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1 JKUAT

2 ACTS

3 Wageningen University & Research

4 CAS

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3R Kenya Project

The 3R Kenya (Resilient, Robust, Reliable — From Aid to Trade) project is a learning initiative supported under the Agriculture and Food and Nutrition Security (FNS) programme of the Embassy of the Kingdom of the Netherlands. 3R Kenya seeks to assess evidence and lessons from FNS and other related programmes that support competitive, market-led models in spurring agricultural development. It focuses on the aquaculture, dairy and horticulture sectors. 3R Kenya is executed at a time when the Dutch government's bilateral relations in Kenya are transitioning from a focus on Aid to a focus on Trade to enhance the development of agri-food sectors. Through evidence generation and stakeholder dialogue, 3R seeks to contribute to an understanding of effective conditions for sustainable inclusive trade for transforming agri-food sectors to be resilient, robust and reliable.

3Rs:

Resilient: dynamic and adaptive capacities that enable agents and systems to adequately respond to changing circumstances

Robust: systematic interactions between agents that enable them to adjust to uncertainties within the boundaries of their initial configuration

Reliable: the ability of a system or component to perform its functions under changing conditions for a specified period of time, to create opportunities for (inter)national trade.

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List of abbreviations and acronyms

3R Kenya	Resilient, Robust and Reliable – from Aid to Trade project
ACTS	African Centre for Technology Studies
AF	Adaptation Fund
AIVs	African indigenous vegetables
CAS	Climate Adaptation Services
CIAT	International Center for Tropical Agriculture
CIDP	County Integrated Development Plan
CO ₂	carbon dioxide
CSA	climate-smart agriculture
EKN	Embassy of the Kingdom of the Netherlands
FAO	Food & Agriculture Organization
FGD	focus group discussion
GAP	Good Agricultural Practices
GCF	Green Climate Fund
GDP	gross domestic product
GESIP	Green Economy Strategy and Implementation Plan
GoK	Government of Kenya
INDC	intended nationally determined contribution
IPM	integrated pest management
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KMD	Kenya Meteorological Department
MoALF	Ministry of Agriculture, Livestock and Fisheries
MTP	medium-term plan
NCCAP	National Climate Change Action Plan
NCCRS	National Climate Change Response Strategy
NGO	non-government organization
RCP	representative concentration pathway
SDG	sustainable development goals
UNFCCC	United Nations Framework Convention on Climate Change
WUR	Wageningen University & Research

Summary

Climate change presents one of the greatest challenges to the productivity and sustainable growth of the agricultural sector in Kenya due to extreme events such as droughts and floods as well as changes in temperature. Horticultural crops are particularly sensitive to climate change because of their high water demand and strict temperature requirements. Increased or decreased rainfall and increased temperature result in drought or flooding, lack of water for irrigation, and pests and diseases epidemic can affect the suitability of areas for growing horticultural crops. Understanding the impacts of climate for a given crop under specific conditions is key to supporting further development of the horticulture sector. While horticulture is a priority economic subsector in many counties, it is not known how the counties position themselves with regard to dealing with climate change threats in the sector.

A review of the literature shows how climate change significantly affects the performance of horticultural crops across a variety of climatic zones and that counties need to be better prepared to address these effects. Horticulture covers myriad crops (including fruits and vegetables), which are affected by climate change in different ways. Seasonal patterns, both for temperature as well as (onset of) rainfall are changing. Temperature thresholds for specific crops are being exceeded, while some areas are now more favourable for growing certain crops where previously temperatures were too low. Suboptimal temperatures affect both the yield and quality of produce. The horticulture sector has also experienced incidences of pests, such as *Tuta absoluta* on tomato; climate change is a confounding factor to the spread and establishment of these pests.

Agriculture which is highly affected by climate change is devolved to counties; as such, policies relevant to it are expected to be implemented at county level. An analysis of the County Integrated Development Plans showed that horticulture is a high-value subsector that plays a major role in generating revenue for county development. Most counties have prioritized horticulture and made substantial investments. Climate change is acknowledged as a threat to different sectors, but there is only scant analysis of the factors causing it, effects it will have and proposed responses to it.

Farmers and crop officers from Kiambu and Kajiado counties are aware of climate change and its effects on horticulture. However, understanding of the relationship between cause and effect and of possible mitigating actions is weak. We observed that at all levels, in the field as well as at county level, preparedness for climate change is low and government support to the farmers is also limited. Due attention and informed decision-making based on, for example the Kenya Climate Atlas that is currently being developed, is required.

1 Introduction

Climate change presents one of the greatest challenges to the productivity and sustainable growth of the agricultural sector in Kenya. Studies have shown that climate change is negatively affecting agricultural productivity and production in Kenya due to extreme events such as droughts and floods as well as abrupt changes in temperature (Mariara and Karanja, 2006; Wens *et al.*, 2018). These studies show that temperature increase is more threatening to the sector than are changes in precipitation. According to the World Bank Climate Country Adaptation Profiles (climate knowledge portal <https://climateknowledgeportal.worldbank.org>), projections under the worst-case scenario (RCP 8.5¹) show that temperature is projected to increase by 1–2.8°C by 2060, with the western regions of Kenya experiencing the greatest warming. The reliance on rain-fed agriculture is a major risk to the agricultural sector of climate change, which is expected to affect food security and increase poverty levels (Kabubo-Mariara, 2015; Kabubo-Mariara and Kabara, 2018).

Most studies on the potential threats of climate change to the agricultural sector in Kenya (Herrero *et al.*, 2010; Bryan *et al.*, 2013; Kabubo-Mariara and Kabara, 2018) take a broad approach to understanding the effect of climate on the sector, offering a general view of the effects and potential adaptation and mitigation measures with only limited analysis of the specifics of the different subsectors. The threats of climate change affect both productivity and profitability of the sector, limiting their growth and sustainable development (Abewoye, 2018). Climate change is also projected to affect investment in the sector (Lobell *et al.*, 2008). The risks and threats of climate change in agriculture and the resultant adaptation and mitigation options depend on the specific crops and their related value chains (Mwongera *et al.*, 2019), hence may not be generalized.

Horticultural crops, which are quite diverse, are particularly sensitive to climate change due to their high water demand and strict temperature requirements. Climate change in the form of increased or decreased rainfall, increased temperature and drought, lack of water for irrigation, and vulnerability to pests and diseases can affect the suitability of areas for growing horticultural crops. As Singh (2013) noted, understanding the impacts of climate for a given crop under specific conditions is key to supporting further development of the horticulture sector.

A quick scan of the horticulture sector in Kenya found that most counties identified the sector as key in driving sustainable economic development (Matui *et al.*, 2016). The sector is the second largest foreign exchange earner within the agriculture sector after tea, contributing 36% to agriculture's share of GDP (KNBS, 2016) and continues to grow. However, Matui *et al.* (2016) noted that one of the limiting factors to the sector's sustainable growth is the threat of climate change. Kenya has developed several policies to respond to climate change and build resilience, including in the agriculture sector. Through intended nationally determined contributions (INDCs) (i.e. intended reductions in greenhouse gas emissions), Kenya aspires to achieve low-carbon and climate-resilient development by 2030 (MENR, 2015). As part of this aspiration, policies and action plans have been developed at both national and county level. The second National Climate Change Action Plan (NCCAP II) 2018–2022 (GoK, 2018a) and the Kenya National Adaptation Plan 2015–2030 (GoK, 2016) are the overarching guidelines for responding to climate change in the country.

Since devolution in 2010, county governments have played an important role in spurring agricultural development. With regard to climate change, based on the provisions of the Kenya National Adaptation Plan, counties are expected to mainstream climate resilience in their County Integrated Development Plans (CIDPs) (see Box 1) to guide sustainable and economically sound sector development.

¹ RCP stands for representative concentration pathways: http://www.ipcc-data.org/guidelines/pages/glossary/glossary_r.html#rcp

While the horticulture sector is a priority economic subsector in many counties (through the Agriculture Sector Development Support Programme), it is not known how counties position themselves with regard to dealing with climate change threats in the horticulture sector. We have observed that several counties do not know about the specific impacts of climate change on their horticultural businesses. Therefore, this 3R Kenya study aims to generate evidence about climate change impacts on horticulture and has analysed policies and actions that are currently promoting resilience of the sector. The study will contribute to Kenya's Big 4 Agenda and Vision 2030 by providing evidence of how to build a more resilient horticulture subsector at the county level. In this study, we interviewed farmers in two counties about their perceptions and experiences of climate change and what strategies and measures they consider as favourable to deal with these impacts.

The main research questions for the study were:

- What medium-term climate change effects are expected in the horticulture sector? (Chapter 3)
- How can these be addressed by national and county governments? (Chapter 4)
- How do farmers perceive their preparedness with regard to climate change? (Chapter 5)

The objective of 3R Kenya in this study is to work towards an evidence-based methodology for integrating/accelerating climate resilience in the CIDPs of counties in Kenya.

Box 1. The role of county governments in climate change adaptation

The Kenya National Adaptation Plan 2015–2030 states that:

"County Governments shall integrate and mainstream climate change actions, interventions and duties into County Integrated Development Plans (CIDPs); and designate a County Executive Committee member to coordinate climate change affairs; submit a report on the implementation progress of climate change actions to the County Assembly for review and debate, with a copy to the Climate Change Directorate for information." (GoK, 2016, p. 11)

2 Methodology

This study combined a number of methods to bring together evidence about the effects of climate change on horticulture and to assess the preparedness of the counties and the sector to deal with these effects:

1. **Literature review** based on selected studies on the effects of climate change on horticultural crops globally, as not many Kenya-specific studies could be found. Examples from other crops were also included where evidence specific to horticulture was not available.
2. **Policy analysis** was conducted at two levels:
 - a. Eight CIDPs of selected counties, in which horticulture is a major economic activity, were analysed for:
 - i. ecology and climate characteristics
 - ii. natural resources
 - iii. main crops
 - iv. evidence of climate change
 - v. adaptation and mitigation measures.
 - b. A review was conducted of the key climate change policy and legislative instruments, including related strategies and implementation plans, to identify governance instruments at both national and county levels relevant to the horticulture subsector.

Table 1 Online sources of County Integrated Development Plans reviewed

County	Website
Kajiado	http://maarifa.cog.go.ke//index.php?fcty=34&fsec=#resources
Kiambu	http://maarifa.cog.go.ke//index.php?fcty=22&fsec=#resources
Kirinyaga	http://maarifa.cog.go.ke//index.php?fcty=20&fsec=#resources
Meru	http://maarifa.cog.go.ke//index.php?fcty=12&fsec=#resources
Nakuru	http://maarifa.cog.go.ke//index.php?fcty=32&fsec=#resources
Nyandarua	http://maarifa.cog.go.ke//index.php?fcty=18&fsec=#resources
Nyeri	http://maarifa.cog.go.ke//index.php?fcty=19&fsec=#resources
Uasin Gishu	http://maarifa.cog.go.ke//index.php?fcty=27&fsec=#resources

3. Focus group discussions

Focus group discussions (FGD) were held using semi-structured questionnaires (see Appendix 1) to obtain further insights from farmers and extension service providers about their perceptions of climate change and its effects on horticulture, actions taken to address these effects and the impacts of these actions. Ten FGDs, each with at least five people and including farmers and extension staff, were conducted in Kiambu and Kajiado counties. At least one FGD was conducted per ward, and at least two wards per sub-county (Table 2) had an FGD. The farmers who took part in the FGDs are engaged in diverse activities and are not confined to horticultural farming. Some are formally employed as doctors and teachers.

