Climate Risk Profile Machakos County

Highlights

- Agriculture is the major source of livelihood in Machakos County, employing about 73 percent of the population and contributing approximately 70 percent to the household incomes.
- The commercially popular value chains in crop production include green grams, pigeon peas and mango while indigenous chicken is the most common livestock in the county with a great potential to alleviate poverty in small holder farms.
- Climate change limits the development of the agriculture sector. Moisture stress, variation in temperature, and intense rain are the most problematic hazards in the county. An interplay of climate vagaries and soil degradation due to poor agricultural practices has resulted in the characteristic low productivity in the county.
- The major problem posed by climate variation is water scarcity. The resource-poor farmers, women, and the elderly are the most affected.
- Adaptation options currently adopted in the county for crop farmers include water harvesting; dry planting; intercropping; use of drought-tolerant varieties; irrigation; value addition and use of indigenous knowledge in post-harvest handling and disease control; conservation agriculture; and collective action in selling. For the local chicken, the adaptation strategies include value addition; use of indigenous knowledge for disease control; and outsourcing for breeding stock. Though remarkable success has been achieved with the adaptation strategies, adoption rates are still low, and most of the underlying vulnerabilities have not been addressed yet.
- Inadequate finances, culture, and efficient markets are the major impediments to adoption of new agricultural technology.
- The major off-farm services offered by different institutions to enhance adaptive capacity include extension, climate and market information, and credit services. Access to these services is still low due to lack of awareness, poor infrastructure, negative attitude especially towards credit facilities and lack of market incentives.
- The major climate change actors in the county include different government agencies, non-governmental organisations, and private institutions. Most of the organisations face financial and human capacity challenges in offering the necessary services for enhancing resilience. There is also a weak link among the different organisations hence poor coordination and duplication of effort.
- The county is yet to benefit from redress of the salient policy gaps for climate change. Like most of the counties in Kenya, Machakos County lacks a climate change policy and still relies on some national policies. The enforcement and link in the already existing policies and legislations is also weak. A conducive environment for undertaking climate related interventions is yet to be created. Alignment of the institutional setup to favor interventions with long-term impacts that are holistic and not only focused on one entry point is pertinent for enhancing resilience in the county.

KCSAP
Kenya Climate Smart Agriculture Project
Republic of Kenya
WORLD BANK GROUP

List of acronyms

ACT	Africa Conservation Tillage
AEZ	Agro-Ecological Zone
AI	Artificial insemination
AGMARK	Agricultural Market Development Trust
AGRA	Alliance for a Green Revolution in Africa
ASAL	Arid and Semi-Arid Lands
ASCU	Agriculture Sector Coordination Unit
ASDSP	Agriculture Sector Development Support Programme
CIAT	International Center for Tropical Agriculture
CIC	Cooperative Insurance Company
CIDP	County Integrated Development Plan
CIMMYT	International Maize and Wheat Improvement Center
DSL	Dryland Seed Limited
ERA	Economic Review of Agriculture
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FGD	Focused Group Discussion
FIPS	Farm Input Promotions
GoK	Government of Kenya
HDI	Human Development Index
ICRAF	World Agroforestry Center
ICRISAT	International Crops Research Institute for Semi-Arid Tropics
IFAD	International Fund for Agriculture Development
KALRO	Kenya Agricultural and Livestock Research Organization
KAVES	Kenya Agriculture Value Chain Enterprise
KCEP-CRAL	Kenya Cereal Enhancement Programme – Climate Resilient Agriculture Livelihoods Programme
KES	Kenyan Shillings
KEPHIS	Kenya Plant Health Inspectorate Service
KFS	Kenya Forestry Service
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KMC	Kenya Meat Commission
KMD	Kenya Meteorological Department
KNBS	Kenya National Bureau of Statistics
KWFT	Kenya Women Finance Trust
LM	Lower Midland
NCCRS	National Climate Change Response Strategy
NDMA	National Drought Management Authority
NGO	Non-Governmental Organization
PCPB	Pest Control Products Board
PSP	Participatory Scenario Planning
RCP	Representative Concentration Pathway
UM	Upper Midland
UNDP	United Nation Development Programme
USAID	United States Agency for International Development
VBA	Village Based Advisor
VCC	Value Chain Commodity
WFP	World Food Programme

Foreword

Climate change is becoming one of the most serious challenges to Kenya's achievement of its development goals as described under Vision 2030. Kenya is already highly susceptible to climate-related hazards, and in many areas, extreme events and variability of weather are now the norm; rainfall is irregular and unpredictable; while droughts have become more frequent during the long rainy season and severe floods during the short rains. The arid and semi-arid areas are particularly hard hit by these climate hazards, thereby putting the lives and livelihoods of millions of households at risk.
In 2010, Kenya developed a National Climate Change Response Strategy (NCCRS), which recognized the importance of climate change impacts on the country's development. This was followed by the National Climate Change Action Plan (NCCAP) in 2012, which provided a means for implementation of the NCCRS, highlighting a number of agricultural adaptation priorities. The focus of these initiatives has been at the national level, there is need to mainstream climate change into county level policies, programmes, and development plans; therefore ensuring locally relevant, integrated adaptation responses with active involvement of local stakeholders.

The Government of Kenya (GoK) through the Ministry of Agriculture, Livestock and Fisheries (MALF), with funding by the International Development Agency (IDA-World Bank Group) is therefore implementing the Kenya Climate-Smart Agriculture Project (KCSAP). This projects objective is to increase agricultural productivity and build resilience to climate change risks in targeted smallholder farming and pastoral communities in Kenya, and in the event of an eligible crisis or emergency, to provide immediate and effective response. This Climate Risk Profile has been conducted within the framework of KCSAP and aims to inform county governments and stakeholders on the climate change risks and opportunities for agriculture so they are able to integrate these perspectives into county development.

This document presents the Climate Risk Profile for Machakos County, one of the ASAL counties where both extremes of drought and intense rains have greatly contributed to poverty, food insecurity, and reliance on food relief since the 1920s[1]. Assessment of rains in the county beginning 1920s shows that dry spells have been occurring in runs after every 3-4 years. Though there has been no significant change in the time interval between consecutive droughts, the drought spells have become more prolonged in the recent past. This has resulted in frequent crop failures over the years, aggravating the already dire need for food aid. In 2011, 1,876 families received relief food in Yatta following drought in that year[2]; whereas in 2015, more than 50,000 people faced hunger[3] also due to drought. Due to the adverse effects on the agriculture sector, people have opted for some deleterious coping strategies such as sand harvesting, which lessen the resilience capacity. The frequency and magnitude of these extreme weather events are likely to increase, necessitating measures that can sustainably cushion the farmers and pastoralists from the climate disasters.

The profile is organised into six sections, each reflecting an essential analytical step in understanding current and potential adaptation options in key local agricultural value chain commodities. The document first offers an overview of the county's main agricultural commodities key for food security and livelihoods as well as major challenges to agricultural sector development in the county. This is followed by identification of the main climatic hazards based on the analysis of historical climate data and climate projections including scientific assessment of climate indicators for dry spells, flooding and heat stress among other key climate hazards for agriculture. The document continues with an analysis of vulnerabilities and risks posed by the hazards on 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 enabling policy, institutional and governance context for adoption of resilience-building strategies. Finally, pathways for strengthening institutional capacity to address climate risks are presented.

1 Source: Tiffen et al. (1994)
2 Source: http://allafrica.com/stories/201108100094.html
3 Source: http://www.hivisasa.com/posts/55482

Agricultural context

Economic relevance of farming

Machakos County covers an area of 6,208 km^2 and is located in the former Eastern Province. The county borders Makueni County to the south, Embu County to the north, Kiambu and Nairobi Counties to the west, Kitui County to the East, Kajiado to the south-west, and Kirinyaga and Murang'a
Counties to the northwest. The terrain in most of the areas in the county is relatively hilly; some of the physical features include the Yatta Plateau and the Athi River, which is one of the major water sources in the county. The county is largely arid and semi-arid, receiving a mean annual rainfall of about 500 mm with variations depending on the altitude[4]. Temperatures range from 18 to 29 °C (Machakos County, 2015).

The county is categorized into five agro-ecological zones (AEZs) based on the potential crop production suitability (Jaetzold et al., 2010; KNBS, 2015):

- UM 2-3: mostly suitable for maize, beans, dairy and coffee. The AEZ falls in Machakos, Kangundo, Kathiani and Matungulu.
- UM 5-6: suitable for ranching; it is found in Mavoko and Matungulu.
- LM3: Suitable for mangoes, maize, pigeon pea, cow peas, and indigenous poultry and is found in Kangundo, Kathiani, Mwala, Yatta, Matungulu, and Masinga.
- LM4: suitable for production of maize, beans, mangoes, cow peas, indigenous chicken, and pigeon peas. Matungulu, Kangundo, Kathiani, Machakos, Mwala, Yatta and Masinga fall under this AEZ.
- LM5: is suitable for dairy, beans, maize, pigeon peas, cow peas, mangoes, and indigenous chicken and is found in Matungulu, Mwala, Masinga, and Yatta.

Despite the climatic and environmental challenges witnessed in the county, agriculture is integral in the economy, contributing approximately 70 percent to the household incomes (Machakos County, 2015), and employing approximately 73 percent of the population (Gichangi *et al.*, 2015).

