during times of floods. The underlying factors that make floods a serious challenge are heavy rainfall and the type of soil (black cotton soils, which have a propensity of waterlogging). Waterlogging during floods causes rotting of the potato tubers, resulting in poor quality harvests or no harvests at all.

Heat stress leads to drying of the seed materials and also causes potato plants to produce smaller poor quality tubers that fetch very low prices. Harvesting of the potato tubers becomes very difficult due to the hardening of the soils increasing the costs of labour.

The most affected zones to flooding and heat stress are the flat LM zones, which have poor drainage (causing waterlogging). Coupled with the poor road infrastructure, this results in difficulties in accessing input supply and increased cost of inputs. This also affects on-farm activities such as planting, harvesting and post-harvesting because of difficulties in reaching the market. The most vulnerable areas are in Buuri and the areas bordering Isiolo County.

Farmers have shifted from rain-fed to irrigated agriculture to address heat stress and to increase their capacity to produce potatoes continuously throughout the year. This has been made possible by the rivers that traverse the highlands where potatoes are grown providing readily available water for drip irrigation. In addition to this, farmers in areas that experience floods have established on-farm structures such as terraces and furrows to help counter the threats posed by floods.

Banana

Banana production is affected by heat stress which results in small-sized banana fingers caused by lack of moisture, reduced growth rate and drying of the banana leaves. All these lead to reduced productivity and lower prices in the market. Floods also affect banana production as it causes fertiliser leaching.

Most farmers in Meru County irrigate their banana stems due to availability of water and because it is harvested throughout the year. Farmers have increased the use of mulching to reduce soil moisture loss thus ensuring that the crop has sufficient moisture for optimum growth. The farmers have constructed on-farm structures to drain away water during the heavy rains. To reduce postharvest losses, value addition is being done through production of banana wine and flour with a number of groups in the County already producing banana flour. Plans are afoot to establish a banana wine processing factory. Farmers in Meru have formed a banana cooperative society that provides farmers with market information. Modern markets have been set up in banana producing areas such as Kanyakine where buyers from far afield come to buy the bananas immediately after they are harvested.

Dairy cattle

Dairy animals are sensitive to climate-change related risks. In Meru County, dairy farmers are mainly affected by heat stress and flooding. During floods, animals are susceptible to diseases such as foot and mouth disease and infestation of worms. Heat stress also greatly

impacts the quantity and quality of fodder production due to unfavourable dry conditions for fodder growth. The dairy breeds reared in the County are susceptible to high temperatures associated with heat stress, affecting animal health. The high temperatures provide perfect conditions for disease-causing pathogens to thrive and thus increased disease incidences. Heat stress also causes spoilage of milk because if the high temperatures as the milk collection centres are far and wide. The most vulnerable farmers are those that occupy the lowland zones (LM) of Meru County, where temperatures are highest.

Floods affect the quantity and quality of fodder crops due to poor growing conditions. They also damage the road network leading to wastage of milk and loss of livelihoods due to reduced income because of non-delivery of milk to markets or processors.

Farmers are practising commercial feed production such as hay to feed their animals and for sale to other farmers. In addition, farmers are conserving feed by making silage using hay which is stored for later use. The majority of farmers are now joining the Meru Dairy Union (MDU), which collects and buys milk for processing thus reducing the likelihood of milk spoilage and wastage. The MDU provides extension services to the farmers, credit and inputs such as concentrates, supplements and services such as artificial insemination at subsidized rates for farmers to improve their breeds.

Adaptation to climate change and variability

Farmers' ability to cope and adapt to changes in climate is hampered by various climatic, biophysical and institutional factors. Some parts of the County like Buuri, Tigania East and Igembe North are semi-arid and arid with poor temporal and spatial rainfall distribution. These same areas also experience high temperatures leading to heat stress due to the low altitudes. Other parts of the County like Meru South and Meru Central have hilly terrain and are prone to climatic hazards such as landslides which occur after intense rains. Overstocking of livestock is a common underlying factor in Igembe North where farmers exceed the stocking rates per given area causing land degradation. The proximity of the zones (Igembe North) to wildlife areas predisposes the animals to increased incidences of diseases. The soils in some areas like Buuri and Igembe North are black cotton soils which are very hard when dry and very sticky when wet. These soils easily flood during intense rainfall. Poor state of the road infrastructure in the rural areas often lead to impassable roads during the rainy season. Poor market organization results in low prices for the farmer.