Table 2 Sub-counties and wards surveyed

County	Sub-county	Ward	Number of people involved
Kajiado	Kajiado North	Ongata Rongai	5
		Ngong	6
	Kajiado East	Kitengela/Sholinke	5
		Kaputiei North	5
Kiambu	Juja	Juja	7
		Theta	8
	Limuru	Tigoni-Ngecha	8
		Ndeiya	7

Box 2. Counties included in the study

The study focused on eight counties: Kajiado, Kiambu, Kirinyaga, Meru, Nakuru, Nyeri, Nyandarua and Uasin Gishu (Figure 1). This selection was in line with a parallel study of the 3R Kenya project that is a broader analysis of the CIDPs (Coninx and Kilelu, 2019) and aims to understand how counties are positioning themselves to catalyse investment for sustainable development of their priority agricultural sectors. The eight counties selected were among those that had identified horticultural development as a priority. The second criterion was the diversity of agroecology.



Figure 1 Location of the eight study counties

3 Changes in climatic factors

The literature review aimed to highlight the changes in climatic factors, namely temperature and precipitation, and the resultant effects on the performance of horticultural crops. As mentioned previously, not much literature was found on the impacts of climate change on horticultural crops in Kenya. Hence, literature reviewed in this study focuses on the impacts on different crops (mainly horticultural) in various countries globally. This literature still shows how climate change significantly affects the performance of horticultural crops across a variety of climatic zones and that counties need to be better prepared to address these effects. Horticulture covers myriad crops (including fruits and vegetables), which are affected by climate change in different ways. In this chapter we examine how some of these crops are affected by increases in temperature and precipitation and by extreme weather events, as we look at possible adaptation strategies. We have used scientific as well as grey literature. The latter includes County Climate Risk Profiles (MoALF, 2017a–e) developed by the International Center for Tropical Agriculture (CIAT) in partnership with county governments. These were used to gather insights about some of the impacts of climate variability on horticultural crops in the different counties where these crops are considered key value chains in terms of production, economic value and/or food security. Alongside the interviews and surveys carried out in Kiambu and Kajiado, potential long-term changes in the climate were modelled (see Figure 2 and <http://www.climate-atlas.ke>; <https://www.climateadaptationservices.com/en/project/en/climate-services-for-smallholder-farmers-in-kenya/>; more detail will be published in a separate report on the development of the climate atlas).

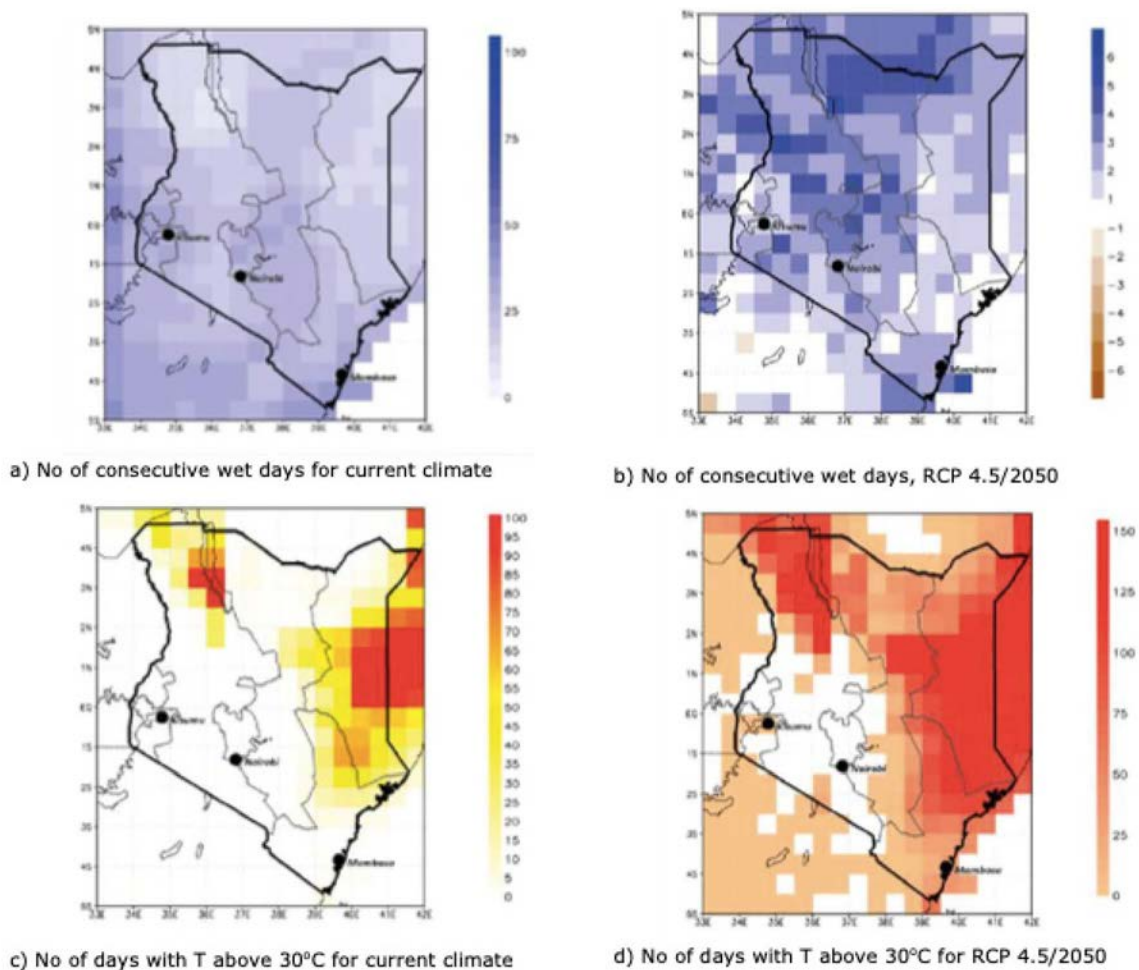


Figure 2 Scenarios from the climate atlas

3.1 Temperature

There is clear evidence of increasing temperature with the changing climate according to the IPCC fourth assessment report, which shows a 100-year warming trend globally in the period 1906–2005 (IPCC, 2007). Expected changes in temperature can also be seen in the Kenya Climate Atlas (<http://www.climate-atlas.ke>) developed under the 3R Kenya Project, Project and supported by the Copernicus Climate Change Service programme, which showcases climatic projections in 2050 and 2080 based on RCP 4.5 and 8.5. Increased temperatures have been observed by farmers in Embu in the months of January–March and August–October, mostly in the hot and dry semi-arid lowland areas. Since most living organisms, including horticultural crops, have optimum temperatures within which they grow and produce, these changes are likely to affect horticultural crops, positively or negatively. Additionally, other organisms that interact with the horticultural crops are likely to change as well with changes in temperature, which may mean that more pests and diseases may occur due to climate change. The following sections highlight some of the key effects of the changes in temperature on horticultural crops and how farmers can respond to them.

3.1.1 Seasonal crop patterns

One of the effects of temperature increases is the creation of unfavourable conditions for plant growth as temperature thresholds for specific crops are exceeded (Pathak *et al.*, 2018), as well as making some areas more favourable for growing certain crops, where previously temperatures were too low. This leads to farmers either shifting the growing seasons or changing to crops that are more suitable. For instance, Kenyan farmers and agriculture officials need to prepare for a possible geographic shift in maize production as climate change threatens to make some areas of the country much less productive for cultivation while simultaneously making other regions more maize-friendly (Odera *et al.*, 2013).

Temperature changes will also affect horticultural crops, especially perennial fruit trees, through frost and extremely high temperatures. Fruit trees may change the synchrony between the growth cycle and frost due to climate change (Singh, 2013). Temperature increases make it difficult for chilling requirements to be met. Crop failure is another phenomenon observed as a result of a change in temperature (Dosery *et al.*, 2012; Luedeling *et al.*, 2011; Thornton *et al.*, 2011). In mangoes, delay or advance of flowering as a result of extreme weather events and climate variability has been observed (Rajan *et al.*, 2013). Mango has vegetative bias, and this becomes stronger with increase in temperature, thus influencing the flowering phenology. Increased temperature and reduced rainfall also increase annual evapotranspiration, raising crops' water requirements. A study by Hesham *et al.* (2016) indicated that water requirements and water budget for maize, wheat and sugarcane will increase by 12–18% compared to current use. The same is expected to be true for horticultural crops. Possible adaptation strategies are the development of new crop varieties that are adapted to high temperatures at different parts of the season and are resistant to salinity and drought (Dosery *et al.*, 2012).

3.1.2 Yield and quality of crops

Changes in temperature affect yield and quality of horticultural produce (FAO, 2008, 2016; Esteve *et al.*, 2015). Higher temperature (31–32°C), in general increase the rate of plant maturity in banana, thus shortening the bunch development period (Turner *et al.*, 2007). High air temperatures (usually greater than 38°C) and bright sunshine cause sunburn damage on exposed fruits. In grapes, higher temperatures may advance the ripening of berries and alter the berry composition in both table and wine grapes, thereby affecting the quality of the produce (Sharma *et al.*, 2013). Reduction in yield of wheat due to high temperatures has been reported in Bangladesh; a key highlight from the study is that temperature has larger impacts on crop production than rainfall (Ochieng *et al.*, 2016).

Temperature can affect yield and quality through its effects on flower and ovary development, pollen germination and pollen tube growth kinetics (Dosery *et al.*, 2012). Tropical and subtropical crops respond differently to temperature compared with temperate crops (Verma *et al.*, 2013). In tomato, high temperatures can cause significant losses in productivity due to reduced fruit set, smaller size and low-quality fruits (Singh, 2013). This could be due to the reduced germination of pollen grains at high temperatures (Sato *et al.*, 2000).

Elevated temperatures have also been shown to affect the quality of horticultural crops through physiological effects (Shivashankara *et al.*, 2013) such as tip burn in lettuce, black heart in potato and translucent fruit flesh in pineapple. Exposure of tomato fruits to temperatures above 30°C suppresses many of the parameters of normal fruit ripening, including colour development, softening, respiration and ethylene production. High temperatures decrease vitamin C, starch, sugars and many antioxidants, especially anthocyanins and volatile flavour compounds in fruits (Singh, 2013). In cucumber, sex expression is affected by temperature, with low temperatures favouring female flower production, which is desirable, and high temperatures leading to production of more male flowers (Singh, 2013). High temperature drastically reduces tuber yield of potato which becomes a problem in areas where, due to an increase in temperature, the growing season is reduced (Haverkort and Verhagen, 2008). High temperature affects tuber quality by causing heat sprouting and internal necrosis. High temperatures limit both vegetative and reproductive growth of pepper fruit (Erickson and Markhart, 2001), resulting in significant losses in crop productivity (Thuy and Kenji, 2015).

3.1.3 Pests and diseases

Pests and diseases are also influenced by temperature, as it affects their range and distribution (Feehan *et al.*, 2009). Climate change is likely to cause changes in host physiology, the life cycle of pests and diseases and their interactions with control measures and weather (Chakraborty *et al.*, 1998). However, temperature-dependent life cycles, such as developmental time and responses to both cold and warming, will differ among and within species (Bentz *et al.*, 2010).