In 2014, production of major crops was valued at KES 13,742.46 million whereas slaughter and sale of major livestock and livestock products was valued at KES 7, 834.1 million[5]. Pigeon pea, sweet potatoes and maize had the highest contribution of about 21 percent 19 percent and 15 percent respectively of the total crop value. For the value from slaughtered livestock and livestock products, beef and milk had the highest contribution of approximately 49 percent and 34 percent respectively. There is an almost equal distribution of adult males, females and the youth headed households (YHH)* in participation in crop and livestock activities.

People and livelihoods

According to the KNBS (2014a), Machakos County had approximately 1,167,480 people in 2014, based on the projections from the 2009 census[6]. The growth rate was about 2 percent, which is relatively lower than the national growth rate of 2.9 percent. The lower- than-national growth rate is attributed to the high utilisation of contraceptives in the county (76 percent) and the relatively low fertility rate of about 3.4 (GoK, 2014b). The ratio of male to female populations is almost one to one, with an almost equal distribution of the population in the rural and urban areas. The absolute poverty level in the county is high (60.7 percent) compared to the national level of about 47 percent[7]. Sixty percent of the poor people are found in rural areas; forty percent are found in urban areas. (Machakos County, 2015). The harsh climatic conditions that adversely impact agriculture production, and lack of alternative income sources are some of the reasons contributing to the high poverty level in the county. For the same reasons, the county is characterised by a high food poverty incidence of about 54 percent (Ibid). This contributes to the high incidence of malnutrition where approximately 27 and 7 percent of children below 5 years are stunted and wasted respectively, and to reliance on food aid. The landless, the aged, and the physically challenged are the most vulnerable. The poor segment who rely on seasonal casual wage labour activities are also predisposed to shocks such as diseases, limiting their productivity and participation in economically useful activities.

4 Some areas in the highlands such as Kangundo and Iveti among others receive an annual rainfall of about 1000 mm. The annual amount of rainfall received in the county according to the CIDP is between 500 and 1300 mm.

5 The difference is not a reflection of importance of the two subsectors in terms of value, since the available data (KNBS, 2015) consisted of 18 crops whereas the livestock data only consisted of 6 livestock types.

6 This figure is slightly different from the one given in the Machakos County (2015) as the latter gives projections for 2012 as 1,238,650.

7 The absolute poverty level figure is slightly higher than the 56 percent given in the KNBS (2015)

* YHH - refers to any female or male aged between 18-35 years who is the main decision maker in the household..

Despite the high poverty level, the Human Development Index (HDI) in the county is high (0.541), higher than the national HDI of 0.52 (GoK; UNDP, 2013). This is mostly because Machakos County is relatively well-off in terms of the components used in the construction of the HDI. For instance, the percentage of the population that can read and write stands at 82; unemployment level of persons aged 15-64 years is below the national level (KIPPRA, 2013). The number of literate people is higher among the males (92 percent) compared to the females (82 percent) (KIPPRA, 2013). Access to improved and non-improved water sources is 20 percent - relatively low for an urban area (Ibid). Firewood is the commonest source of energy for cooking used by about 68 percent of the households in the county whereas barely 1 percent of the households use other sources such as solar energy and electricity (Machakos County, 2015). Although the county averages may show a relatively high access to amenities, there is a huge inequality in the sub- counties in terms of the quality of life and access to amenities such as schools and hospitals (KNBS, 2013).

Livestock and crop production play a major role in income generation, creation of employment, and provision of raw materials. Other than agriculture, other important income sources in the county include mining (the county is famous for cement factories such as Bamburi); tourism though the sector is yet to be well established; wood carving; and industry. Some of the industries in the county include the Kenya Meat Commission (KMC) and the Mabati Rolling Mills (MRM).

Agricultural activities

Approximately 60 percent of the total land area in the county is arable. Only about 67 percent of the total arable area has been utilised, out of which food crops occupy approximately 161, 695 ha and cash crops occupy only 86,638 ha (Machakos County, 2015). Production is mostly small scale mainly for subsistence and is dominated by root crops, cereals, and grain legumes. However, crop data show that maize and beans occupied almost 83 and 46 percent in 2013 and 86 and 40 percent in 2014 respectively[8]. The average farm sizes for small- and large-scale production in the county are 0.756 and 10 ha respectively (Ibid). This is a huge decline in the farm sizes, considering that small-scale farms were on average 8.4 ha in the 1940s and 1.3 ha in 1997 (GoK, 2003). Some of the major drivers of the land fragmentation is population increase and culture, where sons have to inherit land from their fathers, and sale of land in the recent past. The land tenure system in the county is both freehold and trust land. However, not many of the freehold land has been issued with title deeds. Therefore, only 28.5 percent of the farmers have title deeds (Machakos County, 2015); more male-headed households have title deeds compared to the female- and the youth-headed households (GoK, 2014). This is mostly attributed to the patriarchal culture in the county.

The major food crops grown in the county include maize, beans, cow peas, pigeon peas, and cassava, which are grown in almost the entire county where farming is possible. The main cash crops are coffee, sorghum, mangoes, French beans, and pineapples; they are mostly grown in Kathiani, Mwala, Kangundo, and Yatta. On the other hand, the common types of livestock in the county include chicken (mostly local chicken), cattle (for beef and dairy), shoats and a few donkeys and pigs. Statistics by the KNBS (2015) show that in 2014 there were approximately 245,440 cattle, most of which were for beef; 330, 300 goats, most of them for meat; and 1,688,620 chicken, with the indigenous chicken numbering 1,306,000. Fishing is also an important agricultural activity in the county. Large-scale fish production is mostly in Masinga Dam; small-scale production is mainly along major rivers such as Athi River. The major types of fish captured include Tilapia and mud fish. Through support from the Economic Stimulus Program and the County government, 200 new ponds have been constructed in each constituency as one of the ways of promoting the enterprise in the county. Nevertheless, challenges such as lack of markets and predators are yet to be fully addressed.

Use of agricultural inputs such as improved seeds, storage pesticides and fertilisers is very low in the county. According to the Agriculture Sector Development Support Programme (ASDSP), only about 40 and 50 percent of farmers growing maize, green grams, pigeon pea and beans used improved seeds in the first and second growing seasons respectively in 2014. Only 43, 37, and 32 percent use storage pesticides, basal fertiliser and top dressing (GoK, 2014). Some of the major constraints to the use of these inputs include high prices and lack of a purchasing power due to high levels of poverty. In addition, inappropriate application of the inputs has resulted in deleterious effects in some cases. For instance, blanket application of fertiliser has resulted in soil degradation, leading to either high acidity or salinity. Moreover, only 1 percent of farmers in Machakos County irrigate their crops. According to the National Irrigation Board (NIB), only 1217 ha of land are under production with another 20 ha earmarked for production[9]. The low utilisation

8 These figures were calculated from the data provided in KNBS (2015).

9 Source: https://www.nib.or.ke/projects/irrigation-projects-per-county?id=160

Livelihoods and agriculture in Machakos

Demographics

3% Of Kenya´s population

1,166,517 inhabitants

49% Live in rural areas

51% 49%

Access to basic needs

61% of the population lives in **absolute poverty**

Potable water	1%
Electricity for cooking	0.5%
Electricity for lighting	17%
Education (youth literacy rate)	ND

Food security

54% of the population suffers from **food poverty**

ND of household **income spent on food**

ND People **undernourished**

27% 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 372.020ha 59%

ND of the population employed in agriculture production

29% of farmers have title deeds

ND are women

Farming activities

Food crops ND

Cash crops ND

Of county´s agricultural land

Livestock

2 Group ranches

1 Company ranches

Farming inputs

Water uses

ND ND ND

Fertilizer types (% of households)

NPK

72% Organic manure

37% Planting fertiliser

32% Top dress fertiliser

Pesticide types (% of households)

9% Field pesticides

43% Storage Pesticides

0.3% Herbicide

of irrigation in the county is mainly due to lack of appropriate infrastructure and water scarcity.

Agricultural value chain commodities

A broad diversity of agricultural commodities is grown in the county. Of these commodities, various value chains have been prioritised as being strategic for the county as indicated in the County Integrated Development Plan (CIDP) and the ASDSP as well as by government institutions such as the Kenya Agricultural and Livestock Research Organization (KALRO). For the development of this County Climate Risk Profile, four major value chain commodities (VCCs) were selected for in-depth analysis based on: prioritisation in county frameworks and programmes; economic value (KES/bag or KES/livestock or KES/unit livestock product)[10]; resilience to current weather variability and future climate change[11]; and number of economically active people engaged in the commodity's value chain (including vulnerable groups, women, youth, and the poor[12]). The VCCs selected were local poultry, mango, green grams, and Pigeon peas.

Mango

Mango is an important crop in Machakos County for both nutrition and income generation. Approximately 40-60 percent of the population in the county is engaged in the value chain. Mangoes are produced throughout the county with a high concentration in Mwala and Kangundo sub-Counties, a medium concentration in Machakos, and a sparse concentration in Yatta sub-County. Production under small scale, medium scale, and large scale involves approximately 25-200 trees, 201-1000, and over 1000 trees respectively. Most of the producers are under medium scale.

The common varieties grown in Machakos County are Apple, small-fruited local varieties, Sabre, Peach, Tommy Atkins, Kent, Ngowe, and Van Dyke. Apple, Eden, Tommy Atkins, Ngowe, Van Dyke, Sensation, and Kent varieties are preferred by farmers because they yield more and fetch higher prices in the market compared to the traditional varieties that grow into a big tree but have low yields. The main harvest season is December to March. Mango production has been on the increase due to increased demand for fresh market fruits, processing, and health concerns. The acreage under mango increased by 356% in the period 2009 and 2012 (USAID, 2015). In 2014, the area under mangoes was 5,593 ha, with a production of 67,320 MT, valued at KES 835,580,274 (ERA, 2015). This steady increase can be attributed to expansion of area under mango production in the county, interventions in the marketing systems with various government and private sector initiatives across the value chain, and increased consumption of mango juice and salads. The leading sub-county in mango production by value is Mwala.