The risks posed by climate change have led to the uptake of various strategies to adapt to by farmers in Meru County. The most important on-farm adaptation strategies are listed in Annex 4 and discussed in the remainder of this section.

On-farm adaptation practices

Farmers are predominantly dependent on agriculture as a source of livelihood. However with the attendant challenges that have been occasioned by climate change, farmers have been forced to improve their resilience by adopting adaptation measures. Farmers in Meru County have now started planting short-maturity varieties in an attempt to optimize production during conditions of reduced rainfall. Farmers have also shifted from planting crops like Njahi (Dolicos) which requires significant precipitation to crops such as sorghum, cow peas and green grams which require less precipitation. About 47% of the total households in Meru County have changed crops as an adaptation strategy to climate change with youth-headed households having the highest adoption rate (56%) followed by female-headed households (49%) and being male-headed households (45%) (GoK, 2014). Furthermore, farmers have diversified their feeding habits and crop portfolio by growing other crops that were previously not grown in large areas such as cassava, sweet potatoes, arrow roots and yams. Farmers have also been encouraged to grow high value traditional crops such as sorghum, millet, cowpeas, pigeon peas and green grams to avoid over-reliance on maize as a staple food crop. Most of these crops have a shortened crop cycle and can withstand water stress.

Farmers' reliance on rain-fed agriculture is facing serious challenges brought about by climate change. With the increasing unpredictability and variability of rainfall, farmers are focusing on alternatives such as irrigation to drive their production activities. Meru County has a high untapped potential for irrigation with only about 18% of the available potential utilized.

Roughly 30% of the total households in Meru County have adopted or increased irrigation as an adaptation strategy to climate change with female-headed households having the highest adoption rate (33%) followed by male-headed households 31% and and youth-headed households (22%) (GoK, 2014). There is opening up of irrigation schemes in various parts of the County such as Marega in Tigania East and Kunati. Concerted effort is being put in place by the water and irrigation department for farmers to shift from furrows and sprinklers, which require considerable quantities of water, to drip irrigation which requires less water. Water available for irrigation is not sufficient due to population increase, siltation, low water levels and drying up of the rivers. More boreholes are being sunk with the sole aim of supplementing the available water for irrigation and for domestic use.

In addition to drip irrigation, more farmers are turning to water harvesting from their houses and storing the water in tanks and water pans for future domestic and animal use (GoK, 2014). Giant tanks with a capacity of about 225,000 litres are being built by the County government to store water. The upshot of these irrigation activities is to ensure crop production all year round even when farmers are faced with heat stress.

Greenhouses and hydroponic farming are being adopted by farmers in the County to circumvent the challenges associated with climate change. These technologies are not affected by the vagaries of the weather since production is done in controlled environments and require only limited quantities of water. This seeks to address the unpredictable rainfall patterns that are associated with rain-fed agriculture and contribute to food security.

Farmers have also been practising several technologies to conserve soil and water resources, such as minimum tillage using tools such as ripper, mulching, growing of cover crops to protect the soil, and terracing (in hilly areas). Other farmers are weeding their farms using herbicides rather than manual weeding to prevent soil disturbance. Roughly 56% of the total households are practising integrated soil and water conservation measures (GoK, 2014). These measures are mainly taken during heat stress. Conservation agriculture improves soil fertility, increases infiltration of rainfall, reduces runoff, reduces evaporation of moisture from the soil and interrupt the life cycle of pests and diseases that build up. All these are aimed at reducing the chances of crop failure and higher yields.

On-farm tree planting and establishment of woodlots is another adaptation practice undertaken by farmers in Meru. About 60% of the total households engage in tree planting with 62% of the male-headed households planting trees followed by the youth-headed households (57%) and female-headed households (53%) respectively (GoK, 2014). Agroforestry is highly practised in the County with farmers establishing Community Forest Associations (CFA) where they collaborate with the Kenya Forest Service (KFS) to plant tree on farms and also plant and take care of trees in the nearby forests in the County. Farmers are allowed to establish nature-based enterprises such as beekeeping and plant crops such as tomatoes and spinach in the forest. This is to enable the farmers diversify their income generating activities and cushion them against the adverse weather effects. However some farmers do not want to get involved in tree planting and others are still involved in rampant tree felling.