Emergence of new pests and diseases has been observed, with notable examples such as *Tuta absoluta*, the tomato leaf miner, and *Spodoptera frugiperda*, the fall armyworm. With the average temperature in many places in Africa being optimal for development and survival of *T. absoluta*, the pest is expected to pose a major challenge (Tonnang *et al.*, 2015) as has already been observed in many countries including Kenya. An increase in the number of generations of *T. absoluta* and reduced generation time is a result of increased temperature (Abolmaaty *et al.*, 2010). Increased temperature and CO₂ levels have potential to alter the life cycle, population distributions, virulence, susceptibility to insecticides, and phenological synchrony (Verghese *et al.*, 2013) with host plants of *T. absoluta*, which in turn will have profound effects on crop productivity. Elevated temperatures will drastically alter the occurrence of viral diseases through the altered biology of insect vectors. The increase in temperature will enhance vector population, thereby increasing the number of insecticide sprays needed to keep the vector population in check. Temperatures above the optimal for banana production (27–38°C) lead to infestation of sucking insects such as mites and aphids, as experienced in Embu county (MoALF, 2017a).

Increase in severe outbreaks of fungal and fungal-like diseases such as *Phytophthora* spp. and rusts has been observed in India (Chowdappa, 2010). The effect of elevated temperature on late blight (*Phytophthora infestans*) at a global level (Haverkort and Verhagen, 2008) revealed that with rise in global temperature of 2°C, there will be lower risk of late blight in warmer areas (>22°C) and higher risk in cooler areas (<13°C), with early onset of the epidemic. On the other hand, predictions indicate that for each 1°C increase in temperature, late blight can occur 4–7 days earlier, and the susceptibility period extended by 10–20 days.

3.2 Precipitation

Rainfall in Kenya is irregular and unpredictable. Droughts have become more frequent during the long rainy season, as have severe floods during the short rains. The arid and semi-arid areas are particularly hard hit by these climate hazards (MoALF, 2017a–e). In the coast and highlands, future projections indicate a likely increase in average rainfall (ranging between -3% and +28%), mainly from October to May (USAID, 2018). Changes in rainfall patterns have also been featured in the Kenya Climate Atlas mentioned earlier, which visualizes the impacts of climate change in a set of maps.

3.2.1 Seasonal crop patterns

The changing climate in many areas results in a change in rainfall. Apart from change of onset and increasing unpredictability of rain, precipitation intensity, duration and frequency have also been affected (Trentberth *et al.*, 2003). In many cases, this means a shortened growing period (Malhotra, 2017). Similarly in Kenya, both the rainfall pattern – that is, long and short seasonal rains – and intensity are changing, which has resulted in a decrease in yield (Huho *et al.*, 2012). In the dry Kajiado county (MoALF, 2017b), tomato is a key value chain and it is affected by moisture stress resulting from prolonged dry spells/drought, as well as intense rainfall events. The latter result in poor plant growth due to disruption of the planting programmes. For mango, a key value chain in Machakos county that is grown by 40–60% of the population (MoALF, 2017d), decrease in the stability of the growing season is one of the most problematic hazards. Although mango is a perennial crop, instability of the seasons in terms of onset and duration of the rains significantly reduces production.

3.2.2 Yield and quality

Anticipated water shortage as a result of reduced rainfall is a major driver of climate change effects on horticulture. For grapes, climate change may aggravate the already serious problems of irrigation water availability and salinity (Sharma *et al.*, 2013). Decrease in productivity from more than 25 tons/ha to 8.3 tons/ha during the year 2009–2010 and 11.7 tons/ha during 2010–2011 due to unseasonal rains was reported in India (Sharma *et al.*, 2013). Flooding also affects horticultural crops. High moisture conditions can have negative effects on plants because of oxygen deficiency due to a slow diffusion of gases in water. Flooding causes reduction in stomatal conductance (Folzer *et al.*, 2006) which leads to reduction in gaseous exchange and photosynthesis. It also reduces water uptake (Parent *et al.*, 2008) and transport of sugars within the plant (Yordanov *et al.*, 2000).

Heavy rains associated with climate change result in root damage and reduced yield, soil compaction from use of heavy machinery on wet soils, soil loss from erosion during heavy rain events, contamination of waterways from agricultural run-off and soil crusting (Ubuoh *et al.*, 2016). Flooded tomato plants accumulate endogenous ethylene, leading to rapid epinastic leaf response (Michael and Joan, 1976). Onion is sensitive to flooding during bulb setting, with yield losses of up to 30–40% (Malhotra, 2017). Bananas are highly intolerant to waterlogging and will be severely stunted after being flooded for more than 48 hours (Ravi and Mustaffa, 2013). Extreme rainfall in Kajiado county causes severe waterlogging and rotting of the banana suckers as well as disruption of farming activities during extreme rainfall events (MoALF, 2017b). Moisture stress is another problematic climatic hazard in dry Machakos county. Although the green gram grown there is drought-resistant, moisture stress inhibits the germination and flowering of the crop, resulting in poor quality yield (MoALF, 2017d). Drought poses a serious threat to even the wetter areas of Kenya, such as Kericho county, where banana is grown for both subsistence and commercial purposes by 41–60% of the population. Drought affects sprouting of the suckers, which lowers production (MoALF, 2017c), and high temperatures affect fruit quality by leading to rapid ripening before the produce reaches the market. Bananas graded as unripe/green at the farm would be ripe on arrival at the market/collection centres.

Moisture stress and drought also cause wilting and consequently reduced quantity and quality of local vegetables grown in Kericho county, particularly the African nightshade and spider plant, which are the most popular local vegetables in the county and are grown by 61–80% of the population under small-scale farming. Moisture stress also leads to wilting and deformity of tomatoes, leading to reduced yields that also affects the formation of seeds, as is the case in Embu county where farmers mostly rely on rain-fed agriculture (MoALF, 2017a).

3.2.3 Pests and diseases

Factors such as increased cloud cover, high relative humidity and heavy dew favour outbreak of insect pests and diseases. For instance, higher incidences of spear rot and bud rot diseases in coconut during rainy seasons have been reported (Rupa *et al.*, 2013). Increase in the incidence and frequency of insect pests of grapes such as mealy bug, thrips and mites due to changes in precipitation and serious

downy mildew incidence as a result of increased relative humidity have been reported (Sharma *et al.*, 2013). On the other hand, soil-borne pests and pathogens are likely to be negatively affected by increased flooding (Verghese *et al.*, 2013). As fungal pathogens of insects thrive under high humidity, increased periods of higher relative humidity and wetness could promote their development (Verghese *et al.*, 2013).

Moisture stress, which is a critical climatic hazard in Kajiado county as mentioned earlier, increases cases of pests and diseases and presents good conditions for the proliferation of fungal diseases such as powdery mildew, bacterial wilt and early and late blight, which attack tomatoes (MoALF, 2017b). Weeding and spraying cannot be carried out when there is moisture stress. Fewer seedlings will germinate, which leads to reduced plant population. Those that do germinate and mature are few and produce small tomatoes that fetch lower prices at market. Flash floods from intense rain often wash away fertilizers and pesticides, resulting in high production costs. This happens in Mandera county, which occasionally experiences flash floods (MoALF, 2017e).

4 Policy frameworks for driving a resilient horticulture sector in Kenya

This chapter looks into key policy instruments at county and national levels that can help explain how climate change issues are integrated in agriculture sector development, focusing on horticulture. It first describes how counties are building resilience in the horticulture sector. Then some detail is given about the link between county policy frameworks and the national and global climate agenda.

At the county level, operationalization of devolution is the vehicle for county governments to act with regard to both the horticulture subsector and climate change resilience. It is vital to note that the mandate to formulate national overarching governance frameworks, including national policy and enabling legal instruments, still remains with the Government of Kenya (GoK). In this sense, national legal instruments, including policy and legislative mechanisms relating to climate change resilience and horticulture, prevail over county instruments.

4.1 Review of the County Integrated Development Plans

The CIDPs are key policy documents that aim to guide county developmental interventions with regard to the various sectors of the economy. As critical county policy instruments, CIDPs are framed to chart the sustainable development pathways of each county and at the same time align national and county development agendas. The CIDPs lay out the priority issues and interventions in key sectors that the counties depend on for sustainable and equitable socioeconomic development. The sectors include agriculture, which remains a pillar for development in each country.

The CIDPs of eight selected counties were reviewed to understand the extent to which climate change is recognized as a threat to the agricultural sector, and specifically to horticulture, which is a priority sector for these counties. First, an analysis of the ecological and climatic characteristics was made, apart from for Kajiado and Nyeri counties, which did not provide any data on their ecological zones (Table 3). The selected counties are spread along the arable ecological zones, although it was also noted that counties use different systems of naming these zones and that there is a need to establish a harmonized system for naming the zones used in the CIDPs. The temperatures in the counties is in the range 7–34°C, while rainfall is in the range 300–2500 mm and is bimodal in all eight counties.

Table 3 Ecological and climatic characteristics of selected counties

County	Altitude (m above sea level)	Ecological zones	Temperature (°C)		Rainfall		
			Min.	Max.	Long	Short	Total amount
Kajiado	500–2500	Not available	10	34	March–May	October–December	300–1250
Kiambu	1200–2500	Lower highlands, Upper highlands, Upper midlands	7	34	Mid-March– May	October–November	600–2000
Kirinyaga	1158–5380	Highlands, Lowlands, Midlands	8	30	March–May	October–November	1212–2146
Meru	300–5199	Upper highlands, Lower highlands, Upper midlands, Lower midlands	8	32	Mid-March–May	October–December	300–2500
Nakuru	900–2700	I (Agro-Alpine) III (Medium potential) IV (Semi-arid)	12	29	March–May	October–December	500–1500
Nyandarua	up to 3999	Highland savanna	12	25	March–May	September–December	700–1600
Nyeri	3076–5199	Not available	13	21	March–May	October–December	500–1600
Uasin Gishu	1500–2700	Lower highlands, Upper highlands, Upper midlands	7	29	Rainfall is distributed through the year	March, May, August and September	625–1560

Source: CIDPs of each county

Forests and water bodies directly influence rainfall patterns, including water availability and its sustainability. According to the Forest Policy 2014 (GoK, 2014), there should be 10% forest cover in all counties. Of the eight counties, five (Kiambu, Kirinyaga, Meru, Nyandarua and Nyeri) have more than 10% forest cover, and Kajiado has forest cover of less than 1% (Table 4). Most counties noted the reduction of water levels in the various rivers and lakes and drying of swamps and dams.

Table 4 Forests and waterbodies

County	Forests			Major rivers and waterbodies
	Major forests	Area (ha)	%	
Kajiado	Ngong Hills, Loitokitok, Namanga, Embakasi, Oloolua	16,867	0.77	L. Magadi
Kiambu	Kieni and Kinale forests	47,630	18.73	Nairobi, Gitaru, Gitathuru, Karura, Makuyu, Ruirwaka, Gatharaini, Riara, Kiu, Kamiti, Ruiru, Bathi, Gatamaiyo, Komothai, Thiririka, Ndarugu
Kirinyaga	Mt. Kenya Forest, Njukiini, Murinduku, Kariani, Kamuruana	35,876	24.27	Sagana, Nyamindi, Rupingazi, Thiba, Rwamuthambia and Ragati
Meru	Mt. Kenya Forest, Imenti	177,610	25.61	11 permanent rivers with the major one being the Kathita River
Nakuru	Menengai, Mbogoini, Solai, Mau, Bahati, Subukia, Eburru, Dundori	67,964	9.07	L. Nakuru, L. Naivasha, L. Elementaita, R. Njoro, Makalia, Molo and Malewa
Nyandarua	Ndaragwa, Ol' Bolossat, Geta, North Kinangop, South Kinangop, Muruai, Kirima, Mawingo, Salient, Malewa	49,916	15.38	Malewa, Ewaso Narok, Chania, Kiburu, Mkungu, Kitiri, Pesi, Turasha
Nyeri	12 gazetted forests, including Aberdare, Mt. Kenya, Karima, Nyeri and Tumutumu	86,170	25.82	R. Sagana, Ragati, Chania, Gura and Nairobi
Uasin Gishu	Lurenge, Cengalo, Kapsaret, Kipkurere, Timbaroa, Nabkoi	29,802	8.91	Sosiani, Kipkaren, Nderugut, Daragwa, Sambu, Kerita

In relation to crop production, maize was noted as the dominant crop grown in all eight counties (Table 5). This is followed by beans grown in six counties. Horticultural crops are grown in all the counties and include onions, potatoes, tomatoes, mangoes, watermelons, bananas, citruses. Only Nyandarua and Nyeri indicated cut flowers as major crops. Kiambu and Meru indicated horticultural products without specifying which specific crops are referred to.

