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Assessment of Climate Risks and Strategies to Build Resilience in Regional Food Value Chains in Eastern, Southern, and West Africa

AGRA REGIONAL FOOD TRADE AND RESILIENCE PROGRAMME

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[1] The programme started in in 2019 under the Department for International Development which merged with Foreign and Commonwealth Office to become FCDO on 2 September 2020.

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List of Abbreviations

AGRA	Alliance for a Green Revolution in Africa
GDP	Gross Domestics Product
GHG	Green House Gases
FCDO	Foreign, Commonwealth & Development Office
IPCC	Intergovernmental Panel on Climate Change
RCP	Representative Concentration Pathway
RFTR	Regional Food Trade and Resilience Programme
SMEs	Small to Medium Enterprises
SSA	Sub Saharan Africa
SSPs	Shared Socioeconomic Pathways

Summary with Key Messages

This summary below discusses the key climate change and variability risks and impacts across different stages and activities of crop value chains. The report applies a 'climate lens' to the different stages of the food value chains to understand the climate risks experienced at each stage. The review identified key climate change risks and impacts on activities across different crop value chains. This is important to inform appropriate responses to improve the resilience of food systems and actors at different stages. The risks are not prescriptive and can be applied to any food value chain. However, specific analysis would be required for projects focusing on specific food value chains.

The Key Messages from the Report are Summarised below

- *Climate change and variability risks are exacerbating challenges of poverty, food and nutrition insecurity, malnutrition in many African countries*: limited adaptive capacities worsen the vulnerability of smallholder farming communities and food value chains across the continent. The western parts of the continent are projected to experience severe declines in food production due to climate change.
- *The growing demand for food, fuel and fibre across the continent due to growing population, emerging middle class and changes in dietary and demand patterns present challenges for increased food production*.
- *Regional food trade can contribute to climate change adaptation as well as food and nutrition security*: Trade can help move food from areas of strategic production surplus to deficit consumption areas. The movement of food to deficit areas is also essential in addressing market volatility due to supply and price shocks triggered by climate-related risks.
- *Levels of regional food trade in Africa remains low to adequately address climate change adaptation as well as food and nutrition security*: Intra-African regional food trade remains low across the continent.
- *The impacts of climate change and variability have a ripple down effect on the entire value chain stages*: For instance, climate change and variability contribute to the increased incidences of the Fall Armyworm and aflatoxins in grains. These impact the quantity and quality of grains available for further processing, adversely impacting on food supply as well as food and nutrition security. The reduced quantity and quality of grains affect the throughput for processors and result in increased costs if processors are forced to procure grains from other sources and/or at high prices due to limited supplies. In addition, supplies of contaminated grains increase processing costs as processors invest in more tests and screening of the grains.
- *Climate change disproportionately affects all food value chain stages and actors presenting new challenges and opportunities*: The different activities along the food value chain impact on food and nutrition security outcomes and generate impacts on the environment. Food security is also indirectly linked with the climate and ecosystems through the socio-economic systems.
- *Climate change drivers' interactions with non-climatic stressors are adversely affecting food production as well as food and nutrition security outcomes*: The impacts of these interactions affect all pillars of food security: food availability, access, utilisation and stability.
- *Smallholder farmers experience high risks at the lower stages of the value chains, especially on inputs, production, harvesting and storage*: The impacts of climate change and extreme events on these low stages of the value chain severely impact on smallholder farmers' ability to move their produce up the value chain with detrimental impacts on food and nutrition security, farm incomes and resilience to shocks.
- *Changes in climate and extreme events affect the quantity and quality of inputs (such as seeds) adversely impacting on the rest of the value chains*: Increases in warming, water stress

and changes in the incidence of pests and diseases negatively impact on the quantity and quality (such as the potency of seeds) of inputs which cascades along the whole value chain through reduced quantity and quality of crops.

- *Extreme climatic conditions and events can lead to the destruction of inputs in storage and during transportation*: Heavy rainfall events, flooding, cyclones, prolonged heat waves can lead to the destruction of stored inputs and/or during transportation. The events negatively affect the availability of adequate inputs for planting when the growing season starts.
- *Climate-related risks may force farmers to replant, increasing production costs*: Irregular and unpredictable rainfall may lead to a false start in the rainy season and impact the optimum seed germination conditions. Increased input costs lead to a reduction in area planted, which may also impact on-farm employment and other stages of the value chain. These impacts have knock-on effects on household incomes as well as food and nutrition security.
- *Increases in warming, and heat stress and changing rainfall patterns, soil salinization, loss of arable land from land degradation and erosion are changing agricultural growing conditions affecting the suitability of cropping and livestock activities*: The observed and projected changes in climate across the continent is impacting on growing conditions, the start and end of growing seasons. Changes in agroclimatic conditions, even slight changes could lead to some areas becoming unsuitable for current agricultural activities.
- *The projected increase in temperature, reduced rainfall and changes in rainfall patterns, increasing frequency and severity of extreme events (droughts and floods) present risks to crop yields and upstream activities in the value chains*.
- *Increasing temperatures, humidity, pests and diseases increase the risk of post-harvest losses for food crops and products*: rising temperatures and humidity increase the risks of harvest spoilage affecting the quantity and quality of food available for trade, processing and consumption. Climate changes increase the risk of incidence of storage pests and diseases such as fungal and mycotoxin contamination affecting stored grains.
- *Increasing temperatures, heatwaves, intense rainfall as well as extreme climatic events, adversely affect transport, aggregation and trading activities*: These changes increase the risks of post-harvest crop spoilage, diseases and quality losses.
- *Extreme events and disasters due to climate change may lead to the destruction of transport and storage infrastructure, affecting the movement of inputs and food along the value chain as well as from strategic production areas to deficit areas*. The destruction of infrastructure negatively affects the operations of transport and logistics hubs and services as well as trade hubs. Extreme events also lead to the physical destruction of crops and food in fields, storage and during transportation.
- *The increased intensity and frequency of extreme climatic events disrupt food production and supply as well as transport logistics leading to market volatility through food price spikes for traded commodities.*
- *Climate change adaptation and climate resilience both involve interventions to address climate risks to reduce and or eliminate the negative impacts*. Climate change adaptation and resilience capacity are mutually reinforcing. For example, smallholder farmers can implement irrigation technologies to address drought risks as well as livelihood diversification into non-farm income-generating activities to help them respond to reductions in farm incomes due to drought.
- *Combining supply-side measures such as improvements in efficiency in production, transport and processing with demand-side measures such as reduction of food loss and waste and modification of food choices can help enhance the resilience of the food system and reduce GHG emissions.*

1. Introduction

The agriculture sector is very important in many African countries. It supports the livelihoods of 80% of the African population and provides employment to about 70% of the poorest on the continent as well as around 60% of the economically active population (UNDP, 2017). The UNDP (2017) notes that agriculture growth is twice as effective in reducing poverty as growth in other sectors. However, Sub-Saharan Africa is prone to various climatic risks that have significant repercussions on livelihoods, food and nutrition security, and sustainable development. Many African countries are already experiencing high levels of poverty, food insecurity and malnutrition, alongside the disproportionate impacts of climate change on food systems. Cyclical droughts and floods are occurring more frequently and severely due to climate change, disrupting farmers' production (FAO, 2017). The impacts of climate change, variability and other shocks, especially on food systems based livelihoods, are exacerbating the already difficult food and nutrition security situation in many parts of the continent (IPCC, 2014; IPCC, 2019). Even with no further changes in climate, the continent will continue to experience substantial climate risks.

Over the next three decades, Africa is projected to experience unprecedented population growth, urbanisation and income growth. Demand for food will increase more than in any other region. The continent's population is projected to increase from 1.35 billion in 2020 to more than 2.5 billion in 2050 (United Nations, 2018). Africa's urban population has been rapidly growing from an estimated 285 million in 2000 to 587 million in 2020 (Figure 1). The urban population will increase to 1.49 billion in 2050 (Figure 1). The growing urban and total population, the emerging middle-income class, changes in dietary and demand patterns continue to increase the demand for food in Africa (FAO, 2017a; World Bank, 2012). The growing demand for food, fuel and fibre will require increased productivity in food value chains in the face of changing climate, and the increased need for sustainable natural resources use.

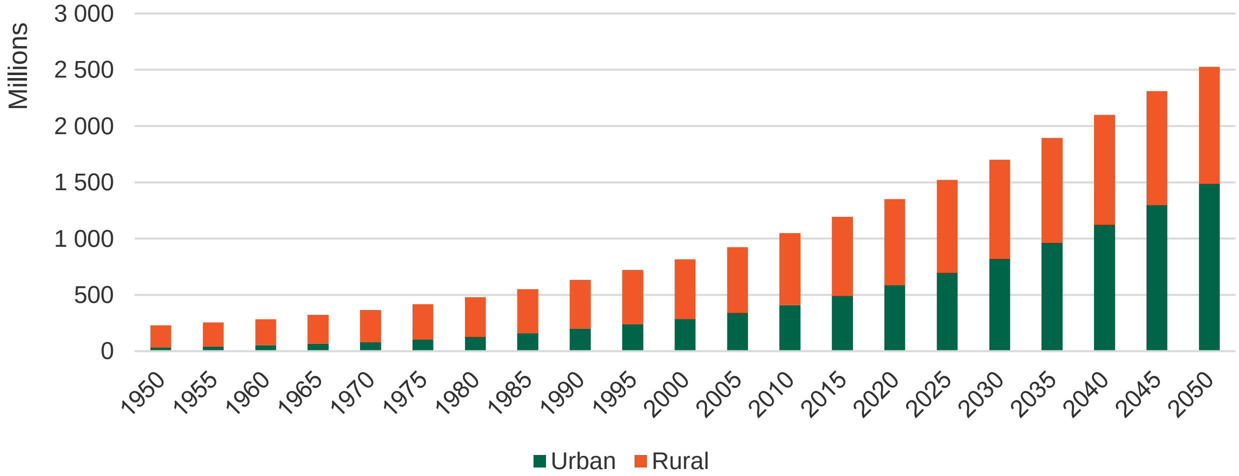


Figure 1: Growth in African urban and rural populations to 2050

Source: Authors' construction based on data from United Nations (2018)

Climate change is also expected to alter comparative advantage and the competitiveness of food value chains across regions and countries, leading to changes in agricultural trade patterns. Regional food trade can significantly contribute to adaptation efforts and food security in many countries. For example, in the short term, trade can help address food production shortfalls due to extreme weather events through moving food from surplus to deficit areas. How regional food markets evolve will impact on the resilience of the poor to climate change as well as on food security and nutrition outcomes. Increasing regional food trade can enhance the prospects of private sector investments in agri-food processing and distribution, as businesses establish more stable regional supplies of produce and serve larger markets. Regional trade can create jobs and increase farmers' access to markets, linking them with consumers in rapidly growing urban areas and companies beyond national boundaries.