The value chain is dominated by men, with women and youth participating only in the production and retailing nodes of the chain. The common marketing outlets are mostly local markets, which include open air markets such as trading centres, kiosks, and roadside stalls. Due to challenges in transporting the mangoes from the farms to the markets or collection points, farmers have embraced collective marketing at established collection centres where the mangoes are purchased by marketing agents / brokers. However, only about 5 percent of the farmers use this approach. When supplies are not enough, the agents are forced to move from one individual farmer to another to meet the supply. This increases the agents' operational costs, eventually affecting both the buying and selling prices. The agents sell the mangoes to wholesale markets in urban areas, for example Wakulima Market in Nairobi, although some of them sell directly to retailers including supermarkets, hotels, institutions like prisons, hospitals, schools, and kiosks. Most of the institutions purchase the mangoes on credit for a period of about one to three months, forcing the agent to pre-finance the business. The agents operate in a climate of uncertainty and encounter all sorts of risks. They search for the mangoes, visit sellers, and negotiate deals individually. They have little working capital, relying mainly on their own funds. Poor transport infrastructure means long, arduous trips that can jeopardise the quality of the mangoes and can translate into heavy losses for the trader. At times they do not sell the mangoes on delivery at the wholesale markets and are thus forced to incur additional costs and further losses (source: discussions with four agents during key informant interviews).

The farmers have no access to cold storage facilities, so the fruits are sold in the open and get destroyed by the sun. The poor infrastructure in both markets and road network as well as poor handling and/or transportation systems, that is, in open pickups and lorries and sometimes in gunny bags, leads to

10 As stated in the 2015 Economic Review of Agriculture (ERA)

11 Resilience is as defined in IPCC (2012); where we consider the general risks posed by climate change in the county. Value chains that are perceived to survive the local conditions under the current production systems holding other things constant (including variations in technology adoption rates among farmers/pastoralists) are considered more resilient.

12 Categorisation of "poor" people was based on the perceptions of workshop participants and not on any standard index normally used to measure poverty.

spoilage. Seasonal gluts also affect pricing in addition to taxes in form of cess (a levy of KES 50 is imposed at local and roadside markets by local authorities). Some farmers sell up to ten fruits for KES 5 only and hence make little or no profit.

Green Gram

Green gram in Machakos is grown for both food and income and is preferred due to its tolerance to the harsh climate in the county. Approximately 41-60 percent of the population are engaged in the value chain, with women playing a greater role in the production compared to both adult male and youth. Production is mostly small scale, on farm sizes of approximately 0.2 ha. However, there are pockets of large-scale production in Mwala, Masinga, Yatta, and lower zones of Machakos sub-County where the farms can be as big as 810 ha. The crop is normally planted in November and December and produced under relay cropping with mostly cereals such as maize. The common varieties in the county are N26, commonly known as Nylon, N22, and KS20 also conventionally known as Uncle. N22 is popular for tolerance to both pests such as aphids and diseases such as yellow mosaic and powdery mildew. Uncle is popular for its bigger size and higher yields relative to the other two whereas Nylon is preferred for maturing early, as it takes only about 60-65 days.

Some of the actors in the value chain include service providers such as the Kenya Meteorological Department (KMD) who forecast weather and disseminate the information to guide on planting periods. KMD also takes part in participatory scenario planning which also helps in dissemination of the weather information. Input suppliers are mostly small- and large-scale agro vets, and companies such as the Dryland Seed Company and research institutes such as the Kenya Agricultural and Livestock Research Organization (KALRO). Utilisation of family labour is common at farm level. Key activities at this level include selection of seed varieties and sourcing for the seeds, land preparation, planting, and weeding. Family labour is also used in crop protection to ensure good crop quality at farm level, as well as in harvesting and storage. Green grams are sold as dry whole grains, without any processing.

Pigeon Pea

Pigeon pea is a drought-tolerant crop that can give yields even after a severe drought. This legume crop is grown by almost all the farming households for subsistence where about two thirds of the small holder farmers sell at least a portion of their produce. It is grown as an intercrop with crops such as grains and other legumes including beans, green gram, and cowpeas. Production is mostly at small-scale level with farm sizes ranging from 0.2 to 1.4 ha. The common varieties are the Mbaazi 1 (ICPL87091), KAT 60/8 and Mbaazi 2 (ICEAP 00040). The first two varieties are susceptible to attacks by insect pests such as pod sucking bugs and pod borers, while KAT 60/8 is tolerant to wilt and leaf spot diseases.

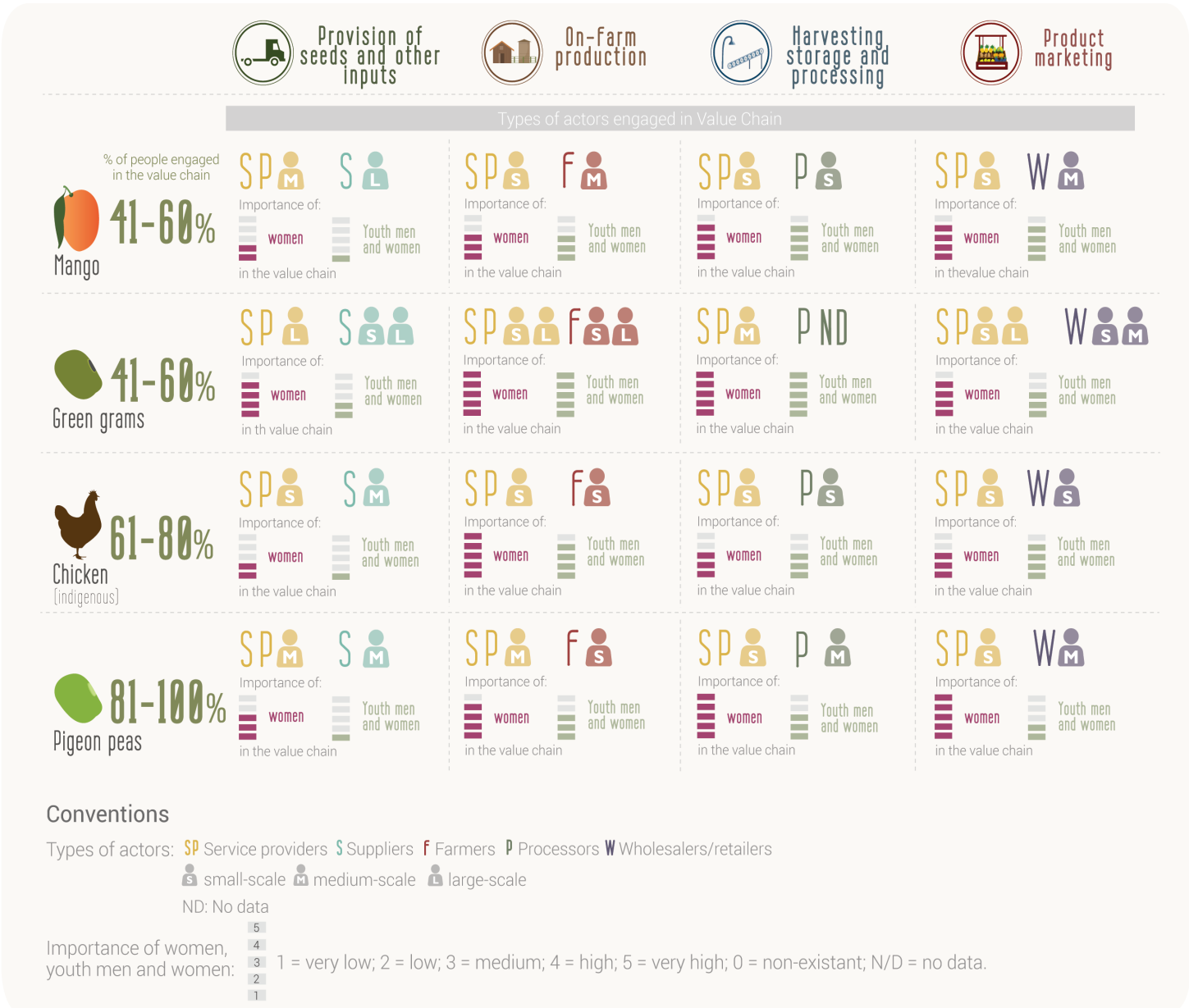
The major actors in the value chain at the input supply stage include mostly medium-scale agro-vet shops, research organisations such as KALRO, seed companies and farmers. Family labour is the most common source of labour, and is mostly provided by women at almost all the stages of the value chain. The youth are more involved at the on-farm and post-harvest stages. However, the ASDSP survey of 2014 revealed that productivity was highest in farms under youth-headed households (71 kg/ha) and lowest among the male-headed households (66kg/acre)[13] (GoK, 2014). The key activities for the production of pigeon pea start with procurement of seeds, agrochemicals, and manure. Activities at the farm level include land preparation, planting, weeding, and spraying. Some of the post-harvest handling activities include threshing, sorting, and packaging. The common marketing outlets for the dry grain is the local markets, where farmers can either sell at farm gate to consumers, or local assemblers (stockists), and middlemen. Sometimes it is sold directly to exporters and processors who then sell it to foreign markets in India and Europe. According to GoK (2014), male-headed households sold more than they produced whereas female- and youth-headed households sold approximately 25 and 42 percent of their produce respectively. This may be due to the fact that the male-headed households engage in some trade whereas female headed households produce mostly for subsistence.