Table 5 Main crops

County	Main crops
Kajiado	Beans, maize, onions, potatoes, tomatoes
Kiambu	Beans, horticultural products , maize, peas, potatoes , pyrethrum, vegetables
Kirinyaga	Bananas , beans, coffee, green grams, maize, mangoes , rice, sugar cane, tea, tomatoes, watermelons
Meru	Bananas , beans, citrus , coffee, cow peas, horticultural products , maize, mangoes , miraa, pigeon peas, tea, wheat
Nakuru	Barley, beans, carrots , finger millet, French beans , maize, onions , pigeon peas, potatoes , pyrethrum, sunflowers, tomatoes, wheat
Nyandarua	Cabbages, carrots, cut flowers, kale , maize, pears , peas, plums, potatoes , pyrethrum, spinach , wheat
Nyeri	Beans, coffee, cut flowers, French beans, Irish potatoes , maize, sunflowers, tea, vegetables , wheat
Uasin Gishu	African indigenous vegetables, avocados , barley, cabbages, carrots, kale , maize, passionfruit, potatoes , pyrethrum, sunflowers, tomatoes , wheat

Crops in **bold** are the horticultural crops mentioned in the specific CIDPs.

According to the Kenya National Climate Change Action Plan, 2013-2017, Kenya is required to submit biennial reports and national communication every four years about climate actions – whether mitigation or adaptation under the Cancun Agreement – at the county level will be communicated to the national level to form part of the national monitoring, reporting and verification system. County climate actions are expected to form part of national actions and contribute to the climate change agenda. The way climate change and its effects on the agricultural sector is perceived at the county level, and how some of the response measures are articulated, is summarized in Table 7 except for Uasin Gishu county, as no information was given in the CIDP.

The most common reference to climate change in the CIDPs was about failed or erratic rainfall, including flooding and temperature extremes. For example, frost was noted in six of the CIDPs. Some of the noted effects were crop failure, increase incidence of crop pests and a decrease in food productivity. The decrease in productivity is quite notable and varies for different crops. Other noted effects include loss of biodiversity, changes to wildlife migration patterns and an increase in diseases affecting humans, such as malaria and waterborne diseases that were noted in two counties.

Box 3. Horticulture plays a key role in county development

Horticulture is a high value subsector that plays a major role in generating revenue for county development. Most counties have prioritized horticulture in their CIDPs and made substantial investment, such as providing greenhouses, training youth, and developing postharvest handling and marketing infrastructure such as bulking centres and market stalls.

The CIDPs outline various policy-directed responses to climate change effects. All the counties seemed to be encouraging tree planting (through agroforestry and afforestation) as a response to climate change. Responses specific to agriculture include use of drought-resistant crops (noted in three counties) and promotion of climate-smart agriculture (CSA) technologies (noted in Nyeri county).

Climate change is acknowledged in the CIDPs as a threat to different sectors, but there is only scant analysis of the factors causing it, effects it will have and proposed responses to it. This is true of its effect on agriculture in general, let alone on horticulture or other specific subsectors. Counties are expected to develop detailed plans of how to promote sustainable agricultural sector development; in the absence of these plans, we find the lack of consideration of climate change in the CIDPs is a

challenge to be addressed. An important consideration, though, is that climate change is embedded in national and global policy frameworks to which counties need to align. In the next section we analyse how these frameworks can guide counties in relation to agricultural sectors such as horticulture.

Box 4. Horticulture development faces serious challenges from climate change

Counties have identified various impacts of climate change and proposed intervention measures. However, the interventions are not based on local data and are not specific to expected climate change scenario hence may not effectively address climate impacts on horticulture.

Table 6 Climate change indicators noted in CIDPs and planned responses in the various counties

Climate change indicators and effects*	Planned response
<u>Kajiado</u>	
<ul style="list-style-type: none"> • Crop failure (more than 90%) • Erratic rainfall, less rainfall • Extreme temperatures • Flash floods and very strong winds • Unpredictable weather 	<ul style="list-style-type: none"> • Agroforestry • Use of drought-resistant crops
<u>Kiambu</u>	
<ul style="list-style-type: none"> • Unpredictability of the timing and intensity of rainfall • Increased flooding • Prolonged dry spells 	<ul style="list-style-type: none"> • Afforestation • Agroforestry • National soil and water conservation programme • National Environment Management Authority (NEMA) ensuring factories treat their effluents • Good agricultural practices • Educate farmers about the effect of climate change • Adopt modern farming technologies such as greenhouses, drip irrigation
<u>Kirinyaga</u>	
<ul style="list-style-type: none"> • Change in weather patterns • Decreased rainfall • Disease prevalence • Erratic rainfall • Increase in malaria • Rise in temperature • Recession of glaciers on Mt. Kenya 	<ul style="list-style-type: none"> • Afforestation • Construction of water pans • Distribution of malaria nets • Promotion of drought-resistant crops • Public education on environmentally friendly technologies • Special projects: <ul style="list-style-type: none"> i. Provision of woodlots ii. River-line tree planting and rehabilitation of degraded catchment areas
<u>Meru</u>	
<ul style="list-style-type: none"> • Drying of rivers • Erratic rainfall • Failure of rainfall • Increase in temperature • Migration of wildlife 	<ul style="list-style-type: none"> • Community sensitization • Implementation of environmental laws • Reclamation of wetlands • Reforestation • Special projects: <ul style="list-style-type: none"> i. Carbon credit trading by Africa Carbon Exchange
<u>Nakuru</u>	
<ul style="list-style-type: none"> • Decline in water volumes • Erratic rainfall • Extreme temperature • Loss of biodiversity • Reduction in agricultural productivity • Unpredictable migration of flamingos 	<ul style="list-style-type: none"> • Agroforestry • Protection of water catchment areas and forests • Special projects: <ul style="list-style-type: none"> i. Promotion of community participation in tree planting
<u>Nyandarua</u>	
<ul style="list-style-type: none"> • Crop failure • Decrease in food production • Drought • Erratic rainfall • Extreme temperature leading to frost at night • Incidence of malaria in an area previously considered malaria-free • Reduced livestock production (dairy and beef) 	<ul style="list-style-type: none"> • Enforcement of laws regarding encroachment of rivers banks, forests and wetlands • Planting drought-resistant crops

Climate change indicators and effects*	Planned response
Nyeri	
<ul style="list-style-type: none"> • Proliferation of thrips causing great crop loss • Prolonged and cyclic drought and famine • Reduction in pasture • Reduction in productivity: potatoes (40%), wheat (70%), sunflowers (30%) and horticultural beans (40%) • Soil black worm infestation • Temperature extremes 	<ul style="list-style-type: none"> • Agroforestry • Building partnerships • Creating awareness • Institutional capacity-building • Promoting climate-smart technologies in agriculture • Proposed regulations: <ul style="list-style-type: none"> i. Carbon footprint policies ii. Mainstreaming of climate change iii. Payment for ecosystems services iv. Pricing of natural resources • Research and development unit whose role is to: <ul style="list-style-type: none"> i. be the advisory body to the county ii. conduct trials on drought-resistant crops iii. investigate carbon credit possibilities, mandate and or recommend adoption and or stoppage of technologies, species and practices iv. keep track of climate change v. map cropping and energy technology • Special projects: <ul style="list-style-type: none"> i. Ethnobotanical surveys and appraisal of specific Non-Wood Forest Products (NWFP) as potential contributors to rural development ii. Nyeri climate change policy framework

* As no mention was made of climate change in the CIDP of Uasin Gishu, this county is not included in this table.

4.2 National policy and strategies for building climate resilience

National policy documents prioritize agriculture as one of the low-carbon development sectors but remain generally vague on horticulture. The plans mainly identify CSA as being the key option for horticulture and propose technological interventions such as greenhouse farming and drought-resistant seeds as ways to drive resilience in the agriculture sector (GoK, 2018a). The Kenya Climate Smart Agriculture Implementation Framework (GoK, 2018b) makes no mention of specific horticulture-related intervention. The NCCAP (GoK, 2018a) only mentions horticulture in terms of reduced productivity of horticulture commodities for export. The horticulture sector taps into both international and domestic markets; enhancing such trade could be an opportunity to finance climate resilience.

National climate change policies have also not adequately integrated with other policies that aim to promote productivity and investment in the horticulture sector, such as the National Policy on Water Resources Management and Development – Sessional Paper No. 1 (1999), the National Irrigation and Drainage Policy (2007) and the National Disaster Management Policy (2009), all of which seek to support resilience in agriculture and other key sectors. This means that most climate change provisions could be viewed from a relatively narrow perspective, missing opportunities available in the system-wide approach that considers, for example, investment and social systems. Instead, policies have mainly been aligned to the global discourse, but it may be difficult for counties to apply these to the local context. There is a need for intentional and tailored capacity support to the counties on how to do this. Technical capacity to pursue climate change investment funds through, for example, the National Adaptation Fund and the Green Climate Fund, is critical for counties to develop resilient business models and climate change finance policy and legislation to attract more finance. It is worth noting that at the national level there are relatively well-established systems, institutions, departments and expertise which would benefit from a more targeted and tailored approach to resilience-building.

Box 5. Evidence on what works or not is required to inform policies on resilient horticulture

Climate change is a national function. Counties mainly draw evidence from the national level climate policies to develop climate resilient actions at the county level. There is need for evidence on what technologies, activities, projects work or not to inform effective policies and programmes for horticulture. Ongoing climate actions undertaken by various stakeholders e.g. NGOs within counties could generate lessons on what is feasible and inform the development of robust and inclusive climate resilient programme for the horticulture sector.

5 Climate change perceptions and preparedness in Kiambu and Kajiado counties

This chapter presents the findings of interviews with key informants and the FGDs with selected farmers in Kiambu and Kajiado counties. Farmers and agricultural staff were asked about their perceptions of climate change and its effects on horticulture value chains as well as the adaptation measures being implemented by farmers. Their responses help in identifying gaps that can be addressed to strengthen policy frameworks and responses to climate change in the horticulture sector. The interviews and FGDs also revealed the extent to which farmers receive government support for adaptation/mitigation measures related to the noted effects of climate change. Kiambu and Kajiado counties were selected for their agroclimatic differences, with Kajiado being drier than Kiambu, and for their climate change indicators and planned responses according to their two CIDPs. Table 8 shows the change in county policy from 2013 to 2022, with additional crops included in the latest CIDP for illustration.

CIDPs covering the period 2018–2022 are now in place. The biggest change in the current CIDP compared with the previous one has occurred in Kiambu county, where the county government established a department of energy and climate change (currently called “Water, Environment Energy & Natural Resources (<https://kiambu.go.ke/water-environment-natural-resources/>) in February/March 2018 to facilitate integration of climate change into county sector plans, programmes, policies, legislation and strategies. Recruitment of climate change officers has started. The Kiambu county government strategy to tackle climate change shifted from entrusting the responsibility to national government bodies like NEMA, to taking charge of the task by proposing to establish a county environment committee, realigning the county development model to be more climate resilient in terms of lowering greenhouse gas emissions and encouraging use of green energy. The county also proposes afforestation and reforestation campaigns and implementation of principles like ‘User pays and polluter pays’. The change in Kajiado CIDP is smaller, with a shift from activity-based responses towards more policy-related responses. Kajiado county has initiated consultation on formulating a county climate change policy and has budgeted for CSA. For Kiambu this is not directly clear from the CIDP but might be included under other activities.