Despite the potential of regional food trade to address climate change, food security and development challenges, intra-regional trade in SSA remain consistently low compared with inter-continental trade. For example, only 5% of Sub Saharan Africa's (SSA) imports of cereals come from other SSA countries (World Bank, 2012). Across Africa, at least 80 percent of the continent's exports are destined for outside markets, with the European Union and the United States of America accounting for more than 50 percent of this total (Suleymenova & Syssoyeva-Masson, 2017). In addition, there is limited coordination and investments in food value chains from private sector companies that efficiently engage and service smallholder farmers.

Changes in climate and variability presents new challenges and opportunities for the entire food value chain. All value chain stages and actors are disproportionately affected by climate risks such as extreme events like droughts and floods. Food production is already experiencing adverse impacts from climate change and variability ranging from rising warming beyond thresholds for crop and livestock production, changes in patterns and timing of rainfall, increases in the intensity and frequency of extreme events. These changes are causing shifts in suitable agricultural production areas to current cropping and livestock activities, change in the length of growing seasons and reducing yield potential of both crops and livestock, especially in marginal areas (USAID & EAC, 2017). Climate change will also affect supply, transport and distribution chains with significant impacts on regional food trade. For example, extreme events such as floods may lead to the temporary closure of transport routes and damage infrastructure that is important for regional food trade. These constitute a significant risk to agri-business and the business investment climate.

There is an increasing focus on the value chain approach in building and strengthening climate resilience in food systems (IFAD, 2015; Dazé & Dekens, 2016; Lim-Camacho, et al., 2016). The value chain approach emphasizes the interdependency among stages and actors, and the need to consider climate change impacts and responses beyond the production stage for more integrated interventions, a gap that the 2015 Intergovernmental Panel on Climate Change (IPCC) Expert Meeting on climate change, food and agriculture identified (IPCC, 2015). Food value chains in Sub-Saharan Africa experience low productivity levels due to low input use (such as improved and climate-resilient seeds, fertilizers and machinery). Climate change interactions with low use of improved inputs heighten the vulnerability of food value chains.

Although food value chains and farmers have experienced climate risks throughout the history of agriculture, current and future changes in climate have significantly increased in intensity, frequency and variety of the risks. The risks from changes in temperature, rainfall patterns, increased intensity and frequency of extreme weather events threaten the sustainability of food value chains and their contribution to developmental goals such as poverty reduction, food and nutrition security and livelihoods of smallholder farmers. It is, therefore, critical to understand how food value chains are impacted by climate change and variability and how they can effectively respond through adaptation and mitigation strategies. Therefore, the main objective of this paper is to discuss the climate change risks and strategies to build resilience in regional food value chains in East, Southern and West Africa. The paper contributes to informing the development of climate resilience interventions in the Regional Food Trade and Resilience (RFTR) Programme.

1.1 Overview of the Regional Food Trade and Resilience Programme

The Africa Food Trade and Resilience Programme (AFTR) is a five-year initiative funded by the United Kingdom Foreign, Commonwealth & Development Office (FCDO) and implemented by the Alliance for a Green Revolution in Africa (AGRA). The goal of the AFTR Programme is to increase regional food trade in Sub Saharan Africa to bolster regional food security and inclusive income growth. The

Programme seeks to achieve this through two mutually reinforcing objectives contributing to improve the transparency and predictability of government policies to unlock regional food trade, and (ii) working with companies that source, process, and trade food in the region, to maximize investment, coordination and benefits to smallholder farmers.

The policy predictability component of the RFTR Programme focuses on addressing policy and regulatory gaps impeding the effective functioning of food markets through targeted policy engagement and influencing to help build ownership of reforms and constituencies for change. The Programme provides technical assistance support to national and regional institutions in data gathering and monitoring of food security, trade, and prices, which are key components for policy predictability. The Programme also supports implementation of policy and regulatory reforms for more open trade that encourages private sector investment in regional value chains that offer opportunities for increased smallholder farmer participation.

Under the market systems workstream, the AFTR Programme is applying a demand-pull and competitiveness analysis approach to determine key regional value chains, trade corridors and actors as well as challenges to determine high potential interventions for building resilient and inclusive supply chains. The Programme also uses a technical assistance approach providing support to large agribusiness off-takers/processors, traders, and other value chain actors to help them build resilient and sustainable supply chains for food. Through this approach the Programme also addresses supply side constraints related to improved access to quality value chain support services and inputs by farmers which are important for boosting yields and quality of products. This will enable farmers to meet the demand requirements of off-takers thus increasing their participation in regional supply chains, which are important for their physical and economic resilience as well as food security.

The AFTR Programme also addresses cross-cutting issues of gender, nutrition, and resilience. The Programme interventions have a high level of ambition on gender and prioritize investments that maximize benefits to women, mitigate gender-based risks and create opportunities to shift women to positions of greater financial return, and transforming gender relations. The AFTR investments also implement prioritized interventions to build and strengthen climate resilience, improve smallholder farmers' integration in regional food value chains and their productivity and profitability, and improve access to better services, new markets, advice, and finance.

Across the key intervention areas, the AFTR Programme has four main outputs areas namely:

(a) Up to date market and political economy analysis of regional food trade flows.

(b) More predictable, private sector friendly and climate friendly government interventions that reduce obstacles to regional food trade.

(c) Improved coordination and investment in regional food value chains, with commercial companies supported to efficiently engage and service smallholders, based on actionable data-driven insights and advice; and

(d) More resilient smallholder farmers accessing better services, new markets, advice, and finance through integration in regional food value chains.

The AFTR Programme complements ongoing and pipeline interventions of AGRA in influencing policy reforms and strengthening of state capabilities to implement along the whole value chain. The Programme's interventions targets countries in East, West, and Southern Africa and the Sahel involved in regional food trade.

2. Methodology

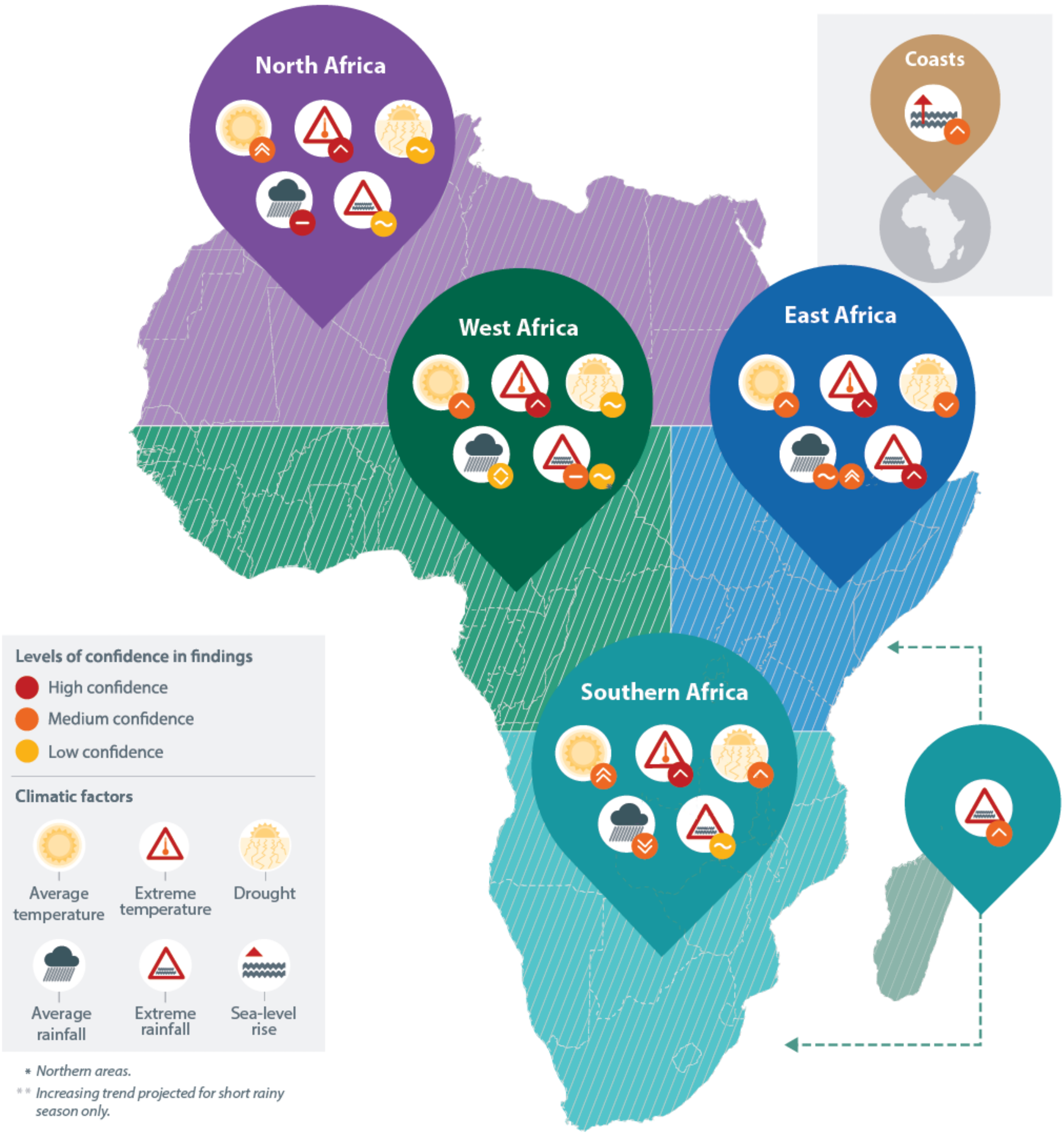
This report is based on a desk review of published and grey literature on climate change risks, adaptation and resilience in food value chains and food systems. The report applies a 'climate lens' to the different stages of the food value chains to understand the climate risks experienced at each stage. The review identified key climate change risks and impacts on activities across different crop value chains. This is important to inform appropriate responses to improve the resilience of food systems and actors at different stages. The risks for specific crop value chains are discussed in the respective Africa Food Trade and Resilience Programme's policy and structured market development projects.