Improving livestock breeds in the drier zones of the County is one of the adaptation strategies being undertaken to address climate hazards risks. The dual purpose sahiwal bulls are used to upgrade the east African zebu so that they grow faster and bigger within a short period of time and produce more milk. Furthermore new breeds such as the girr cattle have been introduced. This breed serves a dual purpose as it requires less feed and is disease resistant, therefore helping circumvent the scarcity of forage caused by climatic changes. In addition to the cattle, dairy goats have also been introduced to the farmers in the County. This is because they require les feed compared to cattle (e.g. feed for one cattle can feed up to six goats). The farmers in the lower zones are also provided with free vaccines for cattle, bulls and poultry to help them build their resilience.

Commercial fodder growing and feed conservation is being encouraged in the County to address the issue of forage shortage. In Meru, 11% of the total households are practising feed conservation (GoK, 2014). Rhodes grass is being promoted in the lower zones of Meru where maize has become very sensitive and producing poor yields. The Rhodes grass is dried and stored as hay which is fed to livestock. The County government has purchased a bailer, raker and mower, made available to farmers at affordable rates to help them produce more hay. The hay is also used to make silage which can be stored for longer periods and fed

to livestock during times of scarcity. Furthermore, the use of crops residues such as maize stovers is on the rise among dairy farmers to help combat the issue of fodder scarcity.

Value addition is another adaptation strategy being undertaken by farmers in Meru County to mitigate against climate variability for optimum profits. About 27% of the total households are adding value to their commodities. Bananas are being converted to flour and production of banana wine is expected to commence soon. For the dairy sector, milk is processed into products such as yoghurt, fermented milk, and long life milk to increase value and reduce post-harvest and output market losses. It also helps the farmers to earn more of their products since commodities sold in raw form fetch poor prices. In addition, modern markets have been constructed to assist farmers in disposing off their livestock by linking them to traders.

Off-farm adaptation practices

Off-farm services are public and/or private services offered to farmers to enable them to cope with climate risks and adapt to new climate conditions. In this section, a number of services will be discussed and they include; insurances, early warning systems, value addition and collective action.

The National Drought Management Authority (NDMA) generates, consolidates and disseminates information on drought management and climate change adaptation through the Revise Early Warning System (REWAS). The system provides credible early-warning information on drought risks and coordinates action across stakeholders involved in all stages of the drought cycle at both national and County level. The NDMA publishes monthly bulletins communicating current drought status to relevant government departments and other humanitarian agencies. This service helps planning responses across the entire value chain. The Kenya Meteorological Department (KMD) complements the NDMA by providing weather forecasts for the long and short rains and the department of agriculture advises farmers accordingly on the crop varieties to be planted based on the amounts of rains expected.

Additionally, the NDMA carries out a food security assessment on the basis of weather patterns (long and short rains). This aims to determine the population's vulnerability based on agricultural performance across the seasons. The report is then used by government and non-government actors to design interventions that support vulnerable populations.

Farmers in Meru County have formed cooperatives for different value chains to increase their capacity to deal with the challenges associated with agricultural production especially with the risk of climate change. The cooperative movements provide services such as inputs at subsidized rates due to economies of scale. Additionally, they provide credit facilities to the farmers (both cash and in kind), as well as access to markets for their commodities. The cooperatives act as a safety net for their members and have improved the adaptive capacity of the farmers. Collective action enables farmers to acquire inputs such as seeds, fertilisers, chemicals especially when they are affected by hazards and facilitate links with potential buyers and markets.

Insurances to protect crops and livestock against climate risk hazards (floods and droughts) and animal death (due to diseases) or theft are also provided, but to lesser extents. Only 1% of the total households have bought insurance for their agricultural production systems insofar (GoK, 2014).