Chicken (local)

Local chicken is the most common poultry enterprise in Machakos County. Approximately 61-80 percent of the population is involved in the value chain. Indigenous chicken is kept by almost all the rural households. They are kept for both eggs and meat at small-scale level. Most households own fewer than 100 birds, under free range management. In 2014, there were approximately 1,306,000 local chicken in the county with production of both eggs and meat valued at KES791 million (KNBS, 2015).

13 There is no particular reason that may be attributed to the high productivity among the youth-head households.

Agricultural value chain commodities in Machakos



The actors in this value chain include service providers at the input supply stage such as medium-sized agro-vets and sometimes individuals. Important activities for the value chain include sourcing for veterinary services, chicken feed, and breeding stock. At the farm level, important activities include feeding, disease control, and general management such as breeding, housing, and cleaning the houses. Engagement of the women and the youth in the value chain is high especially at the on-farm production stage. Value addition is limited mostly to slaughtering, defeathering and packaging before sale. During selling, women are mostly involved in decision making for production of chicken in activities such as marketing. Local markets and hotels are the common marketing outlets.

Agricultural sector challenges

The agriculture sector faces important challenges in Machakos County. The largest challenge being the low and declining productivity. A major factor contributing to the low productivity is the erratic rainfall and harsh weather and climate conditions. Farmers face a perennial shortage of water throughout the county due to frequent and prolonged droughts. As a result, farmers and pastoralists spend much time searching

for water at the expense of productive activities. The decline in crop productivity reported especially for cereals (maize) and legumes (beans) is attributable to soil degradation. Poor soil fertility, reduced soil organic matter, increased acidity, and depleted micro and macro nutrients is common in Machakos. Given that shifting cultivation and fallowing are no longer possible owing to scarcity of land, most farms have continuously (unsustainably) been cropped for over 100 years. All-year-round cultivation combined with poor land management practices lead to depletion of soil macro and micro nutrients and acidity, which affects yields negatively.

The poor road, storage and irrigation infrastructure in the county is also an inhibiting factor to the development of the sector. Machakos County is ranked among the counties with the poorest road transport network in the country (KIPPRA, 2013). Though the situation has significantly changed in the last few years, farmers still incur high costs of transporting their produce to markets, and sometimes never access both input and output markets due to poor road transport. This is why farmers sell produce such as mangoes to middlemen though the prices may not be good. The poor storage infrastructure and lack of capacity to add value in order to, for instance, increase the shelf-life of the produce aggravates the situation.

Adoption of improved agricultural technologies is mostly undermined by cultural beliefs/practices and lack of financial and technical capacity. For example, production of maize and beans is common even when there is evidence that the crops never do well due to erratic weather. This has led to food insecurity in many households. Moreover, use of improved methods such as application of fertilisers without necessarily knowing the soil requirements contributes to soil degradation. Poor access to extension services that can enlighten farmers on input utilisation contributes to this situation, as does rigidity of the farmers to change their production systems. In other instances where farmers are willing to adopt new climate- resilient production systems, they are inhibited by lack of finances[14]. The ASDSP survey of 2014 revealed that credit was the least accessed service by farmers in Machakos County (GoK, 2014). Poor access to credit persists despite the many financial institutions in the county, ranging from banks to microfinances and SACCOs; this is probably due to low priority in funding agriculture.

Climate change-related risks and vulnerabilities

Climate change and variability: historic and future trends

Machakos is an ASAL county, receiving an annual rainfall of about 500mm-1300 mm (Machakos County, 2015). Annual averages for the long and short rains were 107mm and 89.9 mm in 2013 and 88.7mm and 57.6 mm in 2014 (KNBS, 2015). The long rains are normally received in March to May whereas the short rains are received in October to December. Temperatures range from 18 to 29° C; July is the coldest month and October and March the warmest. Due to the high temperatures and scarce rainfall, crops and pastures are normally affected by moisture stress, though areas along the Athi River occasionally experience floods.

An assessment of past climate data in the county reveals a significant change in the weather conditions over the last few decades, confirming the evidence of climate variation from the farmers. Findings from our analysis of data from 1980 to 2005 show an increase in temperature in both the first and second season; the increase is more pronounced in the first season[15], where it is about 0.5° C. Precipitation on the other hand depicts a declining trend in both the first and second season; the decline is more pronounced during the first season, where it is about 25 mm. This analysis also showed that 1984, 2000, and 2009 were very dry years in the first season whereas 1997 and 2007 were very wet during the second season. These results are in agreement with those from other analyses such as those by Huho (2017). Earlier analyses such as that by Tiffen et al. (1994) for data covering 1895-1987, show that during that period, there were about 90 droughts with varying magnitudes. This result suggests climate variation rather than climate change (Mutiso et al., 1991).

Looking ahead into the future (2021-2065), both the two climate scenarios namely RCP 2.6 and RCP 8.5 depict with substantial certainty an increase in temperature in both seasons, especially in season 1 . The number of days with drought stress is also projected to increase in all the seasons with the increase being higher in season 1[16]. The situation

14 Studies such as Mutua-Mutuku et al. (2017) have shown how important access to credit is in technology adoption

15 For this study, the first season (season 1) refers to the 100-day wettest period during the months of January to June, while the Second Season (Season 2) is the 100-day wettest period during the months of July-December.

15 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.

is similar for future incidences of flooding (the 95th percentile of daily precipitation – mm/day), where both seasons are likely to have an increase, with the first season having the greater increase. Although the projections under the two GHG emissions scenarios show some differences, both indicate the possibility of increasingly variable rainfall, shifts in season onset and duration, and continued rises in temperatures with these resulting in an increased risk of droughts, dry spells and floods.

Climate Perceptions by the farmers

Although most farmers are not aware about the difference between climate change and variability, there was a consensus in all the FGDs conducted that there have been remarkable changes in the climate in the county. The changes started more significantly in the 1980s. According to the farmers, droughts are now more frequent and prolonged and the rains more erratic, unpredictable and have significantly reduced in amount compared to the situation in the 1980s. For example, the long rains used to start in March and end in June, but now the rains start as late as late July. The short rains which used to start in October now start in November. Similarly, the temperatures have increased. Most of the farmers attributed these changes to increased deforestation for charcoal, whereas others partly attributed them to religion.

The changes have had consequences on agricultural production, the environment, as well as society at large. For instance, it was noted that since the changes started there has been a remarkable decline in the productivity of major crops in the county such as maize. The soils have become more degraded and less fertile, and the population of pests and diseases has increased. Most of the pastures have significantly declined, resulting in a decrease in the herd size, whereas the water has become scarcer. Major water reservoirs have decreased in volume and rivers that were permanent have become seasonal; others have dried up completely. The water table has receded by about 1.5 meters.

The consequences on the societal set-up include a change in the roles different groups used to play in society. For instance, in the past, men are the ones who could go to seek employment; nowadays even women seek employment to supplement household incomes. As a result, household sizes are reducing as there are more migrations to urban areas in search of alternative sources of income. However, it was also mentioned that most people are now venturing into crop production since livestock keeping under the ordinary extensive production systems has become less viable. Working hours have been remarkably reduced due to the high temperatures and people now work mostly during morning hours. As a result of these factors, food is becoming scarcer.

Climate vulnerabilities across agriculture value chain commodities

Scientific evidence and information from the residents in the county reveal that the agriculture sector and livelihoods in general have been negatively affected. Considering the future projections for the scenarios for Machakos County, the impacts may be even greater in the future. The common climate hazards in the county include moisture stress, drought, highly variable temperatures, season instability and sometimes intense rainfall in some areas. These hazards impose different effects on the prioritised VCCs as in the following discussion.

Mango

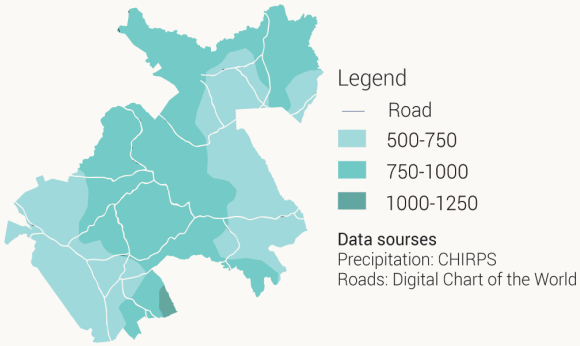
Though mango is relatively well adapted to harsh climate conditions, it has been significantly affected by the climate variations in weather in Machakos; the most problematic hazards have been moisture stress and a decrease in the stability of the growing season. These hazards affect the entire value chain activities differently, with severity ranging from minor to severe.

At the input supply stage, moisture stress results in inadequate planting material, and if the seedlings are available, they are normally of poor quality mainly because at this stage they are very sensitive to water scarcity. Therefore, farmers have to source the seedlings from elsewhere, normally at higher prices. There is a high demand for pesticides since the efficiency of pesticide use is hampered by the dry conditions, and interference in the delivery of extension service. This is because extension agents cannot use approaches such as practical demonstrations due to the dry soil conditions. At the same time, farmers are never incentivised to seek extension services; partly due to the resources used. Moisture stress leads to a reduction in the sizes and quantities produced. This is due mostly to the water scarcity and a proliferation of pests and diseases during this period. The ineffectiveness of the pesticides when dry conditions prevail also contributes to the poor production.