Other ongoing initiatives supporting the process of mainstreaming climate resilience within the county policies include initiatives from the United Nations Development Programme and CARE Kenya. Further discussion with county officials of Kiambu and Kajiado counties revealed that a number of policy initiatives are coming to address climate change, such as establishing county climate change directorates and a climate change investment fund. While there does seem to be a desire to establish climate action in the counties, the processes seem to focus more on the national-level systems that are the source of most interventions and funding opportunities.

According to the county resource people consulted, the CIDPs were done in a hurry to meet the basic requirement to access county finance allocation from the national government. They believed most of the fundamental climate-resilient building blocks were not captured in the CIDPs. This is evident in Kiambu county, where they did not have a separate department of climate change and energy in the period of the first CIDP (2013–2017), only establishing one and appointing a director in 2018. The counties are using the national climate smart strategy to facilitate integration of climate change and resilience-building in the horticulture and, more broadly, the agriculture sector, but they face huge challenges because this strategy does not address their contexts. This potentially represents policy deficit which – as discussed later – manifests in the experiences of farmers who noted lack of government support as key impediment to resilient horticulture.

Table 7 Comparison of the first and second CIDPs for Kiambu and Kajjido counties

Aspect	Kiambu		Kajjido	
	2013–2017	2018–2022	2013–2017	2018–2022
Major economic activities and main crops*	Industrial crops farming Beans, horticultural products, maize, peas, potatoes, pyrethrum, vegetables	Industrial crops: coffee and tea . Maize, beans, Irish potatoes, bananas, vegetables, pyrethrum and peas	Pastoralism, wildlife, tourism Beans, maize, onions, potatoes, tomatoes	Main crops: maize, beans, Irish potatoes, tomatoes, capsicum, watermelon , cow peas , vegetables and bananas
Rainfall	600–2000 mm; rainfall is bimodal	Relatively wetter, with bimodal rainfall. Short rains: October–November; long rains: mid-March–May. Annual rainfall: 600–2000 mm	300–1250 mm; rainfall is bimodal	Relatively drier with bimodal rainfall. Short rains: October–December; long rains: March–May. Annual rainfall: 300–1250 mm
Temperatures	7–34°C	7–34°C (cooler period: July–August; hotter period: January–March)	10–34°C	10–34°C (cooler period: July–August; hotter period: November–April)
Climate change indicators	<ul style="list-style-type: none"> - Unpredictability of the timing and intensity of rainfall - Increased flooding - Prolonged dry spells 	<ul style="list-style-type: none"> - High spatial and temporal variability of rainfall - Change in water levels of glacier 	<ul style="list-style-type: none"> - Crop failure (more than 90%) - Erratic rainfall / less rainfall - Extreme temperatures - Flash floods and very strong winds - Unpredictable weather 	<ul style="list-style-type: none"> - Drought, flash floods and winds - High spatial and temporal variability of rainfall - Change in water levels
Planned response	<ul style="list-style-type: none"> - Afforestation - Agroforestry - National soil and water conservation programme - NEMA ensuring factories treat their effluents - Good agricultural practices - Educate farmers about the effects of climate change - Adopt modern farming technologies e.g. greenhouses, drip irrigation, etc. 	<ul style="list-style-type: none"> - Institutionalize legislative arrangements that govern climate change actions; establish the county environment committee Emca.No.8 of 1999 REVISED 2016 (29). - Facilitate public participation awareness, access to information, ownership and oversight of county's climate change response efforts and action plans. - County government building partnerships with various stakeholders from the public, government, NGOs, civil society and the private sector, as well as vulnerable communities and populations including women and youth, to achieve effective implementation of this goal. - Realignment of county's development model to one that is climate-resilient, based on lower greenhouse gas emissions, and takes full advantage of the green economy. - County accessing international finance for ambitious climate-resilient and low-emission development programmes. - Ensure that all sources of finances are mobilized: international, domestic, public and private, including through public-private partnerships. - Afforestation and reforestation campaign - User pays and polluter pays principles. 	<ul style="list-style-type: none"> - Agroforestry - Use of drought-resistant crops 	<ul style="list-style-type: none"> - Enhance agricultural production by investing heavily in irrigation, modern farming technologies, climate change initiatives and the hay production project, as well as reducing post-harvest losses - Scale up CSA practices - Training/awareness creation in the community; legislators and officers on climate change mitigation, adaptation, impact reduction and early warning - Creation of a climate change unit in every county department - Investing in renewable energy such as solar and biogas - Develop a county climate change policy resource mobilization plan for climate change - Support the establishment of environmentally friendly industries
Budget allocation for climate in agriculture		No specific budget allocation		Kenya Climate Smart Agriculture KES 468 million

(*additional crops in the 2018–2022 CIDPs not featured in the 2013–2017 CIDPs highlighted in **bold**)

Sources: Kiambu CIDPs 2013–2017 and 2018–2022 and Kajjido CIDPs 2013–2017 and 2018–2022

Kiambu and Kajiado counties are yet to develop climate change plans, policies, strategies and legislation. Some detail about climate change was captured in the CIDPs; however, respondents felt that it was not given sufficient attention and treatment because other priorities needed to be addressed. As mentioned previously, there is a limitation to using the national CSA strategy at the county level because it does not capture the local context. The process of making climate change policy suit the context of the county is yet to begin.

5.1 Perception of farmers and agricultural staff on climate change and its effects

FGDs carried out in Kiambu and Kajiado counties showed that farmers and extension staff have already experienced climate changes effects. They mentioned in particular the increase in temperature and reduction in rainfall. However, they could not clearly distinguish between the effects of high temperature and those of drought. Most farmers associated climate change only with reduced rainfall, not with more rainfall. None of the farmers or extension staff had had training about climate change and its effects, which may explain why they only partially understand how these weather effects are associated with climate change. This partial understanding may also hamper their ability to respond to the problem.

Farmers and extension officers in Kiambu and Kajiado unanimously agreed that weather extremes and climate variability and change are affecting horticultural farming. The challenges they face include unreliable and unpredictable rainfall patterns, prolonged dry periods, frost and emergence of new and intense pest and disease attacks on crops. Some emerging pests, such as *Tuta absoluta* and fall armyworm were indicated as possible outcomes of climate change. In Kajiado, respondents noted that prolonged dry periods and the emergence of new and increased pest and disease attacks on crops are the primary challenge, while in Kiambu, unreliable rainfall is the major threat to horticultural farming.

Contrary to expectations, there was hardly any government initiative to support farmers in dealing with climate change effects, despite emphasis placed on horticulture for county development. Farmers in Kajiado are used to dry conditions, so perceive climate change as more disastrous; they have taken some measures, such as investing in sinking boreholes. Kiambu farmers, however, are more used to relying on rainfall and are therefore less prepared to deal with climate change impacts.

Despite the limited government support, the farmers are very passionate about horticultural farming. More than two-thirds are small-scale farmers growing common horticultural crops, such as tomatoes, beans, kale, cabbages and spinach. Farmers acknowledged that these crops are emerging as high-value crops that can spur more business opportunities and generate more household income than conventional crops, such as maize. Farmers associate horticulture crops with shorter maturity timespans compared to conventional crops such as cereals, hence are more attractive in the unreliable climatic conditions and markets for the conventional crops. Further, with demographic pressure and shrinking land sizes, significant areas of farmland in Kiambu and Kajiado are being converted to residential estates. Farmers feel that horticultural farming can still thrive in such land-use transitions by embracing new technologies such as greenhouses, which require relatively smaller parcels of land.

Farmers' views confirmed policy assertions that climate change remains the greatest threat to the horticulture sector (Matui *et al.*, 2016). Severe impacts of climate change experienced include unreliable rainfall, prolonged droughts and emergence of pests and insects. Farmers noted that prolonged droughts means they need to have a faster turnover, as it leads to decreased availability of water, especially when seasonal rivers run dry for longer periods. Prolonged droughts have also increased competition for limited water resources between various uses, such as domestic use versus irrigation in Kiambu and crops versus livestock in Kajiado. Experiences in Kiambu and Kajiado also show that climatic change effects are making pests more tolerant to pesticides. Impacts of climate change have also been identified in infrastructure and marketing. Few roads in the counties are suitable in wet weather and are easily damaged by flash floods during unexpected heavy rainfall, which limits access to markets. Farmers reported large post-harvest losses, which are compounded by

the short shelf life of most horticultural produce. It is also important to recognize that there are interactions and co-dependencies surrounding resilience of horticultural farmers and their broader socioeconomic conditions. Horticulture is not only a food security asset; it is also a business asset representing income, savings, security and social status of households, community, the county and the country. Losing horticultural productivity and associated assets to climate risks represents an economic and social disaster at the household level and national level. Adaptation measures need to be cognisant of these interdependencies across scales.

5.2 Preparedness for climate change

5.2.1 Adaptation

In both Kiambu and Kajiado, farmers already implement adaptation measures in response to changing weather conditions. Findings from this study (Appendix 2) indicate that the most common measures include multiple cropping and adjusting sowing and harvesting dates to increase the chance of success. However, most farmers are still limited in the measures they are able to take, mainly due to financial restraints and lack of knowledge, with the latter resulting in them implementing incorrect adaptation measures for a given climate change effect. For example, they may purchase greenhouses without knowing if this is the best option to address particular climate change effects or not. One measure they would like to take is to install drip irrigation systems to increase their water use efficiency, though most interviews and discussions with farmers indicated they do not have the financial capacity to set these up. The farmers were also not aware of the actual costs of these systems, which are lower than they mentioned. This indicates that it is important to educate farmers about the actual cost of the various technologies so they can make informed decisions.

In the interviews, it was noted that the government, NGOs and the private sector distribute improved technologies, such as tunnels and drip irrigation systems, and water-efficient seeds to farmers to help them produce better yields even with the unpredictable weather and climatic conditions. According to the interviewed farmers and stakeholders, these technologies are deployed as adaptation strategies. Integrated pest management (IPM) is being promoted to reduce costs of inputs and manage pesticide resistance, while irrigation systems such as drip irrigation, water pans and dams remain an important resilience-building option being pursued by farmers and stakeholders.

Social pooling is also used. For example, women farmers have organized themselves into groups to pool their savings into forms such as table banking, which enables them to access small sums on credit for purchasing inputs and deploying climate strategies. Overall, adaptation behaviours highlighted by small-scale horticulture farmers were largely localized, with participants identifying very limited opportunities for adaptation beyond their immediate environments. Most small-scale farmers we spoke to felt they had very limited access to sustainable adaptation strategies, such as business and climate insurance products and other savings safety nets, which are increasingly part of broader climate change adaptation trends (Mahul and Stutley, 2010). A key observation about adaptation efforts is that the women farmers had very deep understanding of adaptation needs that could spur entrepreneurship and support household livelihoods at the same time, with most female interviewees and FGD participants demonstrating insightful knowledge about key livelihood needs, assets, opportunities and stressors.

The interviewed agricultural extension workers indicated that they are advising farmers to plant earlier and use fast-maturing cultivars in response to climate change. Other recommended measures include planting trees, using IPM and rainwater harvesting. Staff members indicated that some of the reasons farmers may not take up these adaptation measures are lack of knowledge and capital. Farmers also need to be trained to understand climate change and how to respond to it.