Adapting agriculture to changes and variabilities in climate: strategies across major value chain commodities

Maize

	Provision of seeds and other inputs	On-Farm production	Harvesting storage and processing	Product marketing
Floods	Inaccessibility to inputs (seeds; fertilizers; chemicals)	Poor stand establishment; increased seedling mortality after planting; reduced growth rates, logging and loss of plant vigour; increased use of pesticides/herbicides	Low quality and quantity of harvested yields; increased changes for grain spoilage during harvesting and storage; Increased aflatoxins incidence; farm to storage transportation challenges of harvested produce	Reduced market activity (few market players) leading to market monopolies; distortion of farm-gate and market prices; loss of market/marketing opportunities
Magnitude of impact	Moderate-Minor	Moderate	Moderate-Severe	Severe-Minor
Farmers' current strategies to cope with the risks	Informal seed acquisition pathways (neighbour and community seed systems); planting of certified seed; outsourcing inputs outside the community and county	Soil conservation and erosion control (terracing/gabions/drainage structures); conservation agriculture; timely planting; agroforestry; use of organic manures; IPM; early warning systems; crops diversification	Dry grain to recommended moisture content for harvesting and storage; use of gunny bags; IPM; awareness creation and testing on aflatoxins; alternative grain transport means from the fields to storage (boda boda)	Community-based road maintenance exercises to facilitate produce access to markets; engagement in farmer associations for group marketing; supply to local institutions and markets
Other potential options to increase farmers' adaptive capacity	Research on moisture-tolerant seed varieties; availability of inputs through county and state mechanisms/programs; access to farm equipment used for drainage and erosion control activities	Promotion of land management and conservation measures; water harvesting techniques; enforcement of existing laws on soil, water and land conservation; IPM strategies; promotion of labour-saving technologies; crop insurance	Continued research on aflatoxins; sensitization of harvest and post-harvest technologies; revive and maintain government grain driers; improved road infrastructure	Development of rural road networks; establishment of grain reserves (by NCPB); government policies to regulate commodity prices; development of market policies
Heat stress	Reduced farmer numbers access to farm inputs by suppliers (seeds; fertilizers); increased costs of agro-chemicals	Increased labour costs; poor stand establishment leading to re-planting; increased weed infestation and new invasive weeds; weak plants with reduced vigour	Poor quality and low quantity of harvested produce; reduced perishability of stored grain (longer shelf life)	Loss of income by producers; external grain sourcing by processors; increased prices due to grain scarcity and diversion to household use
Magnitude of impact	Severe-Minor	Severe-Moderate	Moderate	Severe-Moderate
Farmers' current strategies to cope with the risks	Planting seed supply by aid and government agencies; inputs supply by local agro-dealers	Conservation agriculture; farm mechanization; use of IPM technologies; intercropping; adoption of new methods of weed control; small scale irrigation; application of organic manures; diversification to other crop commodities; timely planting	Testing of grain moisture content; sun drying of harvested grain; shade drying after crop harvest; adoption of hermetic storage bags	Collective grain marketing; access marketing information (media, marketing agencies); market regulations by NCBP; liberalized internal and external markets for grain
Other potential options to increase farmers' adaptive capacity	Research and access to drought-tolerant varieties; preservation of germplasm to maintain biodiversity; government subsidies to farm inputs; decentralization of input supply role by NCPB	Increase acreage of irrigated land; reliable advisories from Early Warning Systems and metrological bodies; use of drought-tolerant varieties; capacity building on plant pest and disease control; use of certified seed; awareness of weed control methods; need to embrace commercial village strategy; subsidy to mechanization	Awareness of quality standards regarding harvesting and storage; promotion of community-based grain aggregation centres; restoration and repair of government and private driers	Enhance grain grading (for market pricing); promotion of contract farming; open NCPB management to producer stakeholders; improved NCBP delivery systems at local levels