3. Regional Climate Change-Related Risks Affecting Food Value Chains

3.1 Summary of Future Climate Trends in Africa

Figure 2 summarises future climate trends across Africa. The 2019 IPCC Special Report on Climate Change and Land reported with high confidence that the increase in warming together with changing rainfall patterns, resulted in changes in the start and end of growing seasons, negatively affecting regional crop yields, reducing freshwater availability and further stressing biodiversity (IPCC, 2019). The impacts of climate change are increasingly striking in their severity and are being felt more rapidly than expected. The increase in warming in the last five years is on track to be the warmest on record, the frequency and intensity of natural disasters has increased, and 2019 witnessed unprecedented extreme weather events across the world (WEF, 2020). Projections indicate that global temperatures will increase by at least 3°C towards the end of the century which is about twice the limit warned by climate experts to avoid most severe social, economic and environments impacts (WEF, 2020).

Global warming has resulted in the increased frequency and intensity of some extreme weather, and climatic events (e.g. heatwaves and droughts) and these are expected to continue to increase under medium and high emission scenarios (IPCC, 2019). For example, projections indicate that heatwaves will increase in frequency, intensity and duration in most parts of the world (including most of Africa) (high confidence) and regions that are already prone to droughts (such as southern Africa) are projected to experience increased drought frequency and intensity (medium confidence) (IPCC, 2019). The projected changes will significantly affect food security, ecosystems and land processes (high confidence).



Symbol	Rainfall	Temperature	Extreme rainfall, extreme temperature, sea-level rise
⇈	up to 30% increasing trend	1–6°C increasing trend	–
↑	up to 10% increasing trend	1–4.5°C increasing trend	increasing trend
↕	both increasing and decreasing trends	–	both increasing and decreasing trends
↓	up to 10% decreasing trend	–	decreasing trend
⇊	up to 30% decreasing trend	–	–
–	inconsistent trend	inconsistent trend	inconsistent trend
~	no or only slight change	inconsistent trend	inconsistent trend

Figure 2: Future climate trends for Africa

Source: Adapted from CDKN & ODI (2014)

Hot climates in the tropical regions are expected due to the ongoing warming, increasingly exposing ecosystems in these regions to temperature and rainfall extremes beyond the climate regimes that they are adapted to (high confidence) affecting their composition, structure and functioning (IPCC, 2019). Figure 3 presents the distribution of dryland areas in Africa based on the aridity index. In East Africa, the Horn of Africa areas are semi-arid, arid and hyper-arid on the tip on the horn. Most parts of Southern Africa are semi-arid and arid with the western parts of Namibia being hyper-arid. In West Africa, the Sahel region and northern parts of West Africa are semi-arid, arid and hyper-arid.

Land degradation in arid, semi-arid and dry sub-humid areas (desertification) has negatively affected agricultural productivity and incomes (high confidence) and biodiversity loss in some dryland region (medium confidence). Projections indicate that desertification risk would increase as a result of climate change (high confidence). The projected increase in desertification risk due to climate change and other factors negatively impacts the provision of ecosystem services and biodiversity in the affected areas (high confidence) (IPCC, 2019). Also, the changes in climate and increased desertification would result in reductions in crop and livestock productivity (high confidence), including loss of biodiversity (medium confidence) (IPCC, 2019). These changes would have severe impacts on food and nutrition security, incomes and livelihoods, especially those dependent on agriculture and other land-based ecosystems. Environmental degradation is projected to have severe impacts on women than men, especially in areas that largely depend on agricultural-based livelihoods (medium evidence, high agreement) (IPCC, 2019).

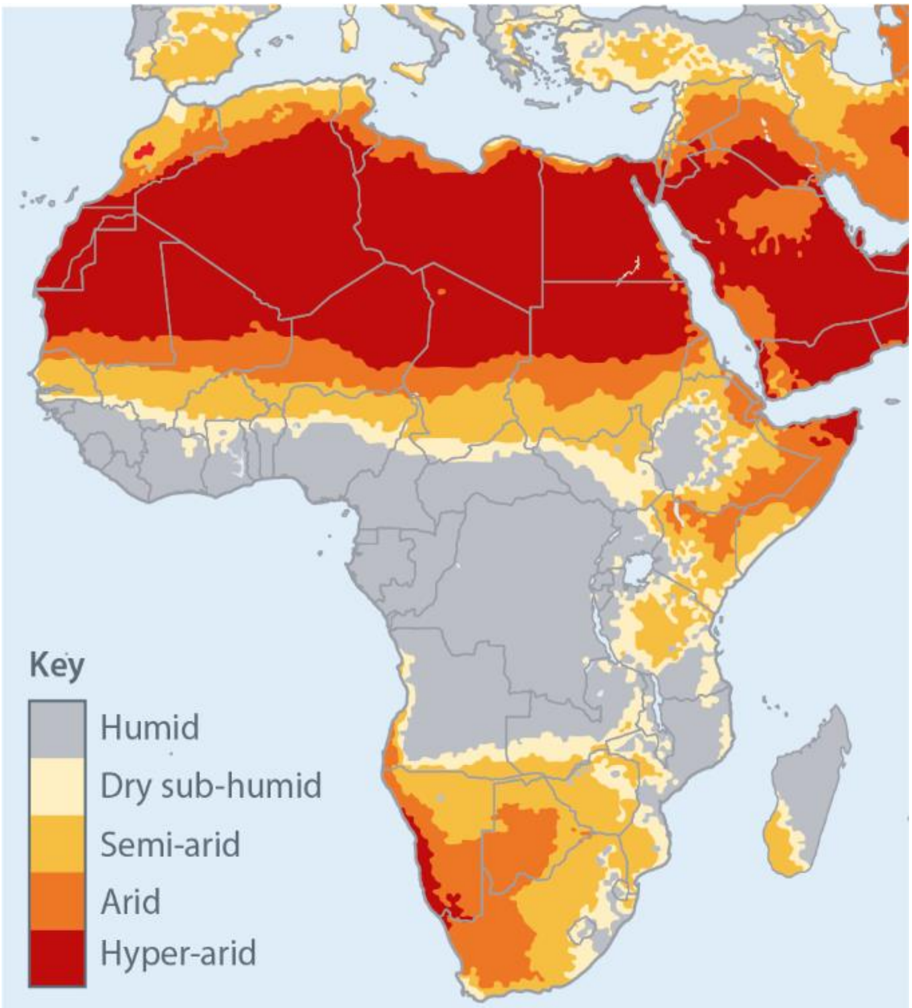


Figure 3: Dryland in Africa: Geographical distribution of drylands in Africa, delimited based on the aridity index (AI)

Source: (Dupar, 2019)

3.2 East Africa

3.2.1 Regional Overview of Climatic Conditions

Climate change and variability exacerbate vulnerability in the East Africa region that is already grappling with the impacts of increasing temperatures and changing rainfall patterns on livelihoods, food security, economic growth, health and ecosystems. More than 70 percent of the population in the region resides in rural areas and mainly depend on climate-sensitive rainfed agriculture for their livelihoods. Climate change and variability are projected to result in rising food and nutrition insecurity and poverty in the region.

Figure 4 presents the main climatic zones for the East Africa region. The climatic zones range from arid, temperate to tropical. The region's geography includes savannas and deserts, coastal regions, vast forests and lakes (that include Lake Victoria - the second largest freshwater lake in the world), and mountainous areas (including Africa's two tallest mountains – Mt Kilimanjaro and Mt Kenya). The region experiences high temperature with little seasonal variation. Annual average temperature ranges from as high as 30°C in the northern interior (Sudan), to around 26°C in coastal areas and as low as 6°C in high-elevation areas of Kenya and Tanzania. The region has three main rainfall regimes: the equatorial regions have two rainy seasons with peaks in April and October; in the south, the primary rainy season is December to February, while June to August is the primary rainy season in the north. The seasons are linked to the annual north-south movement of the rainfall-inducing Intertropical Convergence Zone that shifts towards warmer air bringing rainy seasons in the respective warm months of areas north and south of the equator. The El Niño Southern Oscillation periodically influence rainfall (every two to seven years) resulting in alternating periods of below- and above-normal rainfall. The annual rainfall across the region ranges from more than 2000 mm in the highland areas to nearly 0 mm in parts of northwest Kenya. The region experiences frequent droughts and floods, and substantial interannual and interdecadal rainfall variability (USAID, 2020).