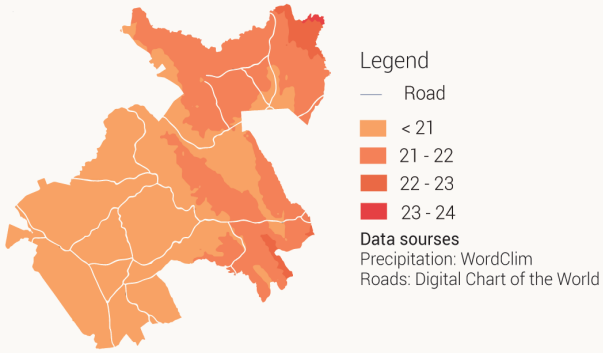
The poor quality mangoes normally have a short shelf-life, increasing the farmers' vulnerability. This may happen largely due to lack of storage facilities and lack of a capacity to add value. In addition, due to the low quantities, aggregation becomes more tedious and costly as aggregators have to cover longer

Past and future impacts of climate hazards in Machakos

Historical annual mean precipitation (mm/year)



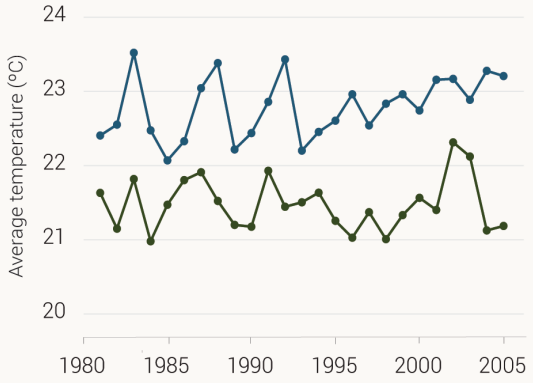
Historical annual mean temperature (°C)



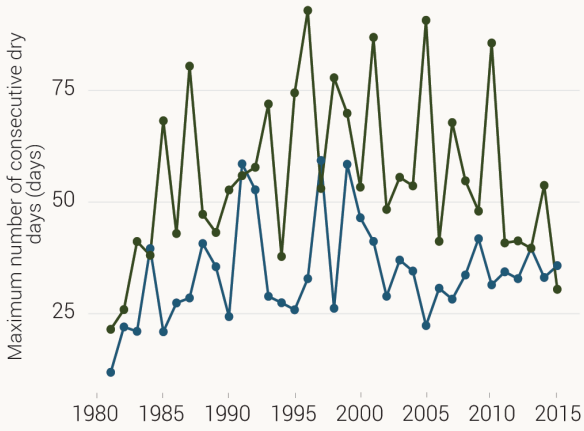
Heat stress hazards

Drought hazards

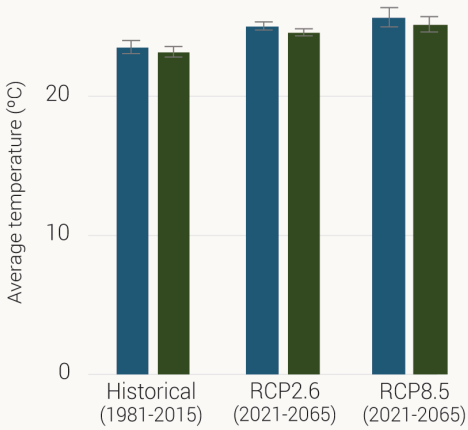
Historical extreme heat stress events



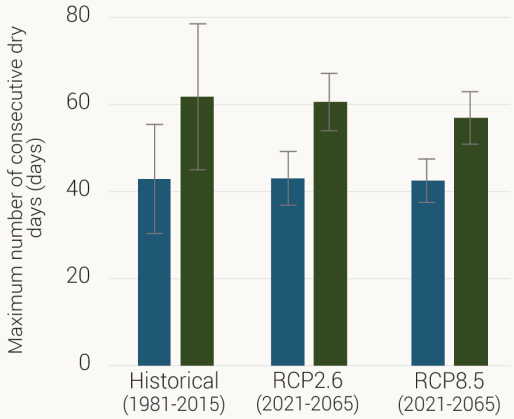
Historical drought stress events



Historical and expected extreme heat stress events



Historical and expected drought stress events



January - June July - December

distances and spend more time in the aggregation. The marketability of the mangoes is also impaired, and farmers normally get lower prices for the mangoes if they manage to get a buyer.

Even though mango is a perennial crop, instability of the seasons in terms of onset of the rains and duration of the rains significantly affects the crop. The effects are more pronounced at the on-farm production stage, as this results in poor production, reduced functionality of the pesticides and interruption of extension delivery. Under such conditions extension agents are not able to determine the right time for visiting the farmers. Due to unfavourable effects on the farm, the quality of the produce is also compromised, hence presenting challenges in storage and marketability. The poor farmers, those that are in the interior areas away from major road networks and those with low literacy levels are affected the most by these hazards. This is mostly because they never have the capacity to adopt alternative measures that can increase their resilience.

Green gram

Green gram is a drought-tolerant crop that can withstand the hot climate of Machakos. However, moisture stress during the germination and flowering period, and intense rain at especially the on-farm and post- harvest stages, can be problematic. Moisture stress does not have significant effects on the major activities at the input acquisition stage and the post-harvest stage; the dry conditions offer favourable conditions for storage and harvesting. Nevertheless, the poor quality of the green gram due to moisture stress effects at the production stage increases the time needed for sorting and grading the produce.

Moisture stress poses big challenges during the production stage since the soils harden, increasing labour requirements for land preparation. The stress also leads to poor germination and establishment of the crop. The quality and quantity of the crops are therefore reduced significantly. Due to water scarcity, green gram becomes more susceptible to diseases so there is a higher demand for pesticides; this increases the cost of production.

Intense rain on the other hand has serious ramifications at the on-farm production stage since it results in delayed land preparation and subsequently a reduction in the crop area in the long run. It also increases the probability of the planted seeds rotting, requiring the farmers to replant; Weeds become more vigorous necessitating more frequent weeding. In the same manner, the normal harvesting of the crop is delayed significantly resulting in high post-harvest losses. Intense rain aggravates these consequences in terms of access to markets mostly due to impassable roads and the poor quality of the produce, which challenges marketability.

Pigeon pea

Pigeon pea is mostly affected by moisture stress and intense rainfall, although it is a drought-tolerant crop. Traditionally, farmers are reluctant to use better and more inputs especially when water is scarce and when rainfall is above normal and poses the risk of floods. Due to the low demand for inputs such as fertilisers and even seeds during such periods, stockists usually do not stock pigeon pea seeds. The inputs therefore become expensive for those who are willing to use them despite these hazards. The situation is worsened when rainfall is intense and roads become impassable. In addition, the quality of important inputs such as manure is seriously compromised due to leaching; farmers therefore avoid buying manure during periods of intense rain.

At on-farm production, moisture stress impedes land preparation as the soil hardens, requiring more labour. The hazards, especially moisture stress, lead to reduction of the area under the crop. Moreover, intense rains lead to poor germination as they cause some of the seeds to rot. More weeds grow when rain is intense, hence increasing the cost for weeding. Whereas moisture stress has no severe effects at the post-harvest stage since the dry conditions are favourable for harvesting and storage, intense rains contribute to higher post-harvest losses since the crop rots while in the field and when stored. The chances of contamination for instance with aflatoxins increase. Impassable roads increase the costs of marketing, especially during promotion. Resource-poor households are the most affected by these consequences.

Chicken (local)

Local chicken is the most preferred livestock especially in the county due to its smaller size, less husbandry attention requirement, and resilience to harsh climate. Nevertheless, the value chain gets affected indirectly and directly by mostly moisture stress and decreases in temperature; such decreases arise as a result of high temperature variations that have become common in the county.

The effects of moisture stress on the availability of inputs such as veterinary services and breeding stock are moderate. However, the indirect effect on feed availability is severe as the chicken depend on feeds

like maize grain, which require water. This effect translates into severe reduction in production, poor health, hence susceptibility to diseases and pests; this leads to higher costs for management. Low production increases farmers' transaction and transport costs for selling the eggs despite an increment in price due to scarcity.

A slight decrease in temperature on the other hand is detrimental to the performance of the bird since it reduces immunity. Therefore, the demand for veterinary services increases and feeds become scarce. These factors also reduce availability of breeding stock. The consequences of a decrease in temperature on the key activities at the post-harvest and marketing stages are similar to those of moisture stress --output of both eggs and slaughtered birds decrease, thus increasing the transaction as well as transport costs. The profits that farmers make when production is low are not commensurate with the increases in the prices of eggs and chicken; this is mainly due to the high per unit transport cost as well as transaction costs.