Banana

	Provision of seeds and other inputs 	On-Farm production 	Harvesting storage and processing 	Product marketing 
Floods	Shortage and low quality of organic inputs at planting (manure)	Limited field access to perform agronomic activities (land preparation, ploughing, harvesting); pests and diseases incidence; weak stems unable to support fruits	Reduced harvest; increased fruit perishability due to poor road infrastructure and storage facilities	Quality and quantity of produce compromised due to muddy/wet conditions; limited access to markets
Magnitude of impact	Severe-Minor	Moderate	Minor	Moderate
Farmers' current strategies to cope with the risks	Establish water runoff control structures (trenches/furrows); tree planting in nursery fields; acquiring planting material from research and aid organizations	Establish on-farm flood control structures (trenches, pits); integrated pest and diseases management; use of manual labour to perform agronomic activities; establish structures to support mature banana stems; minimum tillage; crop insurance	Community mobilization to improve road access and facilitate transport to storage facilities; Improved storage structures (above ground and moisture free)	Use of wooden platforms to place banana's at marketing; market manipulation by producers through delayed marketing (scarcity/increase demand)
Other potential options to increase farmers' adaptive capacity	Harvesting of rainwater; establish raised nurseries; outsourcing clean planting material from government and development organizations; input access through fertilizer subsidies	Widespread campaign for soil and land conservation structures (support by county and state governments); research and promotion of moisture tolerant banana varieties	Improved transport infrastructure; promote moisture free banana storage facilities	Modern markets with relevant facilities (platforms/loading bays/proper hygiene)
Heat stress	Shortage of water for irrigation; poor quality of planting materials (suckers); Poor nursery vigour and increased seedling mortality	Poor stand establishment; increased seedling mortality after planting; reduced growth rates and plant vigour	Low quality and quantity of harvested yields; increased incidence for fruit spoilage and reduced perishability	Reduced market activity (lack of supply contracts); loss of market/marketing opportunities
Magnitude of impact	Moderate	Minor	Moderate	Major
Farmers' current strategies to cope with the risks	Use of water pans and drip irrigation in nursery tuber preparation	Use of conservation agriculture (minimum tillage), agroforestry and intercropping with trees; application of organic manures and mulches; application of pesticides and insecticides; enterprise diversification; growing cover crops; crop insurance	Dry storage covered with banana stems; application of pest control chemicals; use of traditional banana preservatives (salt) to reduce perishability	Divertion of produce to local consumption (household) and sale (community); postharvest value addition (flour/wine)
Other potential options to increase farmers' adaptive capacity	Construction of mega dams; supply of clean planting materials by research institutions	Adopt improved banana production structures (greenhouses) and irrigation facilities; research on drought resistant varieties	Capacity building on good harvest husbandry practices (hygiene; post-harvest handling and storage)	Capacity building (marketing opportunities); value addition of banana pseudostem (agro-processing into wine, flour, crisps); mineral supplementation to post harvest products; flexible market pricing (quality dependent)

Potato

	Provision of seeds and other inputs	On-farm production	Harvesting storage and processing	Product marketing
Floods	Damaged planting material (rot due to excessive moisture); inaccessibility to inputs by producers	Increased production costs (increased agrochemicals application); poor stand establishment; delayed planting and crop husbandry operations; rotting of planted material; leaching of agrochemicals; soil degradation; high pests and diseases incidence	Low quality and quantity of harvested tubers; rotting of stored product; destruction of storage structures (increasing post-harvest losses); reduced quantity of seedling material available for bulking	Reduced shelf life due to poor harvest and storage conditions; fluctuating market prices; market inaccessibility due to destruction of market structures and limited opportunities
Magnitude of impact	Severe-Minor	Moderate-Minor	Severe-Minor	Major-Minor
Farmers' current strategies to cope with the risks	Early procurement of inputs; construction of improved input stores; bulk purchase for sharing within farmer members; community led efforts to ease transport through roads repair	Early land preparation and planting; drain flood water (excavating furrows); crop rotations, cover crops; grass strips, intercropping; terracing; tree planting; crop insurance; water harvesting (trenches)	Immediate sale (at farm gate price) to avoid storage losses; short period drying under tree shades and storage facilities; use of localized transport to ferry produce to stores	Higher prices due to grain scarcity and high market demand; promotion of local markets (local towns and institutions); value addition (dry and wet processing)
Other potential options to increase farmers' adaptive capacity	Construction of communal tubers storage structures; establish mechanisms for direct input acquisition from manufacturers; ease input access through roads rehabilitation	Adoption of water harvesting and drainage technologies at farm and community levels (terracing and water pans); reclamation and management of degraded lands	Construction of high quality and modern storage facilities at strategic areas within community	New opportunities in value addition and export markets; establishment of village-based aggregation centres (holding facilities) to ease marketing challenges (ease of access by buyers)
Heat stress	Poor quality of planting material	Plant wilting; shortened crop cycle; poor stand establishment and crop vigour; increased incidence of pests and diseases; low quality tubers (discoloration from exposure to sunlight)	Sprouting of harvested and improperly stored tubers; increased incidence of storage pests (rodents)	Low quality and quantity of marketed product (shrinkage); low market prices; poor quality of post-harvest value added products
Magnitude of impact	Major	Severe-Minor	Major	Moderate
Farmers' current strategies to cope with the risks	Storage of tubers with dry matter; storage of potato suckers in open and dry shed; proper tuber sorting and storage according to state	Use of efficient irrigation techniques (small scale drip irrigation); mulching; cover crops; intercropping with maize; tree planting; conservation agriculture; use of organic manures; use of chemicals to prevent early sprouting; early planting; crop insurance	Harvest and sale at farm gate after observations of tuber sprouting; pest and rodent control using baits and traps	Cover market product with dry matter to prevent tuber drying; sorting and grading of product for different markets; join together with local associations for best tuber price bargains
Other potential options to increase farmers' adaptive capacity	Increased access to improved tuber varieties; establishment of community-based large scale potato bulking; research on heat tolerant potato varieties	Widespread use of drip irrigation; explore opportunities of intensive intercropping with newly emerging crops; government support to communal potato propagation efforts	Improved storage facilities (pests and rodent free); rely on Early Warning Systems and advisories on best harvest periods	Farmer associations to market produce locally and externally; explore post-harvest value added products