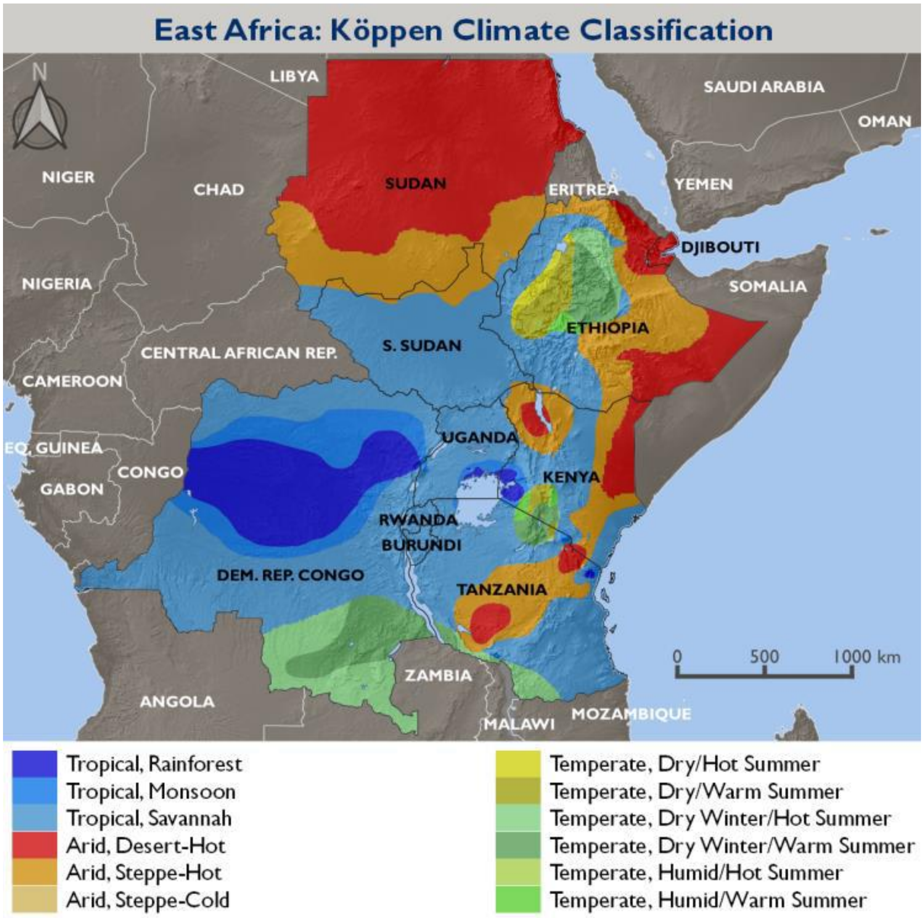


Figure 4: The main climatic zones for the East Africa region

Source: USAID (2020)

3.2.2 Historical Climate Trends and Projections

Historical Climate Trends

The observations for the region since 1901 indicate a clear trend of rising average temperatures and the trend for rainfall is more variable with a marginal increasing trend (Figure 5). Projections of future temperatures and rainfall show further increases in average temperatures (and heatwaves) and increased frequency and intensity of heavy rainfall events. Despite uncertainty in rainfall changes, the majority of climate models indicate increased rainfall (with seasonality) for most parts of the region except southern Tanzania (Table 1). Droughts are also expected to intensify in the 21st century due to longer dry spells and increased evapotranspiration and much of the rainfall coming in heavy rainfall events (USAID, 2020; USAID & EAC, 2017)

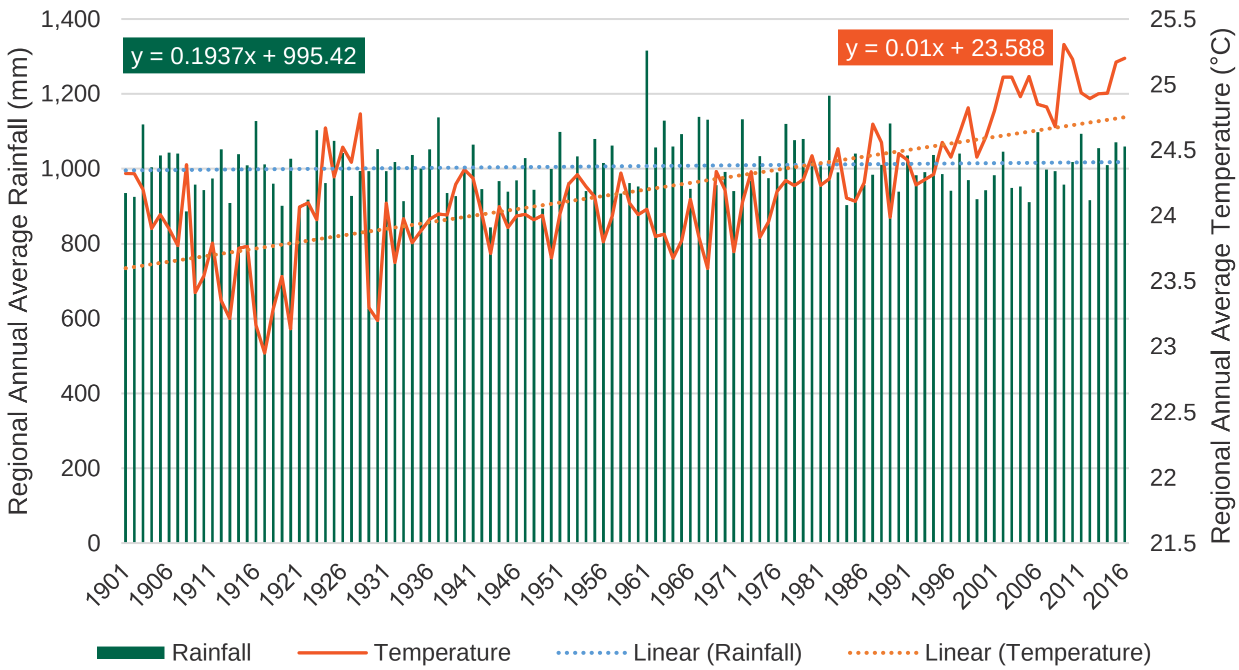


Figure 5: Temperature and rainfall trends for East Africa: 1901 - 2016

Source: Own construction based on data from World Bank (2020)[2]

Table 1: Summary of historical trends in climate

Variable	Summary of historical trends in climate
 Temperature	• Average temperatures increased by 1°C to 2.5°C from the 1960s, and most of the warming is experienced in the central and northern parts of the region. The affected countries include South Sudan, Sudan, Uganda and coastal areas of Kenya.
 Rainfall	• Despite weak and variable rainfall trends, March to May rainfall has decreased since the late 1970s affecting parts of central Kenya; western South Sudan and Uganda.
	• Heavy rainfall events increased in frequency and intensity.

[2] Countries included are Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Mauritius, Rwanda, Seychelles, Somalia, South Sudan, Tanzania and Uganda

Variable	Summary of historical trends in climate
Heavy rainfall	
Drought and dry spells	• Since the 1990s Kenya, Sudan, Tanzania and Uganda experienced increased frequency and severity of droughts.
Sea level rise	• Sea level rise observed in coastal parts of the region: ○ 3.46mm per year rise in Mombasa between 1986 and 2016. ○ 1.58mm per year rise in Zanzibar (Tanzania) between 1984 and 2016. ○ 11.5cm rise between 1955 and 2003 as well as declines in sea level in some areas of Tanzania.

Source: USAID (2020)

Projected Future Climate Trends

By the end of this century, maximum and minimum temperatures are projected to rise over the equatorial parts of the region resulting in more warmer days compared to the baseline (Tables 2 and 3). The rainfall projections indicate a wetter climate by the end of the century with more intense wet seasons and less severe droughts in the months October to December and March to May contrary to historical trends. Parts of Kenya, South Sudan and Uganda are projected to be drier in August and September by the end of this century. Also, shorter spring rains are projected in the mid-21st century in parts of Ethiopia, southern Kenya, Somalia and Tanzania as well as larger autumn rains in southern Kenya and Tanzania. The IPCC's Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (IPCC, 2012) indicated with high certainty that the East Africa region would experience increased chances of more heavy rainfall by the mid-21st century. On the contrary, projections for extreme drought conditions are inconsistent in the region (IPCC, 2012).

Table 2: Projected changes in climate in East Africa

Variable	Projected changes in climate
Temperature	• Average temperatures projected to increase by between 1°C and 3°C by the 2050s and the central and northern parts are projected to experience the greatest increases. • Heatwaves projected to increase in frequency and duration (between 4 and 36 days) by 2050, especially in the north-eastern parts of the region covering Djibouti, Ethiopia, Kenya, and Sudan.
Rainfall	• Average annual rainfall trends uncertain across models, but majority indicate increase average annual rainfall by 2050 affecting especially the northern monsoon period (except in southern parts of Tanzania). Ethiopia and Kenya are projected to experience the greatest increases. • Rainfall seasonality shifts for most parts of the region: ○ Increased rainfall during the short rainy season (October to December) in the north of the equator. ○ Decreased rainfall during the long rainy season (March to May) in the north of the equator. • Increased variability in inter-seasonal and interannual rainfall.