Adaptation to climate change and variability

On-farm adaptation practices

Quantitative evidence on how climate change impacts the economy of Machakos County and livelihoods of its people is scarce. However, available evidence in for instance (Cleassens et al., 2010) shows that climate change is likely to impact at least 60 percent of the farmers in the county. There is also no evidence on which adaptation strategies are most effective in the county in combating the effects of climate change and building resilience. However, farmers have been adopting measures since independence to cushion themselves from the adverse effects of climate change. Some of the measures that have been documented include use of drought-tolerant varieties of crops like maize and potatoes (Cleassens et al., 2010); water conservation methods; irrigation; tree planting; water harvesting; change of crop type; feed conservation; staggered cropping; value addition; and agricultural insurance (GoK, 2014). Though these measures have been in existence for a long time, the impacts of climate change are still eminent in the county. This is mostly due to the low adoption rates of the measures. For instance, the survey by the ASDSP revealed that the most common adaptation strategy is water harvesting; it has been adopted by about two thirds of the households. Strategies such as purchase of agricultural insurance, communal seed banks, and diversification of enterprises are the least adopted.
Most of the adaptation options are undertaken in the entire county with a few such as irrigation localised to areas where a water source[17] exists. In addition, some adaptation options are specific to certain value chains; though most of them apply to all the value chains, largely because important activities for the crops are similar. Most farmers are aware of many of the adaptation options. However, the farmers have not necessarily adopted all the strategies. Some of the factors that have contributed to his situation are: inadequate finances; location of the farmers, i.e., some farmers are in regions with black cotton soils, which are more vulnerable to water-logging and flooding; a cultural belief by some farmers that certain crops such as green gram do not require fertilisers; lack of technical knowhow and over-reliance on rain fed agriculture.

The most common way through which farmers respond to unavailability of inputs such as fertilisers for crops and stocking breed for local chicken is through sourcing from other counties. Farmers also keep stocks from their previous harvests to use as seed for the next season. This approach is not always sustainable as the farmers sometimes end up consuming the seed. The strategy also contributes to the spread of diseases, hence reduced yields. Some of the potential options for addressing the challenges at input acquisition level for both crops and livestock are: input subsidisation with an efficient distribution mechanism; stocking fertilisers and seed; and establishing communal seed banks for crops. Communal seed banks are currently used by barely 2 percent of the households (GoK, 2014). The current mode of using government agents to provide extension services has not been effective especially when the hazards strike. An alternative approach is to use the farmer to farmer mode of information sharing.

The adaptation methods that are used on-farm in the county include conservation agriculture, terracing, early planting, dry planting, traditional disease and pest control practices such as use of ash, and intercropping. Little research has been conducted to show how and where these methods are most effective. However, a few studies such as Cleassens et al. (2010) show that the use of drought-tolerant varieties of maize and potatoes considerably increase the adaptive capacity of the farmers. Similarly, FAO (2014) highlights how soil conservation measures such as use of gullies and terraces have reduced the damage downstream and enhanced water availability for both domestic and livestock purposes. According to the ASDSP survey of

17 Irrigation in Machakos County is constrained by scarcity of water, worsened by the high levels of contamination and pollution of the Athi River (Aywa et al., 2017).

2014, the most common adaptation option is water conservation. This option is adopted by about 69 percent of the households, the majority being male headed (GoK, 2014)[18]. Conservation agriculture is also used in the county, though the current adoption rate is low. Up scaling of the adaptation strategy through interventions such as provision of the relevant equipment and technical support can help in building resilience. On-farm adaptation strategies for indigenous chicken include reduction of the number of birds, feed supplementation, feed conservation, and use of traditional methods for disease control. However, not all the adaptation options have been taken up by all the chicken keepers. Some of them such as feed supplementation and conservation are prohibitively costly.

For post-harvest handling, the adaptation methods currently used for the crops include storage in hermetic bags and use of traditional methods such as smoking. More effective strategies that are yet to be introduced include seed priming and value addition. Currently, only about a quarter of the households undertake at least a value-adding activity to their produce. The low level of value addition is largely attributed to lack of technical knowhow and financial capacity. Potential avenues to enhance value addition in the county include promotion of cottage industries especially for crops such as mangoes, and improvement of road infrastructure and electricity coverage. Value addition as a strategy also has potential to increase prices received for the products as well as to increase access to markets. Strategies that farmers use to cushion themselves from the output marketing vulnerabilities especially due to impassable roads include selling at farm gate at extremely low prices, and collective selling. These strategies have not overcome the marketing risks arising from the vagaries of climate variation. This is largely due to poor farmer organisation and lack of measures that can promote market access even when the quality of the products is significantly reduced. Potential coping approaches at this stage include promotion of contract farming and formation of cooperatives.

Off-farm adaptation practices

Besides the on-farm interventions, other initiatives are Besides the on-farm adaptation options, a number of services are offered by different government and non-governmental organisations to enhance resilience to climate variability. These include early warning systems, extension, veterinary services, market information, and credit through for instance livestock insurance.

Early warning is normally offered by the Kenya Meteorological Department (KMD) with collaboration from the Participatory Scenario Planning (PSP) group that comprises ASDSP, the Ministry of Agriculture, Livestock and Fisheries, the Ministry of Water and Irrigation, KALRO, and the Kenya Forestry Service (KFS). The early warning system involves forecasting weather and disseminating the information to the farmers. The information is disseminated through monthly bulletins in English, Kiswahili, and the local Kamba language to inform their planting calendars. However, according to the ASDSP survey of 2014, the major sources of climate information for the farmers are radios and indigenous knowledge accessed by approximately 35 and 25 percent of the households respectively. Utilisation of the early warning information is very low; the farmers keep on planting the same crops irrespective of the weather. The low utilisation may be attributed to sentiments by some of the people interviewed that the information given is sometimes not accurate. In addition, a large proportion of the farmers do not access this information due to challenges of coverage by the PSP group.

Extension is also another important service that is offered by different government bodies such as the Ministry of Agriculture, Livestock and Fisheries, and research organisations such as KALRO. Farmers are normally guided on best agricultural practices such as the use of drought- tolerant crop varieties and how to minimise post-harvest losses. Non-governmental organisations that offer extension include the Dryland Seed Company, World Vision, Arysta Life Science, and TechnoServe. TechnoServe in partnership with the Rockefeller Foundation, helps mango farmers to access and adopt technologies such as utilisation of crates instead of sacks for transportation, and basin formation for water retention[19]. Rockefeller and TechnoServe also link the farmers to markets and offer relevant market information. The major challenge hindering extension is the current demand-driven model for extension; farmers rarely seek extension mostly due to financial limitations.

A number of financial intermediaries operate in the county. These include banks such as Equity Bank and the Kenya Women Finance Trust (KWFT) and insurance companies and Cooperatives such as the Universal Traders Sacco that offer credit services to the farmers. For instance, the Co-operative Insurance Company (CIC) of Kenya Limited is the intermediary for the crop and livestock insurance programme that is being implemented in the county. KWFT provides credit to female individuals as well as women self-

18 The difference in adoption rates between male, female, and youth-headed households is explained by the differences in access to both resources and information.

19 Basins are structures (holes) made around the plant to hold rain water.

help groups. Despite the presence of these financial facilities, only 5 percent of the households' access credit according to the GoK (2014). This may be explained by the high risk in the agriculture sector, which makes financial intermediaries restrain from offering credit for agricultural production. Another factor is that farmers do not seek credit mainly due to lack of awareness, high interest rates considering the high poverty levels among small-scale farmers, and negative farmer perceptions about financial institutions.

The Veterinary Department of the Ministry of Agriculture, Livestock and Fisheries offers disease control measures where they engage in vaccination of local chicken in the event of a disease breakout. The department also offers Artificial Insemination (AI) services for other livestock.

Policies and Programmes

According to the National Government Coordination Act of 2013, each county government is supposed to ensure uniformity to national standards in the agricultural sector through legislation and administrative actions in accordance with the national policy guidelines. Machakos County like most of the Kenyan counties lacks elaborate policies and legislation that directly address climate change in agriculture as well as in other sectors. However, the county borrows from the national level policies in designing programmes intended to incorporate climate change into the development agenda and build resilience. One of the reasons for this is that the policies at the national level are more cognizant of climate change compared to the county legislations which address climate change in a piecemeal manner or indirectly. Some of the national policies that are still fully or partially implemented in the county are stated in the following discussion.

The National Climate Change Response Strategy (NCCRS) of 2010 was the first document to coherently acknowledge the existence of climate change impacts such as frequent droughts and floods in Kenya. The document envisions a Kenya that is resilient to climate change and identifies policy and institutional restructuring to include climate change into the development plans and engagement of all stakeholders as one of the possible pathways to achieving this goal. This strategy led to development of policy documents such as the National Land Reclamation Policy of 2013 to promote cost-effective land resource utilisation through for instance rehabilitation, reclamation, and restoration; the National Environment Policy of 2013 that lays out the need and importance of the government promoting efficient adaptation measures; and the National Policy for the Sustainable Development of Northern Kenya and other Arid Lands of 2015, which touches on matters not limited only to sustainable utilisation of existing land-based resources but the general well-being of the people in the arid and semi-arid regions. It is in light of these policies among others that the county government of Machakos has designed legislations and programmes aimed at addressing the issues identified in the national policies.

The Machakos County Sand Harvesting Act of 2014 seeks to ensure sustainable exploitation and equitable sharing of the accruing benefits. Administration and enforcement is by the Machakos County Sand Harvesting and Management Committee, which comprises the chief officers for finance and natural resources and representatives from special interest groups among others. Some of the activities to ensure compliance with the Act include development of an inventory of sand-harvesting associations, licensing sand harvesting, and collaboration with other environmental agencies in developing environmental conservancy programmes with regard to sand harvesting. Despite the presence of the legislation, compliance has always been a problem. This is because several people can use the same license and harvest beyond the recommended sand quantities especially along Rivers Thwake and Athi. Sand harvesting activities have a bearing on water and soil conservation.