Dairy (cow)

	Provision of inputs	On-Farm production	Harvesting storage and processing	Product marketing
Floods	Increased drugs demand due to anticipation of increased diseases and pests incidence (mastitis); lack of access to drugs, feeds and inputs due to transport challenges	Increased pests and diseases incidence; reduced animal vigour; increased drugs usage; reduced cattle weight; reduced efficiency of administered drugs due to infections	Compromised milk quality (watery milk); low profitability due to increased transport and handling cost; increased perishability due to poor/damaged infrastructure	Late supply to markets by farmers and high distribution costs by processors due to transport challenges; reduced market activity and reduced marketing opportunities
Magnitude of impact	Major-Minor	Major	Moderate-Minor	Minor
Farmers' current strategies to cope with the risks	Seek input suppliers (within and beyond counties); use of efficient transport means (boda boda) to access inputs; feed conservation; access to free vaccines	Supplementing feeds with mineral concentrates; proper animal husbandry (keeping animals in dry sheds) drug administering and application of insect repellents; enterprise diversification (crop growing)	Rejection of unhygienic milk; sharing of transport costs by farmers and processors; use of clean equipment to handle and store milk; capacity building programs on milk production	Divertion of milk to local consumption (household) and sale (community); engagement with milk buying companies/organization; supply to local towns and institutions
Other potential options to increase farmers' adaptive capacity	Improved road network to facilitate inputs access; promote improved cattle breeds (GIRR); promote commercial fodder growing and feed conservation technologies	Development and implementation of flood management and control policies; provision of subsidized drugs to farmers	Centralized milk storage at community and regional level; establish refrigeration structures at sub-county level; capacity building on value addition products (yogurt, ghee); intensify extension services (milk production, veterinary services); improved infrastructure (ease road transport)	Improved road infrastructure to facilitate market access; use of refrigerated vehicles; forming robust farmer organizations for milk marketing; government control of milk marketing to prevent farmer exploitation
High Temperatures	High costs of inputs (drugs; pastures) due to increased refrigeration and storage requirements; inaccessibility to high quality breeding seed	Reduced animal vigour and high pests and diseases susceptibility; increased animal mortality; increased production costs (Increased drugs usage; low fodder availability)	Increased perishability; increased costs due to high demand for cooling and refrigeration equipment	High market prices due to low production and milk scarcity by farmers; low profitability due to increased milk spoilage by processors
Magnitude of impact	Major-Minor	Major-Moderate	Moderate-Minor	Major-Minor
Farmers' current strategies to cope with the risks	Provision of subsidized drugs to farmers (aid organization); use of local animal breeding stocks; seek alternative medicinal sources (indigenous knowledge); feed supplements (hire balers, rakers); use of crop residues as feeds	Introduction of disease resistant animal breeds; disease control; fodder and pasture preservation and conservation (silage/hay)	Milk delivery to cooling centres; use of electricity to manage cooling process	Production on long and short life products (processed/dried); use of market pricing regimes based on demand and supply
Other potential options to increase farmers' adaptive capacity	Scale out availability of subsidized drugs to farmers (through county and aid agencies); commercial fodder growing and feed conservation	Provision of subsidized drugs and vaccines; development of early warning systems and advisories; enhanced extension and veterinary services to famers; sensitization of fodder preservation and conservation technologies	Construction of centralized storage and refrigeration centres (community based); small scale (on-farm) refrigeration facilities; use of solar energy to manage dairy production activities	Extended shelf life of dairy products through modern value addition technologies; establish more preservation facilities to cater for milk supply in dry periods; introduce market price standards

Policies and Programmes

Several national and local policies and programs have been developed to address climatic and broader vulnerabilities in the County of Meru. These are discussed in the section below.