Variable	Projected changes in climate
Heavy rainfall	• Heavy rainfall events will increase in frequency and intensity affecting central and northern parts of East Africa. The affected countries include Burundi, Democratic Republic of Congo, Ethiopia, Rwanda, Tanzania.
Drought and dry spells	• Increased intensity and occurrence of droughts.
Sea level rise	• 16cm – 46cm sea level rise by 2050.

Source: USAID (2020)

Table 3: Areas projected to experienced significant changes in climate

Affected area	Months projected to experience increased rainfall	Months projected to experience decreased rainfall
Eastern parts of the region: Ethiopia; Kenya; Tanzania	• October to December (short rainy season north of the equator). • January to February. • July to September.	• March to May (long rainy season north of the equator).
Western parts of Ethiopia	• March to May (long rainy season north of the equator).	• June to September (rainy season).
Northern parts of Sudan	• August - October (2nd half of rainy season) and November–January.	• No projected rainfall decrease.
Democratic Republic of Congo	• November - April (rainy season).	• No projected rainfall decrease.

Source: USAID (2020)

3.2.3 Climate Change Impacts and Vulnerabilities on Food Production

Subsistence and cash crop production that are primary sources of livelihoods and economic activity in the region are vulnerable to increases in warming and changes in rainfall patterns. Agriculture contributes at least 24 per cent of GDP in most countries in the region except in Djibouti, DRC and South Sudan. Small-scale farms account for up to 90 per cent of crop production in the region and are a primary source of employment for the region's 297 million rural population (USAID, 2020).

The main crops produced in the East Africa region include a mixture of cereals and legumes: maize, sorghum, millet, wheat, beans; major cash crops (tea and coffee). Changes in temperature and rainfall patterns increase the vulnerability of the mainly rainfed crop production that is already facing challenges of low-input use, limited processing, storage and transportation infrastructure. Crop yields at low elevation areas in the regions, especially maize, bean, banana and plantains are projected to decline due to heat and water stress by the 2030s and 2050s. On the contrary, in high elevation areas, increases in temperatures would expand areas for crop production potential. However, the expanded crop production potential in high elevation areas could increase pressure for cropping activities on mountain slopes and protected areas threatening ecosystems services and biodiversity (USAID, 2020). Also, the region has generally a larger area of lowland crop production vis-à-vis high elevation areas; meaning that any potential increases of yields in highland areas would not off-set potential losses in lowland areas.

Maize is the main staple crop accounting for almost half of the calorie intake in the region. However, maize is projected to experience yield reduction between 8 and 37 per cent across the region by the 2090s. Increases in temperature beyond optimal threshold levels would result in yield reductions and adversely impact on food supply. A 1.5°C increase in warming by the 2030s is expected to result in about 40 per cent reduction of land areas suitable to current maize cultivars while crop production could decrease by 10 per cent with less than a 2°C warming by the 2050s. Higher levels of warming could lead to yield reductions between 15 and 20 per cent across all crops and regions (USAID & EAC, 2017).

The production of lowland bean, an important nutritional crop, is projected to become unviable as a result of increasing temperatures after the mid-21st Century, especially in Tanzania and Uganda. The production of drought-resilient millet, sorghum and cassava is projected to become increasingly marginal in drier parts of East Africa affecting South Sudan and Sudan. On the other hand, although wetter rainy seasons might be favourable for crops, particularly perennials and a range of fruits and vegetables, the same could prevent staple crops such as maize and sweet potatoes from maturing. Also, warmer and wetter climatic conditions could increase crop and post-harvest losses as a result of increased risk of mildew, leaf spot, bacterial stem and root rot and increased growth of fungus in stored seeds (USAID, 2020).

The area suitable for tea and coffee production is projected to diminish by 20 to 40 per cent due to increases in heat and pest stress (such as coffee berry borer) by 2100, particularly in Burundi, Ethiopia, Kenya, Rwanda and Uganda. On the other hand, areas suitable for coffee production are projected to expand into high elevation areas that could also have negative environmental impacts such as reduced water availability, deforestation, nutrient loading in streams. Areas along the coast are projected to experience sea-level rise resulting in increased salinization, waterlogging and inundation of agricultural lands, significantly affecting yields of mango, cashew and coconut production (USAID, 2020)

Table 4: Climate stressors and climate risks on Crop Production

Climate Risk/ Stressors	Potential Impacts on Agriculture/ Risks
• Rising temperatures. • Increased heat stress on crops. • Shifting seasonal rainfall patterns. • Increased frequency and intensity of heavy rainfall. • Sea level rise.	• Crop failure/loss reduced yields and quality. • Changes in crop suitability due to shifting agroecological zones. • Increased incidence of pest and diseases (e.g., maize stalk borer, coffee berry borer). • Soil degradation from heavy rainfall, flooding, and erosion. • Saltwater intrusion, coastal erosion, storm surges, and inundation.

Source: USAID (2020)

Figure 6 shows trends between cereal yields and rainfall in East Africa between 1961 and 2016. Trends of both rainfall and crop yields indicate a close relationship between the two variables with years of rainfall decline and or extreme rainfall associated with a decline in crop yields. Staple crop yields across the continent have decreased due to climate change, increasing the food and nutrition insecurity risk, particularly among the poor and vulnerable populations.

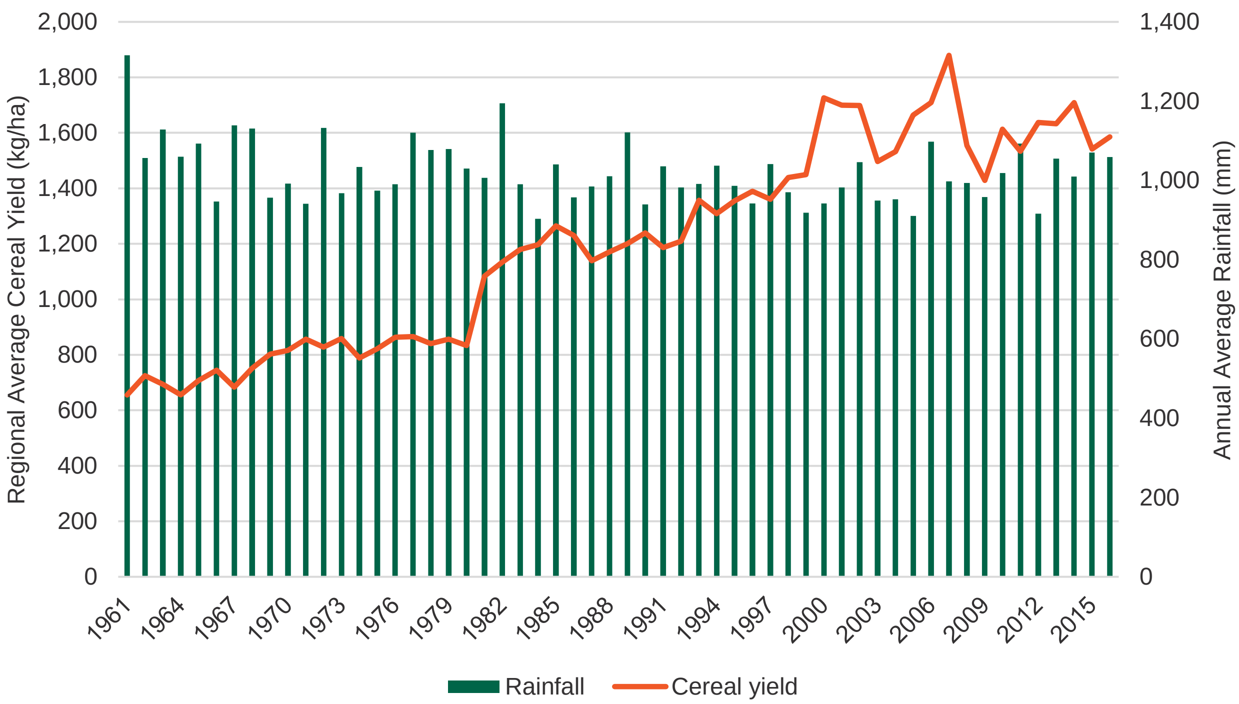


Figure 6: Relationship between rainfall variability and cereal yield, in East Africa

Source: Own construction based on data from World Bank (2020) and FAO (2020)[3]

3.3 Southern Africa

3.3.1 Regional Overview of Climatic Conditions

The Southern Africa region experiences spatial climate variability. The agroclimatic regions ranges from semi-arid in the east, to semi-arid and temperate areas in central zones; including a few sub-humid areas in central regions and arid areas in the west (Chishakwe, 2010). Livelihoods and economies in Southern Africa are sensitive to changes and variations in climatic conditions and climate extremes present a significant risk to resilience in the region. Rainfed agriculture - mostly cereal production - is the primary source of income for most of Southern Africa's rural population. Southern Africa is experiencing rapid population growth, encroachment into ecologically marginal areas, urbanization of coastal areas and poverty. The region's climate ranges from arid to humid subtropical influenced by topography and large-scale seasonal atmospheric patterns (USAID, 2016).

The region usually receives rainfall in the summer months (November to March) except South Africa which also has Mediterranean climate. The rainfall varies across the region characterized by an east-to-west gradient that ranges from higher rainfall in the Mozambique coast to very dry conditions in the western Namibia coast (USAID, 2016). The El Niño Southern Oscillation phenomenon is highly associated with long-term variability in rainfall patterns in the region. El Niño events are usually associated with warmer and drier conditions, while La Niña events are associated with cooler and wetter conditions (USAID, 2016). The region experiences significant variations in temperatures with highest temperatures recorded in the Kalahari Desert (>40°C) and coastal Mozambique. In contrast, the lowest temperatures are experienced in Lesotho, South Africa and Zimbabwe highlands.