5.2.2 Government support

The interviews farmers said they do not receive sufficient government support for horticultural crop production in general, nor particularly for addressing the adverse effects of climate change, although this support is greatly needed. Assistance is mainly needed in water and pest management, which are the biggest challenges for horticultural farmers. Such support might include subsidies to lower prices for water pumps or irrigation systems and provision of better and cheaper chemicals and technical training to control pests more easily. This would help farmers to bridge the yield gap and boost horticultural production, allowing them to better compete in the market. Farmers also indicated they need government support to deal specifically with *Tuta absoluta*, as this pest species is the most problematic.

Farmers have explored financing mechanisms, such as bank loans, government-administered enterprise funds for youth and women, as well as microfinance institutions to help in the purchase of inputs and adoption of climate-smart strategies. However, farmers face challenges with these financing options, such as lacking collateral to secure loans. The challenge is greater for women, whose sociocultural gender roles around resource use and access confine them to informal settings where they experience higher exposure to climate risk as well as additional barriers to building resilience within their business activities. These include reduced access to land, capital, markets, new technology and educational opportunities. Furthermore, the uncertainty due to climate change has increased the risk of using financing mechanisms to fund horticulture production.

In contrast to the opinion of the interviewed farmers, the extension staff mentioned that farmers do get support from the government in several ways, including through provision of early-maturing seeds and tree seedlings. Moreover, the government also provides support by digging water pans. This mismatch in understanding between the two groups could mean that farmers are unaware of the opportunities available to them, hence there is need for better communication between farmers and county governments on opportunities they could explore in adapting to the effects of climate change.

5.3 Potential responses to predicted changes in the climate

The probability of increases and decreases in drought, flood, temperature, humidity, sunshine and wind speed were assessed through modelling (Table 8). Crops officers from the two counties where FGDs were held indicated the potential impact of the predicted changes on farmers' practices and the potential adaptation measures (Table 8). CIDPs and farmers' adaptation practices need to take into account the expected climatic conditions when formulating adaptation measures. The Kenya Climate Atlas can support these farmers, as it aims to feed into the CIDPs, to fill in some of the gaps and prevent a mismatch of expected climate hazards with the adaptation measures proposed by the counties. For instance, from the interviews it was noted that the impacts of increased temperature and rainfall intensity have not received much attention, yet they are forecast in the Kenya Climate Atlas as posing a threat to the counties.

Box 6. Resources and lessons on best practices are required to promote the implementation policies at the county level

Counties could tap into existing global and national funds such as green climate fund, world climate smart agriculture framework among others but this require technical capacity in counties to develop actionable projects and interventions the green climate fund offering financial and technical support for resilient agriculture.

Table 8 Impacts of various climatic hazards on farming practices in Kiambu and Kajiado, and potential adaptation measures

Condition			Climate models predicting	Expected hazard	Potential adaptation measure
Drought probability					
Aridity (actual)	Decrease	Decrease	Many models	<ul style="list-style-type: none"> Reduced production, leading to higher prices Increase in pests The scarcity of water for irrigation Increase in theft because of scarcity and high prices 	<ul style="list-style-type: none"> Use water-efficient irrigation methods Mulching Water harvesting in the wet season
Average rainfall	Increase	Increase	Many models	<ul style="list-style-type: none"> Increase in yield of vegetables leading to low prices and market saturation Increase in diseases Problems with infrastructure – i.e. roads affected by rain Increase in post-harvest losses 	<ul style="list-style-type: none"> Integrated pest management Value addition Staggered planting (better production planning) Storage facilities Greenhouses Forecasting/warning systems Soil conservation measures Water harvesting Investment and priorities to roads Value addition Storage facilities Timely and proper harvesting
- Rainfall Nov–May	Increase	Increase	High		
- Soil moisture Nov–May	Increase	Increase	Many models		
- Soil moisture and rainfall during the dry period	Decrease	Decrease			
Flood probability					
- Discharge	Increases in April/May	Increases in April/May	Many models		
- Run-off	Increases in April/May	Increases in April/May	Many models	<ul style="list-style-type: none"> Soil erosion Leaching of nutrients Contamination of water bodies 	<ul style="list-style-type: none"> Soil conservation measures
Temperature > 30°C	Slight increase	Increase		<ul style="list-style-type: none"> Temperature too high for some horticulture crops Low labour productivity (active working time) High fruit abortion Increase in pests 	<ul style="list-style-type: none"> Grow different crops Adapted varieties Shade house/netting
				<ul style="list-style-type: none"> Reduced water use efficiency Increase in post-harvest losses Plant development is faster, leading to reduced yield 	<ul style="list-style-type: none"> Two crops in one season
Humidity	Slight increase	Slight increase		<ul style="list-style-type: none"> Increases in diseases 	
Sunshine	Very slight decrease	Very slight decrease			
Wind speed	Very slight decrease	Very slight decrease			

6 Conclusions and recommendations

6.1 Climate change and its effects on the horticulture sector

- According to both the literature and the interviews with respondents in Kiambu and Kajiado counties, weather extremes such as drought and flooding as well as temperature increase and variability in precipitation have had negative effects on horticultural crops.
- Despite farmers and extension staff being aware of climate change in terms of increase in temperature and reduction in rainfall, they could not clearly distinguish the effects of high temperature from those of drought.
- The literature has provided evidence that temperatures above the optimum for growth of horticulture crops result in negative impacts such as impeded plant growth, reduction in yield (and quality) resulting from physiological effects of climate change and increased incidence (as well as emergence) of pests and diseases.
- According to both the literature and the interviews with farmers and extension staff in Kiambu and Kajiado counties, water shortage due to reduced rainfall has already had, and is expected to have further, detrimental effects on horticulture and result in yield loss. Most farmers associated climate change with reduced rainfall and identified prolonged dry periods as a major challenge they face as a result of climate change. According to respondents interviewed, prolonged droughts have increased competition for limited water resources between various uses.
- Soil compaction from use of heavy machinery on wet soils during flooding and erosion resulting from heavy rains also have negative effects on growth and production of horticultural crops, resulting in yield loss and reduced quality. Variability in precipitation also affects the distribution of pests and diseases that attack horticultural crops, with some diseases and soil-borne pests and pathogens, such as fungal pathogens of insects, thriving under high humidity and wet conditions.

6.2 Preparedness for climate change and government support

- Findings from this study indicate that the most common measures implemented in both counties to address climate change include multiple cropping and adjusting the sowing and harvesting dates to increase the chance of success. Other measures include early planting, planting of early-maturing varieties, planting trees and using IPM.
- Government supported adaptation measures include subsidy and input support to large-scale horticultural ventures, enterprise funds for youth and women, and provision of early-maturing seeds and tree seedlings.
- According to interviews with farmers and extension workers, these adaptation measures complement response measures outlined in the CIDPs, as tree planting stood out as the main response measure being encouraged through afforestation, reforestation and agroforestry.
- According to interviews with farmers, the main challenges limiting adoption of adaptation measures in general are inadequate financial capacity and lack of knowledge.
- Farmers have indicated that current government support for water and inputs supply, assisting during harvesting, training on climate change and adaptation, and pest management is insufficient. Extension staff reiterated the need for training on climate change to build the capacity of farmers.

6.3 Gaps in county governance and regulatory framework

- Kiambu and Kajiado counties depend on the horticulture sector. With much of the agricultural activity in the counties and across the country being rain-fed, the subsector's vulnerability to climate change is increasingly becoming apparent.
- Devolution has presented counties with the space to not only localize nationally overarching policy frameworks but also to create and implement policy frameworks that enhance climate-resilient development of the horticulture subsector at county levels.
- There are policy deficiencies such as poor articulation of policy objectives, lack of implementation frameworks and weak agency of farmers in the policy process, which potentially curtail the development of a climate-resilient horticulture subsector at design and implementation level. If a climate-resilient horticulture sector is to be developed, these policy challenges will need to be addressed so that policy is effective.
- There are provisions in the Constitution and the county government legislation to support county governments to make county-based policies, plans, strategies and legislation, but since establishment in 2013, the counties have not been able to put in place clear implementation structures.
- The most common reference in the CIDPs to climate change was erratic rainfall and temperature extremes. This reveals a gap in the CIDPs in terms of other climate extremes affecting the agriculture (and horticulture) sector that also need to be addressed. This study has examined the climate-related hazards affecting the counties in more detail such that this could feed into the CIDPs and help fill some of those gaps. There is also a mismatch between the planned strategies and the expected climate changes, for example, counties focusing more on drought – which is a current challenge to the horticulture sector – and failing to prepare for projected climatic hazards such as intense rainfall and flooding. In most cases, it is not obvious which climate change impacts are targeted by the various strategies and planned actions by the counties. As seen in Chapter 4, the planned actions and strategies are not focused specifically on horticulture, despite its prioritization for county development.
- The interviews with farmers indicated that government interventions are insufficient. There seems to be an implementation gap due to lack of implementation structures and strategies to build resilient horticulture, which is due to limited human resource capacity and budgetary allocation and inadequate planning as reflected in the respective CIDPs.
- Kiambu and Kajiado counties recognize the need to build resilience in the horticulture sector. However, only Kajiado has developed a draft county climate change policy as provided for in the national CSA strategy; the second medium-term plan of Vision 2030; and the national climate change strategy, action plan and legislation. Kiambu lacked a specific department of climate change and energy in the period of the first CIDPs (2013–2017), only establishing one and appointing a director to head it in 2018.
- Though some detail about climate change was captured in the CIDPs, respondents felt that climate change was not given the special attention necessary. Counties are having to use the national CSA strategy to facilitate integration of climate change and resilience-building in the horticulture and entire agriculture sector, but they face huge challenges because the strategy does not address the local context. This potentially represents policy deficit which manifests in farmers noting lack of government support.

6.4 Alignment of County Integrated Development Plans with climate change for resilient horticulture

- County climate actions are expected to form part of national actions and contribute to the global climate change agenda. Therefore, linking the CIDPs to the wider climate policy framework provides a holistic understanding of the operations at the county level and their impacts.
- Our analysis shows that national policy documents prioritize agriculture as one of the low-carbon development sectors, but remains generally vague on horticulture.
- Our analysis also shows that national climate change policies have not adequately integrated with other non-climatic policies aimed at promoting productivity and investment in the horticulture

sector, such as the National Policy on Water Resources Management and Development – Sessional Paper No. 1 of 1999, the National Irrigation and Drainage Policy of 2009 and the National Disaster Management Policy, all of which seek to support resilience in agriculture and other key sectors. This means that most climate change provisions could be viewed from a relatively narrow perspective, missing opportunities available in the system-wide approach that considers, for example, investment and social systems such as Indigenous knowledge systems.

- At the national level, efforts have been made to domesticate the provisions of the Paris Agreement into the national system. The NCCAP 2013–2017 (GoK, 2012); currently being updated), INDCs and National Adaptation Plans provide guidelines for implementing climate-resilient actions. The Kenya National Adaptation Plan (2015–2030) operationalizes the NCCAP into resilient options for current and future climate trends. The plan provides an avenue for implementation and devolved actions by guiding county governments to integrate and mainstream climate change actions into their CIDPs.
- Other policy documents guiding Kenya’s low-carbon emission and adaptation initiatives include the Climate Change Policy and the Green Economy Strategy and Implementation Plan (GESIP, 2017). The Climate Change policy enhances the country’s adaptive capacity, building resilience to climate variability and change while promoting low-carbon development pathways through all key sectors from national to county levels. GESIP aims to propel growth towards realizing Vision 2030, inculcating the principles of sustainable development in the country’s growth strategy. The strategy is designed to be in line with the globally competitive low-carbon development trajectory.