The Kenyan government initiated the National Environment Action Plan (NEAP), in response to the need of a national policy and law that links development with the environment. The objective of this policy is to provide a framework for an integrated approach to planning and sustainable management of Kenya's environment and natural resources. The policy therefore provides a legal and institutional framework for good governance, effective coordination and management of environmental and natural resources. This policy is linked to the production activities of all the prioritized value chains. Farmers in the country who are small-scale in nature are supposed to increase in productivity in a sustainable manner without causing adverse effects to the environment.

Increase in population continues to exert pressure on forest resources through growing demand on forest products, services and land for alternative uses. The country has experienced a major decrease in forest cover over the past years. The Kenya Forest Service Act (also known as the Forest policy) ensures that measures are put in place to significantly increase the area under forest cover with the aim of attaining the target of 10% of the land area of the country. To attain this objective, the government is promoting farm forestry, intensifying dryland forestry management and also promoting community participation in forest management and conservation. The policy stresses the need for greater cooperation and linkage among resource owners, users and resource planners. It is to this end that the KFS has established CFAs to help in the management of forests by preventing logging and poaching. For instance, in Meru County the CFAs have been allowed to establish nature-based enterprises in the forest including setting up of beehives for honey production.

Another program being championed is the Plantation Establishment and Livelihood Improvement Scheme (PERIS), a strategy for afforestation whereby portions of the forest are given to farmers to plant crops as they take care of the growing trees for a given period of time. This helps to address food security and improve forest cover.

The Green Schools Programme, which encourages tree growing in schools, is another strategy being employed to increase the tree cover. Households and institutions are also being encouraged to use energy saving jikos to reduce the amount of firewood used and thus help reduce deforestation. The tree seedlings are bought with funds from the Upper Tana Natural Resource Management project. The initiative benefits households and communities that surround the forests.

The Water Act (also known as the Water policy) takes cognisance of the contribution of water resources development to economic productivity and improvement of livelihoods. It therefore seeks to enhance availability of water and reduce conflicts over the use of water resources. The objective is to promote optimal, sustainable and equitable development and use of water resources for livelihoods of Kenyans. One of the ways to ensure this objective is achieved is by progressive restoration and protection of ecological systems and biodiversity in strategic water catchments. This is done throigh forests and biodiversity restoration and reforestation. To achieve optimal use of water, professionally designed systems are being promoted such as calibrated sprinklers and drip irrigation kits. Furthermore, water harvesting is being encouraged through roof water harvesting, river dams, water storage, and construction of on-farm water pans to store water for future use and protect water springs. These are intended to reduce conflicts over the use of water.

The Irrigation policy recognizes the fact that Kenya has not fully developed its irrigation potential. By the end of 2013, about 12% of the irrigation potential had been realized leaving more than 80% undeveloped (GoK, 2015). It is through this realization that Meru County, through the Upper Tana Natural Resources Management Project, has been spearheading irrigation activities to increase the area under irrigation and increase production of irrigated agriculture. The County Irrigation Department is advocating the use of professional equipment for drip irrigation and water-saving sprinklers. This intends to benefit the small-scale farmers who are the majority and play a significant role in agricultural production in the County.

Governance, institutional resources, and capacity

Climate risk management and adaptation strategies are implemented mainly through collaborations between various stakeholders in governmental, non-governmental and faith-based organizations. The government departments include the line ministries such as; Agriculture, Livestock and Fisheries department, ASDSP, the KMD, the KFS, and government parastatals such as the National Environmental Management Authority (NEMA). The non-government actors include NGOs such World Vision, The International Small Group & Tree Planting Programme (TIST), Kenya Red Cross Society (KRSC), World Food Programme (WFP) and the Food and Agricultural Organization of the United Nations (FAO). The faith-based organizations include the Catholic Church under the

banner of CARITAS and the Anglican Church. Government departments mainly provide technical support and policy direction while the non-state actors provide research, funding and implementation for the adaptation strategies. The collaboration is largely through a stakeholder's forum which is responsible for planning climate risk management.