The Machakos Water and Sanitation Board was established under the provisions of the Machakos County Water and Sanitation Act of 2014, which borrows from the National Water Act of 2002. The role of the board is to actualise the objectives of the Act such as storm water management, water conservation, and other related purposes. It achieves this through ensuring adequate water supply for domestic, livestock, and agricultural purposes; promotion of water harvesting and recycling; and promotion of efficient water use and management among other functions. The legislation also has a gap in enforcement, one of the reasons why water scarcity still remains a major problem in the county.

The Machakos Agricultural Development Fund Act of 2014 also deals with climate matters. The Act seeks to, among other things, increase agricultural productivity through provision of credit to undertake value addition, water harvesting, provision of farm inputs, facilitation of market research, and dissemination of market information. However, this goal is yet to be achieved considering that the already low agricultural productivity in the county is declining.

Some of the programmes to operationalise these policies include the county government initiative of a comprehensive food sustainability programme. It seeks to enhance agricultural productivity in the county through interventions such as provision of seeds, fertilisers, and tractors. So far the county government has distributed 28,000 kg of maize, 17,394 kg of beans, 1,878 kg of cow peas, and 8,718 kg of

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

Mango

	Provision of seeds and other inputs	On-farm production	Harvesting storage and processing	Product marketing
Drought/ Moisture stress	Limited seedling / planting material availability. High perishability of seedlings	Scorching of leaves. Increase in pests and diseases. Leaf and fruit fall	Reduced quantity, size and quality (colour, shape) of fruits. Limited value addition	Unfulfilled contracts. Increased transport costs. Lower prices. Reduced income and profits for farmers and retailers
Magnitude of impact	Major	Major	Moderate	Severe
Farmers' current strategies to cope with the risks	Home seedling propagation. Group nurseries	Spraying of leaves with water. Reducing chemical mixing rates (less chemical-more water) and increasing spraying frequency. Use of fruit fly traps. Mixed cropping with low lying crops (e.g. cow peas)	Harvesting of all fruits regardless of size. Local processing of juice for immediate consumption	Use of any available transportation (matatu, boda, ox-carts and trucks). Farm to farm collection by buyers. Selling unprocessed fruit to middle men. Reduce prices
Other potential options to increase farmers' adaptive capacity	Enforcement of seedling production regulations and standards. Promote/establishment of commercial certified fruit nurseries	Capacity building of service providers for bulk spraying. Capacity building on IPM. Capacity building on quality management. Water harvesting and small scale irrigation	Capacity building on fruit thinning of undersized fruits. Development of fruit processing industries for wider sales	Development of fruit transportation services using improved vehicles. Establishment of aggregation centres. Group marketing (cooperatives)
Changes in seasons (onset and duration)	Limited seedling availability. Poor quality seedlings (under or over mature)	Ineffective spraying regime. Increased pests and diseases	Reduced fruit quality. Post-harvest spoilage. More labour required for harvesting. Incomplete drying process	Irregular supply to markets. Missing of market opportunities. Breach of contracts (in relation to quantity, size etc.). Explore contract farming
Magnitude of impact	Moderate	Moderate	Moderate	Severe
Farmers' current strategies to cope with the risks	Use of indigenous varieties	Diversification of fruit trees on the farm. Uncoordinated spraying as per farmer requirements. Reliance on information from other farmers to inform farm operations. Bottle irrigation. Digging basins and furrows for water conservation. Reduced spraying	Harvest all fruits at once. Sales of unprocessed fruit. Uncoordinated collection and storage	Sell by piece. Reduce prices. Overloading of transportation to minimise transport costs (also results in spoilage). Promotion by word of mouth (farmer-to-farmer)
Other potential options to increase farmers' adaptive capacity	Use of appropriate varieties guided by local season onset and duration	Water harvesting and small scale irrigation. Improved agro climatic advisory services. Development of bulk spraying mechanism for improved coordination and timeliness between farmers	Capacity building staggered harvesting and grading and sorting of fruits. Establishment of processing (juice making) facilities. Establishment of aggregation centres	Establish contract growing and marketing agreements. Invest in special mango transportation trucks. Use of crates. Improved market information systems. Construction of fruit market infrastructure

Green gram

	Provision of inputs	On-Farm production	Harvesting storage and processing	Product marketing
Flooding	Inadequate seed supply (rotting of seeds). Unavailability other inputs (impassable roads)	High costs of land preparation. Rapid weed growth. Poor seed germination rates. Increased incidence of pests and diseases	High post-harvest losses – rotting and mould damage. Increased processing costs	Impassable roads make transport to market difficult
Magnitude of impact	Moderate	Major	Major	Major
Farmers' current strategies to cope with the risks	Use of small transport (motorbikes) for seed supply. Sourcing seed from further away	Delayed land preparation. Planting on ridges. Increased weeding regime	Storage in ventilated (windows) stores. Immediate sales to reduce post-harvest losses	Farm gate sales
Other potential options to increase farmers' adaptive capacity	Establishment of local seed banks. Improving information on seed and input availability and pricing	Training on weed management and proper seed planting methods. Promotion of indigenous weed, pest and disease management	Use of hermetic storage bags. Exploitation of energy efficient technologies to dry produce (solar). Establishment of modern storage facilities. Establishment of aggregation centres	Promote contract farming. Creation of government warehouse receipts system. Formation of producer/ marketing groups
Drought / Moisture stress	Lack of availability of seeds	Extra labour (and costs) in land preparation (hardpans) and weeding. Low germination rate. Wilting	Low yields. Poor quality produce. On-farm storage. Easier processing of dry produce	Low supply to market
Magnitude of impact	Moderate	Moderate	Moderate	Moderate
Farmers' current strategies to cope with the risks	Reduction in planted area	Delayed land preparation (with onset of rains). Early planting/ dry planting. Use of untreated organic manure. Use of conservation agriculture principles (minimum tillage, mulching, intercropping)	Use of storage chemicals to reduce post-harvest losses. Harvesting, threshing and winnowing in the field	Farm gate sales in small quantities
Other potential options to increase farmers' adaptive capacity	Development of drought resistant varieties and capacity building of farmers on variety selection. Enhanced dissemination and capacity building on use of agrometeorological information	Water harvesting and small scale irrigation development. Establishment and training on use of compost. Scaling up of conservation agriculture	Use of hermetic storage bags. Exploitation of energy efficient technologies to preserve produce and reduce post-harvest losses. Promotion of farm level value addition. Establishment of aggregation centres	EPromote contract farming. Creation of government warehouse receipts system. Formation of producer/ marketing groups

Pigeon pea

	Provision of seeds and other inputs 	On-Farm production 	Harvesting storage and processing 	Product marketing 
Flooding	Unavailability and high cost of seed and other inputs due to impeded transport (flooded roads)	Land preparation becomes more difficult. Reduced acreage. Leaching of nutrients resulting in higher application requirements. Washing away of pesticides resulting in increased application and costs. Increased pest and disease prevalence. Lower yields. Increased weeding requirements. Increased aflatoxin quantity due to increased chemical use	Reduced quantity and quality of crop. Flooding of warehouses resulting in rotting during storage	Irregular/ inadequate supply to markets. Difficulty in transporting to markets due to flooded roads. Higher transportation costs
Magnitude of impact	Moderate	Moderate	Major	Moderate
Farmers' current strategies to cope with the risks	Seed recycling	Late land preparation. Use of traditional pest and disease control measures (ash, smoke and pepper solution)	Use of ash to dry produce	Sales in local markets and shopping centres
Other potential options to increase farmers' adaptive capacity	Subsidized certified seed supply by government. Use of improved varieties.	Promote use of manure and compost. Improved agro climatic advisories. Agro-chemical subsidies. Promote mulching to reduce weeds	Promotion of early harvest. Use of improved storage bags. Construction of modern storage facilities. Establishment of aggregation centres	Cooperative formation for joint marketing. Improved market price information. Improvement of road networks. Use of technology (cell phones, internet) to improve market information and sales
Droughts / Moisture stress	Seed unavailability. Greater cost of seeds. Limited procurement of agrochemicals by farmers. Limited stocks by suppliers	Hardpans make land preparation difficult. Low germination rates. Increased presence of pests and diseases	Severely reduced harvest	Reduced sales to markets. Higher prices at the market due to limited supply
Magnitude of impact	Major	Major	Severe	Minor
Farmers' current strategies to cope with the risks	Seed recycling. Stocking of manure during dry season	Reduce acreage under pigeon pea. Diversify to other crop	Early harvesting. Home storage in bags	Sales at local markets. Transportation using oxcarts. Announcement of availability and prices at local events (church, bazaars)
Other potential options to increase farmers' adaptive capacity	Local seed bulking. Subsidised seeds and agrochemicals. Capacity building on improved manure management	Promote conservation agriculture, rainwater harvesting and small scale irrigation	Mechanised harvesting. Promotion of improved storage bags to reduce post-harvest losses. Establishment of aggregation points	Use of large transportation (trucks and lorries). Use of technology (cell phones, internet) to improve market information and sales

Chicken (local)