6.5 Recommendations

Based on the analysis and previous conclusions, the following recommendations are made:

1. Counties should build an evidence-based and context-specific approach to integrating climate change planning into their CIDPs. This can be done through:
 - a. developing a county-integrated resilience-building framework, which creates systematic linkages between county ongoing climate-resilience efforts and national/global opportunities (technological and financial) and used empirical evidence (farmer realities)
 - b. capacity-building of County officers to understand climate change impacts and ways to articulate climate policies in relation to their county contexts and so they can design optimal and resilience-building responses
 - c. identifying and developing diverse sustainable financial sources and building capacity so farmers can access finances through the Green Climate Fund, Adaptation Fund or county climate funds
 - d. researching knowledge about climate-smart/proof technologies.
2. To improve the 3R Kenya Climate Atlas for use by counties in planning for resilient horticulture, the following areas of new information and refined scenario models should focus on:
 - a. capacity-building of Kenyan stakeholders such as the Kenya Meteorological Department and the Climate Change Centre at Jomo Kenyatta University of Agriculture and Technology (JKUAT), which can take over further development of the Kenya Climate Atlas
 - b. training the counties to use the atlas for planning and climate-proofing their CIDPs
 - c. building a network/platform of stakeholders who work together to provide information to counties, policymakers and others about climate change
 - d. including recommendations from the validation workshops, such as being able to zoom in more specifically on counties, as the scale of the atlas was perceived as too coarse
 - e. vulnerability mapping of the counties, which can be used to leverage access to climate funds
 - f. developing a rubric to assist in interpretation of the atlas and assess climate-proofing initiatives by counties.

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Appendix 1 Survey tool

SURVEY ON CLIMATE CHANGE IN HORTICULTURE

Introduction

Hello, my name is _____ (Moderator) and _____ (Record taker), and we are from Jomo Kenyatta University of Agriculture and Technology (JKUAT). We are here to conduct a survey of the project titled "***Climate Resilient Horticulture***". The project seeks to collect information on how horticultural farmers are coping with climate change.

You have been selected to participate in this exercise because you are key farmers of horticultural crops. We hope that you would be willing to spare some time to respond to some questions we have. All the information you will give us will be strictly confidential. I also have a recorder that will help me to capture the discussion to ensure that I do not miss anything.

Kindly allow me to use it. [***Interviewer seeks consent***].

I would also like to clarify that this interview is entirely voluntary and that you have the right to withdraw from it at any point without any hesitation.

Consent to continue with the interview granted: (**Yes** **No**)

GROUP DETAILS

1. Indicate details of location in the following table

County	Sub-county	Ward	Village	GPS	
				Latitude	Longitude
<input type="checkbox"/> Kajiado	<input type="checkbox"/> Kajiado North	<input type="checkbox"/> Ongata Rongai			
		<input type="checkbox"/> Ngong			
	<input type="checkbox"/> Kajiado East	<input type="checkbox"/> Kitengela/Sholinke			
		<input type="checkbox"/> Kaputiei North			
<input type="checkbox"/> Kiambu	<input type="checkbox"/> Juja	<input type="checkbox"/> Witeithie			
		<input type="checkbox"/> Theta			
	<input type="checkbox"/> Limuru	<input type="checkbox"/> Tigoni-Ngecha			
		<input type="checkbox"/> Ndeiya			

2. Indicate the numbers in each of the following categories among the group.

Total number of respondents=

a) Gender	Male		Female	
b) Your education level	No school		Primary	
	Secondary		College and above	
c) Your age category	18-30 yrs		31-40 yrs	
	41-50 yrs		51-60 yrs	
	Above 60 yrs			
d) Land size	< 1 acre		1-5 acres	
	5-10 acres		10 acres	
e) Land ownership	Owned		Leased	
	Bought		Inherited	
f) Income level	< 10,000 pm		10,000-20,000 pm	
	10,000-20,000 pm		> 50,000 pm	

GENERAL CROP PRODUCTION INFORMATION

3. Which crops do you commonly grow? Which ones do you have on your farms now? Which ones do you grow during long rains, short rains and dry season?

Crop	Currently in the farm		Grown in long rains		Grown in Short rains		Grown dry season (Off season)	
	Open	Greenhouse	Open	Greenhouse	Open	Greenhouse	Open	Greenhouse
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

4. Do you grow tomatoes? How important are the tomatoes to you?
 Not important at all A little important Important Very important

5. Which challenges do you face when growing horticultural crops

6. Are you aware of changes in climate that may affect horticultural crops?
 If yes, which ones

7. Have you been trained on climate change?
 If yes, please list the things you learnt in the training

TEMPERATURE

8. Have you observed changes in temperature in the recent past? Yes No

Statement	No	Remarks
a) Increase in the number of hot days		
b) Increase in the number of cold days		
c) Decrease in the number of hot days		
d) Decrease in number of cold days		
e) It is more difficult to work outdoors around 2 o'clock		
f) It feels hotter these days than in the past		
g) It feels colder these days than in the past		

9. Have your crops been affected by changes in temperature in any of the following?

Statement	No	Crops affected	Season (SR, LR, DS)
a) I have observed plant stress			
b) I have experienced some reduction in yields			
c) I have experienced high yield reduction			
d) I have experienced total crop loss			

SR: Short rains, LR: Long rains, DS: Dry season

RAINFALL AND WATER

10. Have you experienced changes in rainfall?

Statement	No	Notes
Increase in rainfall		
Reduction in rainfall		
Rainfall seasons are not clear		
Shortage of water		
Lost crops due to lack of rain		
Experienced flooding		
Experienced erosion in the farm		

11. Do you grow crops under irrigation? Yes No

For yes, please provide the following details?

Method	No	Crops	Source of water
--------	----	-------	-----------------

Spray irrigation

Drip irrigation

Flood irrigation

Other specify

(1) Surface water bodies, (2) Reservoirs, (3) Groundwater, (4) Rainwater harvesting

(5) Others (specify).....

Notes

12. Is the water supply sufficient to meet the water demand for your horticultural practices? Yes No

If NO, how serious is the water shortage and is this different between the short/long rain and dry season?

13. In case of water scarcity, are there then other water resources available?

14. How deep do you dig wells in this area to get water?

15. How is the status of the well during the different seasons?

	No	Notes
a) The well dries during dry season		
b) The well dries during short rains		
c) The well fills during long rains		
d) The well fills during the short rains		
e) The rain never fills throughout the year		
f) The well never dries up throughout the year		

16. What kind of measures do you take to protect your water resource?

Measure taken

Season

- SR, LR, DS
 SR, LR, DS
 SR, LR, DS

SOILS

17. Have you observed any problems with your soils? Yes No. If so, what are the problems

18. Do you use fertilizers? Yes No. If yes, which ones

Fertilizer

Crop

Amount (kg/acre)

Season

- SR, LR, DS
 SR, LR, DS
 SR, LR, DS
 SR, LR, DS
 SR, LR, DS
 SR, LR, DS

19. Do you do soil testing? If yes, which of the following is assessed?

- Electrical conductivity (EC) Nitrogen Phosphorus Potassium
 pH Soil organic matter Sulphur Calcium Micronutrients
 Soil water content Salinity Trace elements

PESTS

20. Are pests a major challenge in your horticultural production? Yes No

21. Which are the most common pest species?

Pest

Crop

22. Have you observed new pest species in the recent past? Yes No
if YES, which type of pests and on which crop?

Pest

Crop

23. Have you encountered the following in your horticultural production?

Statement

No Notes

- a) Reduction in yields due to pests
b) Lost entire crop due to pests
c) Reduction in quality of produce
d) Produce rejected by markets due to pests
e) I have to apply a lot of chemicals to control pests
f) I have stopped growing some crops due to pests
g) I have abandoned using my greenhouse due to pests

24. How do you control pests in open air and how in a greenhouse?

Crop

In the open field

In the greenhouse (Where applicable)

25. Do you consider your pest management measures effective and sustainable? Yes No

Please explain:

26. Do you think climate change may lead to increase in pests? Yes No

Please explain:

GENERAL ADAPTATION MEASURES

27. Which of the following measures do you take to deal with climate change?

Measure

N

More efficient irrigation operations

Multiple cropping

Adjusting sowing and harvesting date

Application of different (heat tolerant, early maturing) cultivars

Others (Please specify)

28. Which of the above measures would you like to take to deal with these challenges but you are not able?

More efficient irrigation operations

Multiple cropping

Adjusting sowing and harvesting date

Application of different (heat tolerant) cultivars

Others (Please specify)

29. Why don't you take the above measures?

Lack of knowledge

Lack of governmental support

Lack of sources or availability of technology

Others (Please specify)

GOVERNMENTAL SUPPORT

30. Would you need more assistance to deal with the changes in temperature?

31. If yes, which kind of support and in which areas? Select from below

Area

Noted on required support

- Support in soil management?
- Support in water management?
- Support in crop management?
- Support in pest management?
- Other

DISSEMINATION

32. How many of you have a smartphone? Yes No

33. Do you use the WhatsApp application?

- If NO, why don't you use it? Lack of internet, Expensive,
 Draws too much battery power

34. Are you able to access internet on your farm? Yes No

35. Do you want to receive information about climate change? Yes No

36. If yes, what information is useful for your horticulture production?

37. Would you like the climate atlas to help you deal with climate change? Yes No

If yes, which is the best way for you to access the atlas?

- Website Mobile application Offline Other (specify)