[3] Countries included are Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Mauritius, Rwanda, Seychelles, Somalia, South Sudan, Tanzania and Uganda

3.3.2 Historical Climate Trends and Projections

Historical Climate Trends

Figure 7 and Table 5 summarises historical changes in temperature and rainfall in Southern Africa. The observed changes indicate a rising trend in temperature across the region. Despite variability in rainfall patterns, the trends indicate a declining trend in rainfall in Southern Africa.

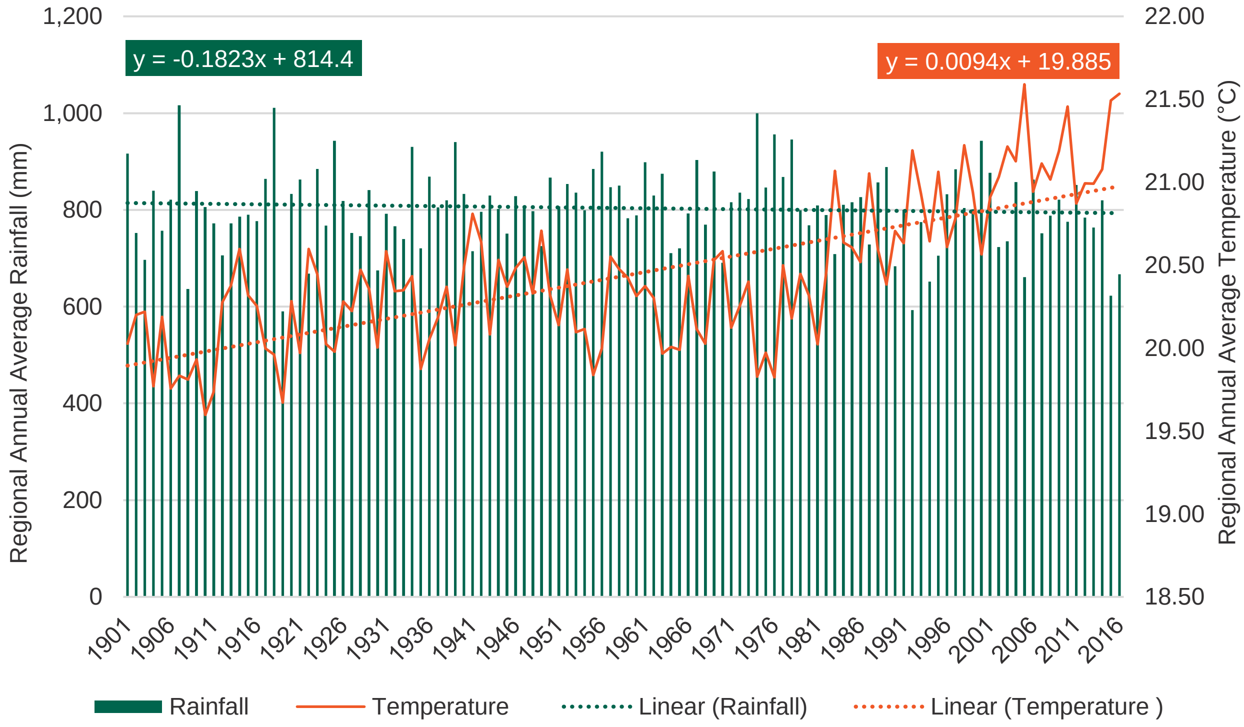


Figure 7: Temperature and rainfall trends for Southern Africa: 1901 - 2016

Source: Own construction based on data from World Bank (2020)[4]

Table 5: Observed changes in climatic conditions in Southern Africa

Variable	Summary of historical trends in climate
Temperature	• Increased temperatures (mean, minimum and maximum), rapid increases have been in minimum temperatures 1–1.5°C on average), particularly in the interior regions (1.6–2°C on average) by 2100.
Rainfall	• Increased summer rainfall in Lesotho, Namibia and South Africa as well as increased variability in Angola. • Reduced late summer precipitation (November–March) in Botswana, Namibia, Zimbabwe and Zambia. • Changes in rainfall patterns and variability (onset, duration and intensity.

[4] Countries included are Angola, Botswana, Lesotho, Madagascar, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, Zimbabwe

Variable	Summary of historical trends in climate
Drought and dry spells	• Increased frequency of seasonal dry spells (breaks in the rainy season of at least five days where no significant rain is received).

Source: USAID (2016)

Projected Future Climate Trends

By the end of this century, maximum and minimum temperatures are projected to rise over the equatorial parts of the region resulting in more warmer days compared to the baseline (Table 6). The rainfall projections indicate a wetter climate by the end of the century with more intense wet seasons and less severe droughts in the months October to December and March to May, contrary to historical trends. The future projections for the region indicate variations that include high warming rates especially in the semi-arid south western parts including Botswana, north-western South Africa and Namibia (IPCC, 2014). In contrast, rainfall projections indicate a drying trend in mean annual rainfall with the most affected areas including the climatologically dry south-west and north-east areas of Botswana and Namibia. Seasonal rainfall projections point to decrease in summer rainfall across the region varying from -10 to -15 per cent in coastal areas and -20 per cent in inland areas (around Western Cape) and -40 to -50 per cent in the Kalahari, Namibia, southern Zambia and western Zimbabwe. Rainfall projections also show delayed onset of seasonal summer rainfall in most parts of the region (IPCC, 2014).

Table 6: Projected changes in climatic conditions in Southern Africa

Variable	Projected changes in climate
Temperature	• Mean temperature rise above 2°C (or more), especially in the arid regions projected to experience temperatures increases between 3.4°C and 4.2°C, which is higher than 1981 -2000 averages. • The temperature increases are expected to be more pronounced in summer (November to March).
Hot days/nights; heat waves	• Higher minimum temperature rise compared to rise in maximum temperatures. • Increased extreme in heatwaves and temperatures.
Rainfall	• Increased changes in rainfall patterns and variability (onset, duration and intensity) as well as increased frequency of seasonal dry spells. • Uncertain rainfall changes and more likely drier conditions.
Heavy rainfall	• Increased frequency and intensity of extreme climatic conditions (floods, cyclones and droughts).
Drought and dry spells	• Increased frequency and intensity of droughts and dry spells.

Source: USAID (2016)

3.2.3 Climate Change Impacts and Vulnerabilities on Food Production

Agriculture production in Southern Africa is mainly rainfed and is vulnerable to climate change and variability. Other factors that affect the vulnerability of the sector include lagging technological research and innovation, poor farming methods and an increase in pests and diseases, poor infrastructure, stagnating farm incomes. Cereals take more than 40 per cent of the region' arable land dominated by maize, millet (in Namibia), paddy rice, sorghum (Mozambique) and wheat (South Africa) (USAID, 2016).

Several countries in the region are food import-dependent, which is worsened by vulnerability to climate change and variability. Intra-regional food markets and trade plays an essential role for most of the food import-dependent countries to meet food and nutrition requirements.

The Southern region is vulnerable to extreme climatic events such as droughts, floods and cyclones that significantly affect the resilience of food systems. The current and projected changes in climate and extreme events exacerbate the vulnerability of food systems through complex interactions with socio-economic, political and environmental factors (see Table 7).

Table 7: Climate risks and potential impacts in agriculture (convert them to value chain stages)

Climate Risk	Potential Impact on Agriculture
• Increased evapotranspiration. • Reduced soil moisture. • Increased heat stress on crops. • Decreased water availability.	• Crop failure and reduced yields. • More conducive environment for pests and diseases. • Shifts in suitability of arable land to agriculture and specific crops. • Sifts in the length of the growing season. • Projected increases in food costs and price volatility.
• Cyclical shocks including droughts and floods sometimes in a single year. • Increased intensity of shocks such as extreme rainfall or prolonged dry periods/ droughts. • Increased frequency and or intensity of cyclones and heavy rains.	• Erosion of adaptive capacity and increased vulnerability. • Projected increases in food and nutrition insecurity. • Projected increases in human and livestock disease outbreaks. • Rising prices (especially for food and fuel), increases in poverty and increased household vulnerability. • Increased instability and social tensions. • Displacement and asset loss.

Source: USAID (2016)

Figure 8 presents trends between cereal yields and rainfall in Southern Africa between 1961 and 2016. Although other factors affect productivity levels, evidence from the graph indicate that years of extreme rainfall conditions (especially low rainfall years) correspond to marked declines in cereal yields. This is also because most of cereal production is based on rainfed systems making it more vulnerable to changes in rainfall patterns.