In Meru County, ASDSP is a lead player in climate risk management by convening a stakeholders meeting through participatory scenario planning methods, where, together with the KMD, briefings on weather forecast and early warning systems are provided. The forum consists of government departments such as agriculture, livestock, fisheries, water, irrigation, health and education, faith-based CARITAS, a host of NGOs such as World Vision, TIST and FAO among others. The assessment is done for both the long and short rains, as well as for any other emergency.

The stakeholders' meeting assesses the situation based on the early-warning system provided by the meteorology department and ASDSP proposes intended solutions and tasks for stakeholder based on their capacity and financial resources. For instance FAO targets to train about 10,000 farmers on conservation agriculture technologies in two years with about 2,000 farmers actively practicing the technologies. The NGOs and faith-based organizations have a high influence in the implementation process due to their financial capacity and a wide reach and influence at the grassroots level with farmers.

There are host of factors that challenge the delivery of the various types of support to manage climate risks to agriculture in the County. Low or no technical, financial, human resources capacity are the most common institutional hindrances. Most County governmental departments (such as the KMD, KFS, NDMA) are insufficiently staffed, hindering the implementation and monitoring of the activities (such as early warning-systems information, extension services, efficient irrigation, conservation agriculture technologies, prevention and management of disease outbreaks, soil and water conservation technologies).

Moreover, in the absence of County-specific legislation on enforcing national climate change policies, the existing institutions act in isolation to each other, with no mechanism to coordinate interventions and deliver support. In order to avoid duplication and improve efficiency in implementation, the different actors involved in climate risk management need to improve information sharing systems and their mechanism to monitor and evaluate interventions to improve implementation efficiency and ensure impact.

Institutions that offer extension services, on the other hand, lack preparation on emergency risk response. There is a need for the key stakeholders involved in climate risk management to be trained in-depth on the topic in order to enhance their skills in the selection of appropriate adaptation strategies.

Synthesis and Outlook

Agriculture is the economic mainstay of the County in terms of food production and income generation. The sector is characterized by high productivity of food crops, high value crops and livestock. However the sustainable growth of the sector is challenged by high input costs, soil erosion, declining soil productivity, reducing agricultural land, environmental degradation and poor marketing systems. This is compounded by the negative impacts of climate change and variation that have led to increased incidences of floods, extreme temperatures, reduced water levels in rivers and drying up of water reservoirs, emergence of new pests and diseases and landslides. This has led to reduced agricultural productivity with the upshot being an increase in rural-urban migration in search of off-farm opportunities thus straining the available urban resources.

Investments in irrigation offer opportunity to address water shortages and tap into the County's irrigation potential. Even though the County has an impressive forest and tree cover, concerted efforts should be made to support and scale-out agroforestry and afforestation initiatives. To reduce declining soil fertility caused by soil erosion, soil and water conservation measures should also be up-scaled. Training on value addition should be enhanced for farmers to get better returns from their produce. Farmers should invest in reducing postharvest losses that result from flooding since the area has previously been prone to incidences of aflatoxin. Alternative crops have been introduced to diversify the crops grown and this should be encouraged to avoid relying on specific crop which might be vulnerable to climate change and variability.

With the increasing incidence of climate hazards, institutional capacity to respond to changes and needs to be enhanced. Adequate budget provisions to enable carrying out climate risk management activities need to be accompanied by policies and interventions anchored in development plans, to provide an enabling framework for various stakeholders in climate risk management to engage, coordinate and work together towards strategies that help farmers cope with climate change and variability. Additionally, concerted efforts in sharing information among the various stakeholders regarding the planning and implementation of climate risk management strategies are needed to improve efficiency and effectiveness of interventions

For further information and access to the annexes, visit https://cgspace.cgiar.org/handle/10568/80452

Annex 1: Crop and livestock productivity in Meru County
Annex 2: Acreage and production of the main crops
Annex 3: Climate analysis
Annex 4: Adaptation strategies

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