	Provision of seeds and other inputs	On-farm production	Harvesting storage and processing	Product marketing
Reducing temperatures	Poor health of chicks and increased mortality. Inadequate feed supply (longer time for feed crop to mature). Low chick hatch rates. Low supply of breeding stock (chicks)	Low hatching rates, high mortality rates and slow growth. Increased feed consumption resulting increased costs. Increased heating costs. Increased costs of health management. Increased susceptibility to pests and diseases	Reduced quality and size of eggs and chickens. Reduced quantity of eggs and birds collected	Fewer birds and eggs available on the market. Low prices due to low quality (size and weight) of eggs and chickens
Magnitude of impact	Moderate	Major	Major	Moderate
Farmers' current strategies to cope with the risks	Purchase of veterinary drugs as and when needed. Self-diagnosis of diseases. Home feed conservation. Sourcing of chicks from neighbouring counties. Diversifying into alternative enterprises	Reduction of the flock. Use of herbal/ indigenous medicines. Hiring part time workers to aid with increased care requirements. Feed supplementation	Home consumption of some produce	Household consumption of alternatives to egg protein (e.g. plant proteins)
Other potential options to increase farmers' adaptive capacity	Recruitment and capacity building of more livestock extension officers. Training of paravets. Establishment of hatcheries and incubators at strategic locations in the county	Training on production and conservation of homemade feeds. Use of heated enclosures	Establishment of processing facilities for value addition (freezing, canning)	Exploring external markets for chicken and eggs. Improved
Droughts / Moisture stress	High mortality rate of chicks. Feed shortages and increase in prices of inputs	Lower productivity due to drought stress. Increased disease incidence. Increased need for veterinary care	Reduced quantity of chicken and eggs harvested. Increased collection and transportation costs	Reduced household income from chicken and egg sales. Reduced supply to local markets
Magnitude of impact	Major	Major	Moderate	Moderate
Farmers' current strategies to cope with the risks	Diversifying into alternative enterprises. Use of local ingredients to supplement feed. Sharing of drought early warning information from farmer-to-farmer. Sourcing chicks and inputs from neighbouring counties	On-farm water harvesting. Reduction of the flock. Allow free ranging	Slaughter of chickens for consumption at household level	Local household consumption. Consumption of alternative proteins
Other potential options to increase farmers' adaptive capacity	Training on production and conservation of homemade feeds. Training of community para-vets	Training of farmers on drought management in poultry production. Training of farmers on flock management practices	Establishment of processing facilities for value addition (freezing, canning)	Formation and capacity building of poultry cooperatives. Facilitate farm gate marketing of chicken and eggs

green grams. The Kenya Cereal Enhancement Programme - Climate Resilient Agricultural Livelihoods Programme (KCEP CRAL) is running for seven years through 2022. The programme is an extension of the initial Kenya Cereal Enhancement Programme (KCEP) to the ASALs. It is a partnership between the Government of Kenya (GoK) and the European Union (EU), the World Food Programme (WFP), International Fund for Agricultural Development (IFAD) and the Food and Agriculture Organization (FAO). It seeks to support farmers and pastoralists from recurrent food insecurity and to shift the conventional subsistence farming to market-oriented farming as well as enhance resilience to climate change and sustainable natural resource management. Other programmes in the county include the ASDSP which is a collaboration between the GoK, the Swedish Government and partners such as KALRO and the University of Nairobi. The programme seeks to enhance capacity building among farmers and assist the participatory scenario planning (PSP) for climate scenarios as well dissemination of climate information in partnership with the National Drought Management Authority (NDMA). Even though the latter does not participate currently in the county, its structures are useful to farmers.

The foregoing section exemplifies efforts being made to mainstream climate change in the development agenda in the county. Several institutional and policy gaps still remain. The existing legislations do not holistically address the climate vulnerabilities in the county, and there exist gaps in the enforcement of the existing policies. In addition, there is a weak link between different legislations targeting the same resources or with similar goals. The county is therefore yet to benefit from synchronisation of the policies to facilitate synergy among the different actors.

Governance, institutional resources, and capacity

A number of institutions are dedicated to enhancing climate resilience in Machakos County. These include government agencies such as departments of the Ministry of Agriculture, Livestock and Fisheries that offer various off-farm services as already discussed, the Kenya Forestry Service (KFS) which is mandated to promote among other things afforestation, the Kenya Meteorological Department (KMD) that provides weather forecasts, the Ministry of Water and Irrigation (MoWI) that is responsible for water resources, the National Drought Management Authority (NDMA) that responds to drought emergencies and undertakes interventions such as construction of water pans to increase the farmers'/pastoralists' adaptive capacity, and various non-governmental organizations (NGOs)[20]. The NGOs include FAO, the United States Agency for International Development (USAID), Farm Input Promotions Africa (FIPS-Africa), World Vision-Kenya, World Agroforestry Center (ICRAF), Care International, Africa Conservation Tillage (ACT) Network, TechnoServe and the Agriculture Market Development Trust (AGMARK).

The FAO promotes various climate-smart interventions in the county, such as conservation agriculture, through provision of the relevant inputs and alternative livelihood diversification options, as well as promotion of improved land and water management. Through these initiatives, farmers have been able to increase their production; approximately 300,000 leguminous fodder trees have been planted in the county. Conservation agriculture has also been promoted by the ACT Network, whose main function is to train farmers and service providers.

FIPS-Africa, which is a not-for-profit organisation funded by USAID, seeks to increase climate resilience in Machakos County through provision of various inputs to farmers and promotion of climate-resilient technologies as one of the ways of enhancing food security in the county. Some of the inputs promoted include early-maturing and high-yielding varieties of maize, beans, cowpeas, and green grams. So far, provision of these inputs has been promoted through a network of 15 self-employed Village-based Advisors (VBAs) using FIPS-Africa's innovative and successful small pack and whole village approach to distribute the inputs to 6,686 farmers. The farmers have also received training on good agronomic practices.

TechnoServe on the other hand has engaged implementation of the Yield Wise Programme in partnership with the Rockefeller Foundation, the partnership aims at reducing food losses among mango farmers and increasing household incomes as well as expanding availability of safe and nutritious foods. Some of the interventions used in the mango value chain include use of fruit fly traps. This has significantly reduced the number of mangoes damaged by fruit flies and improved handling at harvesting and packaging. The number of mangoes damaged during the harvesting and packaging stages has decreased drastically.

USAID funds several initiatives in the county including the Kenya Agricultural Value Chain Enterprises (KAVES) project which started in 2013 and runs through 2018. The project involves different partners

20 The list of government agencies provided does not include all institutions working in climate change.

such as the Kenya Plant Health Inspectorate Service (KEPHIS); the Ministry of Agriculture, Livestock, and Fisheries; Pest Control Products Board (PCPB); Agriculture Sector Coordination Unit (ASCU); KALRO; and the Horticultural Crops Development Authority (HCDA). Some of the objectives of the project include improving smallholder incomes, promoting livelihood diversification; increasing agricultural productivity, and enhancing food security through interventions in capacity building and market development. Other organisations include the Dryland Seed Limited (DSL), which has specialised in dryland agriculture. It engages in development and commercialisation of seeds that are adapted to climate vagaries in various parts of the country including Machakos in collaboration with organisations such as KALRO, the International Maize and Wheat Improvement Center (CYMMIT), the International Center for Tropical Agriculture (CIAT), and the International Crops Research Institute for Semi-Arid Tropics (ICRISAT). Some of the crops DSL has promoted include maize, pigeon peas, cow peas, and sorghum.

World Vision supports the Vision Fund that offers credit for economic empowerment of the remote communities through business support. The Vision Fund offers the Mkopo Shambani loan of up to KES. 500,000 that is a seasonal farming loan to smallholder farmers in Machakos who lack the means and capacity to scale up their farming so as to increase their returns. The AGMARK on the other hand trains agro-dealers to stock the right seeds and fertilisers, and undertake capacity building on soil testing, an initiative funded by the Alliance for a Green Revolution for Africa (AGRA). Care International is mainly a climate information services provider.

Despite the large number of actors implementing various interventions related to climate change, full potential of such interventions is yet to be realized as many people are still at risk in the event of extreme weather events. Inadequate financial and human capacity is the biggest factor hindering efficient operation of the various actors. In addition, some institutions never make decisions autonomously as they depend on either donor objectives or national office quotas. This increases chances of irrelevant expenditure in the county. The county is also yet to benefit from measures that can enhance collaboration among all the institutions; government and government agencies as well as government and NGOs.

Synthesis and Outlook

Machakos County being one of the semi-arid counties in Kenya, continues to suffer the adverse effects of climate vagaries, which have resulted in serious water scarcity among other challenges. Though analysis of historic climate data does not show a significant change in climate, future projections show the likelihood of increased climate variability, which will put more livelihoods at risk. The current impacts of moisture stress, occasional intense rains and declines in temperature have significantly reduced the productivity of major crops in the county. It has also made livelihood options such as pastoralism less viable, thus compromising the county's food security. The most affected are the poor farmers with a limited resource base, the elderly, women, and children.

Farmers have adopted different strategies such as conservation agriculture, water harvesting, intercropping, dry planting, planting of drought-tolerant crop varieties, use of indigenous knowledge in disease control and post-harvest management, irrigation, value addition, restraining from use of purchased inputs, selling at farm gate, and group marketing to cushion themselves from the adverse effects. Although some of the adaptations have been successful, these options have not been widely adopted, and have not addressed the underlying vulnerabilities. This has mainly been due to inadequate resources for both farmers and relevant institutions, and lack of institutional capacity in terms of human resource. In addition, there is a weak link among the various actors in the county, especially among institutions that offer services that promote adoption of the adaptation options. Filling the salient policy gaps through formulation of a climate change policy with an elaborate enforcement strategy will contribute significantly towards enhancing coordination and collaboration. The interventions also need to be holistic, targeting the entire value chain through multi-faceted projects addressing matters such as low technology adoption, market failures, sustainable resource use, and improved agricultural production.

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