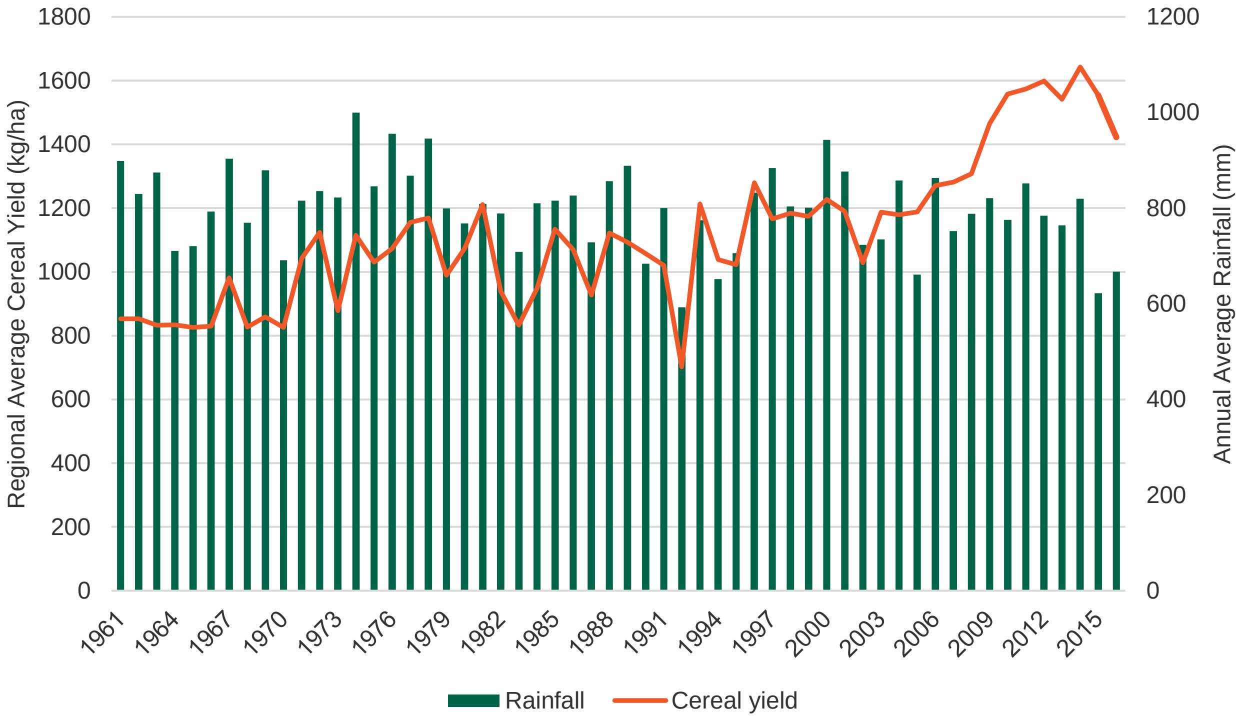


Figure 8: Relationship between rainfall variability and cereal yield, in Southern Africa

Source: Own construction based on data from World Bank (2020) and FAO (2020) [5]

3.4 West Africa

3.4.1 Regional Overview of Climatic Conditions

The West Africa region boasts diverse bioclimatic regions such as rainforests, low plateaus, coastal plains, deserts and isolated highlands like the Jos Plateau, Guinea Highlands, Cameroon Highlands and Aïr Mountains. The region has four distinct bioclimatic zones: the Sahel, Sudan, Guinean and Guineo-Congolian (Figure 9). The annual rainfall in the bioclimatic zones follows a latitudinal rainfall gradient from the north to the south. The Sahel region in the north receives the lowest annual rainfall (as little as 100mm), and the southern coastal region receives the highest annual rainfall (up to 5 000mm). Rainfall is highly variable in the region in terms of amount, onset and duration, especially in the drier zones. In the Sahel and Sahara areas, the annual variability can be more than 40 per cent while it ranges between 10 and 20 per cent in the coastal areas. Annual average temperatures range between 22–28°C while maximum temperatures can reach more than 40°C in the Sahel in the summer (April–September). Table 8 summarises the rainfall and temperature of the climatic zones in West Africa (USAID, 2018).

[5] Countries included are Angola, Botswana, Lesotho, Madagascar, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, Zimbabwe

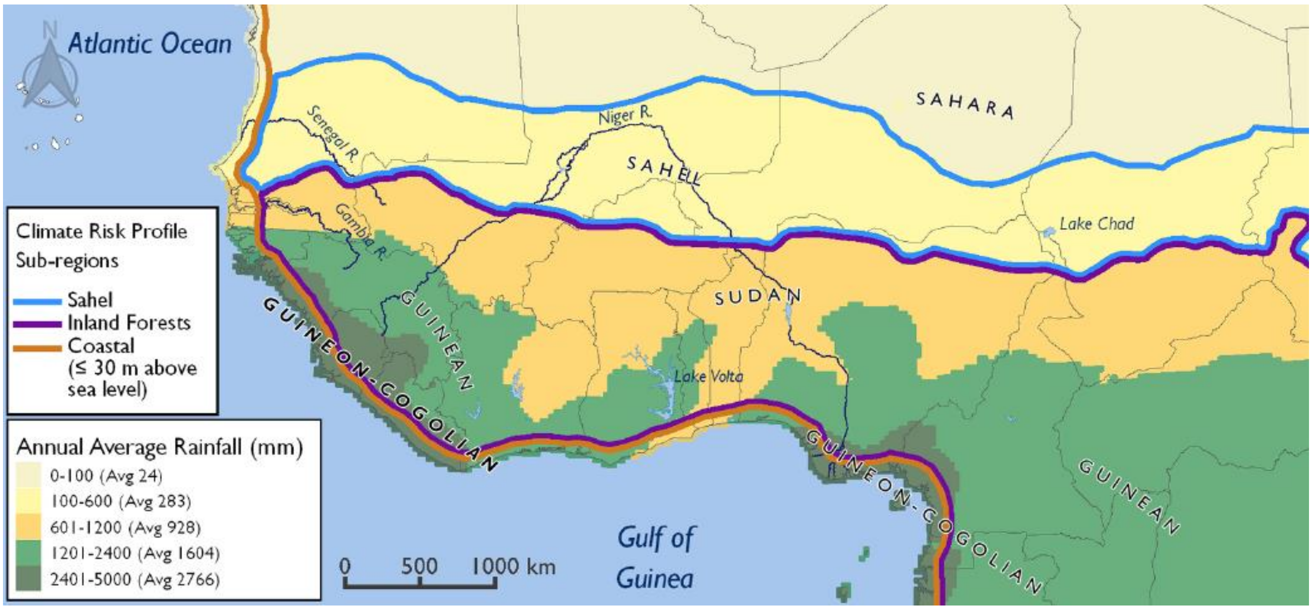


Figure 9: West Africa rainfall and climatic zones

Source: USAID (2018)

Table 8: Bioclimatic zones: vegetation, rainfall, and temperature

Bioclimatic Zones	Rainfall and Seasonality	Temperature
Sahel Grassland, shrubs and small trees.	Average annual rainfall of 100–200 mm (north) to 500–600 mm (south), with a rainy season ranging from one to five months during June–October; maximum rainfall in August.	Average annual temperatures above 22 - 36°C.
Sudan Savannah and open woodlands.	One rainy season (May–October), with an annual rainfall of 600 to 1,200 mm.	Average annual temperatures above 22 - 28°C.
Guinean Dense, seasonally wet and dry forests.	Two rainy seasons (April–July and September–October), with an annual rainfall of 1,200–2,200 mm. Most rain, 75–80 per cent, falls during April–July.	Average annual temperatures above 22 - 28°C.
Guineo-Congolian Dense rainforests.	Two rainy seasons (April–July and September–October) or year-round rainfall; annual averages of 2,200–5,000 mm.	Average annual temperatures above 22 - 28°C.

Source: USAID (2018)

The West Africa region is vulnerable to climate change and variability. Changing rainfall patterns and increasing temperatures are already impacting livelihoods, food and nutrition security, economic and governance stability. The region has experienced persistent losses in the agriculture sector, recurrent food crises, droughts and water scarcity, flooding and environmental degradation due to extreme climate variability since the 1970s. The region's coastal areas accommodate densely populated cities and economic hubs. However, the coastal areas are experiencing rising sea-levels and severe coastal erosion which are both projected to increase due to climate change. These impacts would significantly impact on agriculture and fisheries sectors, coastal aquifers, urban centers and ports and the coastal population. The region's crops and livestock sectors that support an estimated 60 per cent of livelihoods and contribute about 35 per cent of the regional Gross Domestic Product (GDP) are at risk of climate change. The climate risks include variability in rainfall and increasing heat stress, increased frequency and intensity of heavy rainfall and drought events and diminishing rainfall in the west of the region (USAID, 2018).

3.4.2 Historical Climate Trends and Projections

Historical Climate Trends

The summary of historical climate trends in West Africa is presented in Figure 10 and Table 9 below. The observed climate trends in West Africa include increasing average temperatures; increased rainfall in some areas and reduced rainfall in other areas with high interannual and interdecadal variability especially in the Sahel region; increased frequency and intensity of heavy rainfall events and sea-level rises.