38. How specific does this information need to be? Country County Other

39. Any additional information

Thank you for your time

Appendix 2 Results of farmer and agricultural staff survey

Table 9 Results from Kiambu

General profile farmers
<ul style="list-style-type: none">• For this research, 13 farmers were interviewed, six of whom were male and seven female.• 38% had primary school education; 38% had secondary school education; 23% had college and above.• The majority of the of the participating farmers was in the range 31–60, but the span was from 18 to 60.• The average land size is 1–5 acre, with only one farmer having a total land size of 10 acre.• Most farmers have inherited their land and own the farmland themselves.• The average income level of the participating farmers is between 100.00 dollars per month and 200.00 dollars per month.
General crop production
<p>The most important crops that were grown in the open field were tomatoes, cabbages, maize, beans, kale and potatoes. Tomatoes and broccoli were also grown in greenhouses, if present. Cabbage is considered the most important crop species in Kiambu. The selected small-scale farmers in Kiambu reported that tomatoes are considered to be important in terms of economic contribution to their income and livelihood.</p> <p>The main challenge when growing horticultural crops is managing water supply, as lack of water is one of the common problems. Pests and diseases are also one of the most important challenges, as they have major impacts on the horticultural crop production in terms of yield reduction.</p> <p>Farmers in Kiambu have not had any training in climate change and therefore do not have the skills or knowledge to respond to its adverse effects. However, the awareness of climate change is considerably high, as they have experiences with changes in temperature and precipitation. Farmers reported that increases in mean temperature and extreme temperatures have a demonstrably negative effect on their horticultural operations, cause more pressure on water availability, and increase incidence of pests and diseases.</p>
Observations by agricultural staff
<ul style="list-style-type: none">• Staff members confirmed that the biggest challenges for farmers are water shortages for irrigation, and pests and diseases which strongly reduce the yield of horticultural crops. Besides these challenges, the staff members also consider market dynamics and high costs of pesticides and seeds as major challenges for farmers.• It was confirmed that small-scale farmers did not have any training on the impacts of climate change. Staff members predicted the same future impacts of climate change, that is, more frequent extreme droughts, heat stress and higher incidence of pests and diseases.
Temperature
<p>Farmers have experienced an increase in the number of hot days, while the number of cold days has fallen. An exception was 2018, which felt much colder than previous years. Farmers reported that it is more difficult to work outdoors around 2 pm nowadays. They have experienced losses in horticultural crops due to the increasing temperatures, varying from small reduction and plant stress to total yield loss.</p>
Observations by agricultural staff
<ul style="list-style-type: none">• Staff members confirmed that there has been an increase in the number of hot days recently and that it is more difficult to work outdoors around 2 pm nowadays.• Tomatoes are particularly affected by the changes in temperature, and it was confirmed that both plant stress and (strong) reductions in yield have been observed on small-scale farms.• Staff members believe that extreme hot weather events are likely to increase in the future.
Water
<p>The farmers reported a reduction in rainfall (except in 2018) and pointed out that seasonality has become less clear in the sense that the timing of each season has become more difficult to predict. Most farmers have also experienced losses in crop production due to lack of rain, which further demonstrates that water shortage is a common challenge. With the patterns of increasing temperatures and less rainfall, it is likely that this challenge will increase in the future, unless farmers can invest more in water-related adaptation strategies.</p> <p>In Kiambu, drip irrigation and hose pipes are the main irrigation methods. The water is mainly extracted from small rivers, water pans or through rainwater harvesting. The majority of farmers reported that their water supply is often insufficient to last through all the seasons. Only one farmer had a borehole 210 metres deep at his disposal. Farmers are investing in measures to protect their water supply, with the main ones being storage tanks, sunken beds and purchase of rainwater harvesting systems for in the greenhouse.</p>
Observations by agricultural staff
<ul style="list-style-type: none">• Staff confirmed that there are many challenges related to water, in terms of future reductions in water availability and the fact that the seasons are becoming less clear and predictable. Staff members also mentioned crop damage due to flooding caused by extreme rain events.• Staff members confirmed that drip irrigation is the most used method for irrigation, whereas surface waterbodies (in most cases small rivers) are used as the main water source.

Soil

In general, farmers did not have issues with the soil, with only one farmer complaining about soil acidity. Fertilizers are applied by every farmer, which mainly consist of calcium ammonium nitrate (CAN), NPK and manure. Furthermore, farmers do not perform soil tests on their land, due to the high cost.

Observations by agricultural staff

- Staff members said that farmers should use more fertilizer to increase the fertility of their soil.
- Farmers should dig deeper to avoid the hard pan and to make the soil easier to work with.
- Staff confirmed that farmers do not perform soil tests.

Pests

At a similar scale to the effects of temperature increases, impacts from pests are a major challenge to horticultural crop production. All farmers had experienced heavy yield losses due to pests. They also reported reductions in product quality, which increases the risk of the produce being rejected at the local food market. While farmers do apply chemicals and sticky traps to control pests, these measures are not completely successful, as most pest species survive and remain difficult to control.

Some farmers have observed new pest species in their farms recently, and all farmers are aware that pests will become a bigger problem in the future due to climate change as the environment becomes more suitable for pests. The most common pest species on their farms are thrips, red spider mites and whitefly. These affect all crops, but especially tomatoes.

Observations by agricultural staff

- Pests are considered a major threat to horticultural crop production in Kiambu. According to the staff members, farmers experience a lot of reduction in yield and product quality, making it harder for them to compete on the market. Staff members also mentioned that a lot of produce grown in greenhouses has been demolished by whitefly.
- The most common pest species in Kiambu are whitefly, aphids and red spider mite, all of which particularly affect tomatoes. New introduced pest species are thrips, *Tuta absoluta* and fall armyworm.
- While most pests can be eliminated, whitefly seems to be very tough and hard to control. According to the staff members, farmers should implement IPM to reduce the amounts of chemicals that are being used.
- Climate change will play a major role in the increase of problematic pests. New species will arrive which could be resistant to the chemicals farmers are currently using.

Adaptation measures and government support

Farmers already take adaptation measures in response to changing weather conditions, with the most common being multiple cropping and adjusting the sowing and harvesting date to increase the chance of success. However, most farmers are still limited in the measures they can take, mainly due to lack of knowledge or finance. For example, farmers would like to buy a greenhouse or better irrigation system to increase their water use efficiency, but they feel they cannot afford them. However, during the interviews it was clear that most farmers not well informed about the actual costs of these systems, which are lower than the farmers mentioned. This indicates that farmers need to increase their knowledge about smart and budget-friendly investment in new systems.

According to the farmers, there is insufficient government support for horticultural crop production, although this support is greatly needed. Assistance is mainly needed in managing water and pests, which are the biggest challenges for horticultural farmers in Kiambu. This might include lower prices for water pumps or irrigation systems and providing better and cheaper chemicals and technical training to control pests more easily. In this way farmers, can reduce their yield gap and increase their horticultural production, which will allow them to better compete in the market.

Observations by agricultural staff

- In response to climate change, farmers are being advised to plant earlier and use fast-maturing cultivars. They are also being advised to plant trees, use IPM and harvest more rainwater.
- According to the staff members, some of the reasons for non-adoption of these measures are lack of knowledge and capital. Additionally, farmers need to be trained about climate change, to understand the problem and how to respond to it.
- In contrast to the opinion of the interviewed farmers, the staff members reported that farmers are being supported by the government in several ways, including the government providing early-maturing seeds and tree seedlings and digging water pans.

Dissemination

Not all the farmers had a smartphone, which affects the possibility of being able to disseminate information to them. The main reason for not using smartphones is poor internet connection on the farms. For the older farmers, lack of knowledge was also a problem.

When discussing the Kenya Climate Atlas with the farmers, they were all very enthusiastic and said that it would help them respond to climate change. The atlas can be provided in multiple ways; the preference was mainly for a mobile application (if using a smartphone) and otherwise through SMS. More options include a website (if available) or face to face, where agricultural staff would give the information to the farmers.

Observations by agricultural staff

- The staff members agreed that access to the Kenya Climate Atlas would be very helpful for small-scale farmers in the horticulture sector.
 - Mobile application and website are considered the best options for providing the atlas to the farmers.
-

Table 10 Results from Kajiado

General profile farmers
<ul style="list-style-type: none">• In this county, six farmers were interviewed, of whom four were male and two female.• All farmers have an agricultural education to the level of college and above.• The majority of the participating farmers was aged between 41–60.• The average land size is ≤ 10 acres.• Most farmers have inherited or bought their land and own the farm themselves.
General crop production
The most important crops that were grown in the open field were onions, tomatoes, cabbages, kale, capsicums and cucumbers. Tomatoes, capsicums, sweet hot peppers and cucumbers were also grown in greenhouses. Onion is considered the most important crop species in Kajiado. Tomatoes are also considered to be very important in terms of economic contribution to income and livelihood.
Observations agricultural staff
<ul style="list-style-type: none">• Staff confirmed that climate change and pests and diseases are the main challenges in growing horticultural crops. In addition, transport costs are too expensive due to poor infrastructure. This is considered as a major challenge that makes it harder to access the market.• Staff members are also aware that climate change is happening currently. They expect higher temperatures and more poor rainfall patterns, leading to more droughts and increasing plant stress and flower abortion.
Temperature
Farmers have experienced an increase in the number of hot days, while the number of cold days has fallen. An exception was 2018, which felt much colder than previous years. Farmers reported that it is more difficult to work outdoors around 2 pm nowadays. They have experienced losses in horticultural crops due to the increasing temperatures, varying from small reduction and plant stress to total yield loss.
Observations by agricultural staff
Staff members confirmed that there has been an increase in the number of hot days recently and that it is more difficult to work outdoors around 2 pm nowadays. Only plant stress has been observed in tomatoes, with no reductions in yield according to staff members.
Water
Farmers have observed reductions in rainfall in the recent past, resulting in increasing water shortages. Rainy seasons have become less clear. One of the respondents has experienced flooding on his farm due to intensive rainfall. Drip irrigation is the most usual method for irrigation, and all small-scale farmers have deep boreholes for their water supply. These boreholes fill during long rains and almost never dry up throughout the year, which means water is always available for irrigation.
Observations by agricultural staff
<ul style="list-style-type: none">• Most staff observed an increase in rainfall, which contrasts with the observations of the farmers. However, staff did confirm that the rain seasons have become less clear.• Staff members reported that farmers experience shortages in water and even lose their entire crop due to lack of rain. They added that they also have observed flooding events, with erosion damage as result. This contrasts with what the farmers say about never running out of water because of their boreholes?• Staff members confirmed that drip irrigation is the most common form of irrigation in Kajiado. Bucket irrigation is another method that is applied in the field.
Soil
In general, farmers did not have issues with the soil. The only observed problems are increases in salinity and acidity at some farms, but these are not experienced as problematic. Farmers use several fertilizers, including manure, calcium ammonium nitrate (CAN), (Diammonium phosphate) DAP and NPK. The farmers do perform soil tests on their farmland.
Observations by agricultural staff
<ul style="list-style-type: none">• No problems were observed with the soil. The only challenge is that the black cotton soil is prone to waterlogging during wet seasons, making it very hard to work on.• Staff confirmed that farmers conduct soil tests.
Pests
The most common pest species affecting crop production in Kajiado are whitefly, crickets and <i>Tuta absoluta</i> . These pests reduce yield and product quality (especially with tomatoes). Three of the six farmers have lost an entire crop to pests. These farmers do not use a lot of chemicals to control pests, instead using measures such as crop rotation, intercropping, IPM and applying ashes. The farmers consider these measures effective, as they are able to control most pest species. New pest species have been discovered recently, and farmers are aware that more new species will come as a result of climate change.
Observations by agricultural staff
<ul style="list-style-type: none">• Pests are considered a major threat to horticultural crop production in Kajiado. Farmers experience a lot of reductions in their yield and product quality, making it harder for them to compete in the market. Staff members also mentioned that greenhouses have been abandoned due to pest infestations.• The most common pest species are fall armyworm, whitefly, thrips and leaf miners. These pests particularly affect onions and tomatoes. Leaf miners are considered a new recent pest species.• In the open field, spraying and dusting are the most common measures applied to control pests, whereas traps and exclusion are more applied in greenhouses.• Staff members reported that these measures are only effective when conducted by a professional.

Adaptation measures and government support

Many measures are currently being taken to respond to the challenges of climate change. Farmers are aware of climate change and are willing to adjust their current practices accordingly. Multiple cropping, planting cultivars and adjusting the timing in sowing and harvesting are all measures being taken. Farmers are also investing in new efficient irrigation equipment to improve their water use. Despite farmers being able to implement most adaptation measures if they want, the main reasons given for not using a specific adaptation measure are lack of knowledge, resources or technology.

Farmers need government support in responding to *Tuta absoluta*, as this pest species is the most problematic. Farmers would also like more training on modern farming techniques and better prices for pesticides.

Observations by agricultural staff

- Staff members reported that there are many measures farmers could take in response to climate change, including:
 - planting trees
 - replacing chemical pesticides with organic pesticides
 - harvesting more rainwater.
- In contrast to what farmers report, staff reported that the government does support farmers in Kajiado by providing them cultivar seeds.

Dissemination

All the respondents are using smartphones and use WhatsApp and do not experience any problems with internet on their farm. Every farmer would like to use the Kenya Climate Atlas and consider it as very helpful. The best way to provide the atlas is through SMS. The other three options (website, mobile application or offline) would also work for them.

Observations by agricultural staff

- Staff confirmed that the Kenya Climate Atlas will be very helpful for farmers as they respond to climate change. Mobile application is considered the best option to provide the atlas.
-



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Report WCDI-20-107
3R Research Report 010

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To explore
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