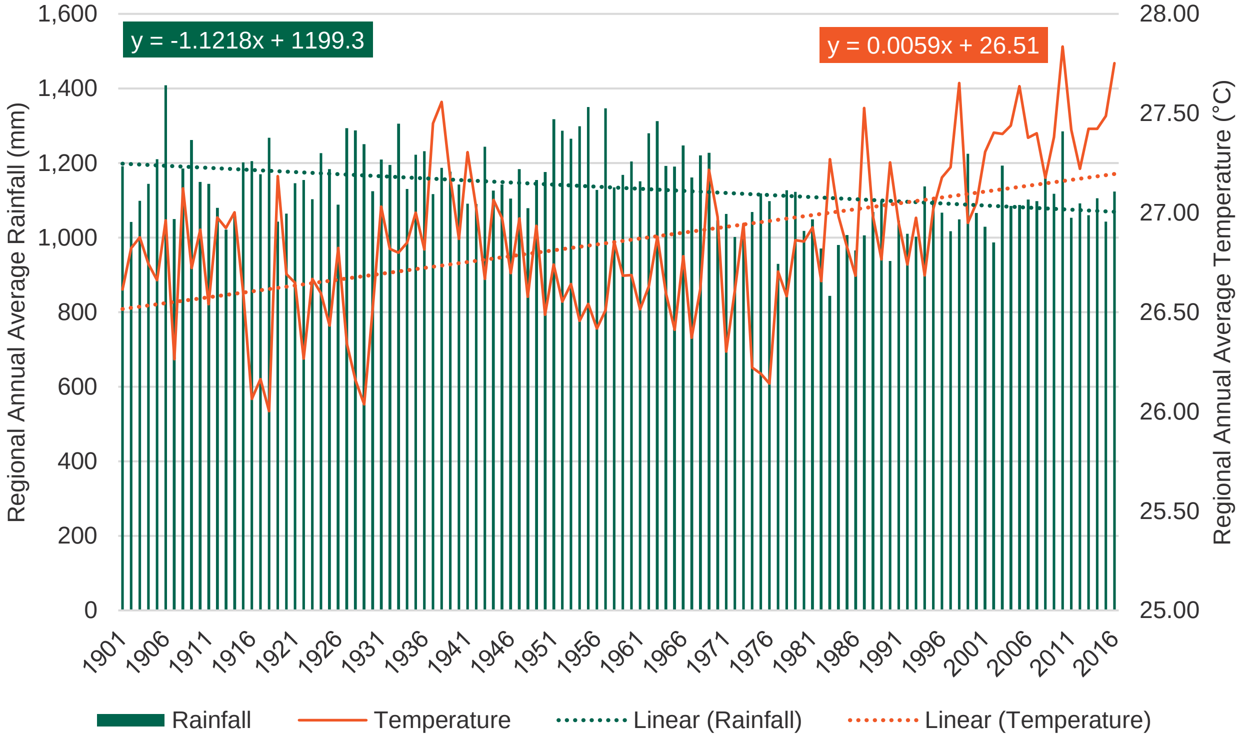


Figure 10: Temperature and rainfall trends for West Africa: 1901 - 2016

Source: Own construction based on data from World Bank (2020)[6]

Table 9: Historical climate trends across West Africa

Variable	General historical trends	Examples
Temperature	• Temperatures increased across the region.	• +0.5 - 0.8°C: most parts of the region (1970 - 2010). • +1.5 - 2.0°C: increased warming in the Sahel, particularly, between April and June (1950 – 2010).

[6] Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo

Variable	General historical trends	Examples
Rainfall	• Reduced rainfall in the western Sahel. • Increased rainfall in the eastern parts of the region. • Increased rainfall variability and shifts in interannual changes since mid-2000s.	• Rainfall decreased (1901 - 2013): -6 percent in Senegal and The Gambia, and -3 percent in Côte d'Ivoire per 30 years. • Increased rainfall between 1983 and 2013 between +4 percent in Benin, Ghana and Togo to +36 percent in Niger.
Heavy rainfall	• Heavy rainfall events increased in frequency and intensity.	• Proportion of rainfall from heavy rainfall events increased especially in central Sahel: 21 percent (2001-2020) compared to 17 percent (1970-1990).
Sea level rise	• Rise in sea level.	• High increase in sea level estimated at: ○ 25cm in Takoradi (Ghana) since the 1930s. ○ +8.4cm between 1942 and 2012 in Dakar (Senegal).

Source: USAID (2018)

Projected Future Climate Trends

The future climate projections for the West Africa region are presented in Table 10 below. The results indicate continued increases in temperature and increased frequency and duration of heatwaves. Rainfall continues to be variable with projections of increased and decreased rainfall across the region. Projections point to delayed onset of the rainy season in spring, and heavy rainfall events will increase in frequency and intensity. Surface temperatures and sea levels are projected to continue rising (USAID, 2018).

Different global and regional temperature projections for the West Africa region show a rising trend ranging from 3°C to 6°C by the end of the 21st century. The Sahel and West Africa are projected to be climate change hotspots with unprecedented climate changes expected between the late 2030s and early 2040s. Despite variations in rainfall projections, global models indicate that by the end of the 21st century the West Africa region would experience a wetter main rainy season and a small delay in the onset of the rain season. The West Africa region is projected to experience increased rainfall intensity by the end of the 21st century (with medium confidence). The region will also experience increased frequency of hot days (high confidence), decreasing dryness trend over large areas (medium confidence) and increased intensity and frequency of extreme rainfall events covering the Guinea Highlands and Cameroon Mountains (IPCC, 2012; IPCC, 2014).

Table 10: Future climate projections across West Africa

Variable	General historical trends	Examples
Temperature	• Temperature increase across the region, the Sahel was affected the most.	• +1.6 - 2.9°C: Burkina Faso, Mali, Niger and Mauritania. • +1.4 - 2.5°C: Senegal and The Gambia. • +1.3 - 2.3°C: Benin, Côte d'Ivoire, Ghana and Togo.
	• The duration of long-lasting heatwaves (between 6 and 28	• +8 - 28 days: Burkina Faso, Mali and Niger.

Variable	General historical trends	Examples
Hot days/nights; heatwaves	days) increase – the east projected to experience the greatest increase.	• +8 - 26 days: Benin, Ghana, Mauritania and Togo. • +6 - 23 days: Nigeria. • +6 - 18 days: Senegal and The Gambia.

Rainfall	• Uncertain rainfall trends with models suggesting:
	  ○ rainfall decrease in Senegal, The Gambia and western Mali,
	  ○ rainfall increases and no change for the other parts of region.
	• Delay in the onset of the spring rainy season.
		• Decreased rainfall for Western Sahel especially in Senegal and The Gambia.
		• Increased rainfall for the region, except the Western Sahel.

Heavy rainfall	• Heavy rainfall events increase in frequency and intensity.	• Heavy rainfall events increase in frequency (+1 - 43 percent) and intensity (+1 - 12 per cent): Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali, Nigeria and Togo. • Increased frequency (+16 - 75 percent) and uncertain trends for intensity (-4 - +21 percent) in Niger. • Uncertain trends in the frequency of (-10 - +31 percent) and intensity (-2 - +14 percent) in Senegal and The Gambia.
Drought and dry spells	• Dry spells increase especially in the western parts of the Sahel affecting Senegal and The Gambia. • Rest of the region projected to experience reduced dry spells.	• Shifts in dry spells ranging from -4 - +22 days in Senegal, Mauritania and The Gambia. • Shifts in the length of dry spells ranging from -11 – 0 days in Nigeria and -8 - +1 days in Benin, Côte d'Ivoire, Ghana, and Togo.
Sea level rise	• Rise in sea level: +17 - 45cm.	• +17 - 43 cm: Senegal and Nigeria. • +18 - 43 cm: Benin, Ghana and Togo. • +18 - 45 cm: Côte d'Ivoire.

Source: USAID (2018)

3.4.3 Climate Change Impacts and Vulnerabilities on Food Production

Crop and livestock production systems in West Africa are vulnerable to current and projected changes in climate change and variability. The current crop and livestock losses due to climate change and variability are projected to increase in the future. For example, increases in temperatures above 2°C will result in stressing conditions for crops resulting in cereal yield decreases of about 11 percent. The impacts will severely affect maize and rice in most parts of the Inland Forest subregion and yields of millet and sorghum in areas such as Burkina Faso and Niger could decrease by between 15 and 25 per cent. Sea-level rise of up to 1 m by the 2050s would inundate about 18 000 km^2 of the region's coastline affecting important transport corridors, cropland, and livelihoods. Although the impacts of climate change and variability on agriculture would be mainly localized, they can extend beyond national borders. The projected decreases and variability in crop and livestock production have implications in regional food and nutrition security worsening conflict over land and water resources. The climate risks across the region are summarised in Table 11 below.

Table 11: Climate stressors and climate risks on Crop Production

Climate Risk/ Stressors	Potential Impacts on Agriculture/ Risks

• Rising temperatures and evaporation rates.
• Heavy rainfall events increase in frequency and intensity.
• Increased rainfall in east and centre; reduced rainfall and longer dry spells in the western Sahel.
• Rise in sea level.
	• Crop failure, poor grain yields and quality as a result of heat and water stress, flooding, heavy rainfall, land degradation, waterlogging.
	• Livestock reproduction, milk production and growth rates reduced in the Sahel and Inland Forests due to heat stress.
	• Increased heat stress affecting farmers/ pastoralists and reduced hours for agricultural work per day as a result of heat stress.
	• Crop and livestock pests and disease incidence and prevalence increase, for example, Rift Valley Fever, locusts, oil palm fungal diseases.
	• Increased erosion and degradation of rangelands, reduced dry season grazing potential and loss of perennial grasses in the Sahel.
	• Rising food prices, food and nutrition insecurity, and increased migration to southern and urban areas.
	• Conflicts over resources increased especially between farmers and pastoralists as cultivation expands and pasture mobility patterns change.
	• Transportation networks and access to agricultural markets (input and output) disrupted, for example, heavy rainfall events, flooding lead to destruction and damage of infrastructure such as roads and other market infrastructure.
	• Destruction and damage to storage facilities and increased risks of losses of stored inputs (such as seeds), crops and food:
	  ○ Increased humidity can result in high changes of fungus infection in stored seeds, crops, and food.
	  ○ Heavy rainfall events/ flooding can damage stored seeds, crops, and food.
	• Diminishing coastal arable land due to coastal erosion, inundation and salinization.

Source: USAID (2018)

Sahel Sub-Region

Agriculture remains a primary source of livelihoods in the Sahel region. Crop production predominantly depends on the region's low highly variable rainfall and is vulnerable to climate change and variability as well as extreme climatic events. The staple crops in the Sahel subregion include millet, sorghum and cowpea while main cash crops are cotton and groundnuts. The agriculture sector contributes between 40 and 50 per cent to GDP in Chad, Mali and Niger and lower percentages in other countries in the subregion. More than 70 per cent of the population in the following countries: Burkina Faso, Chad, Mali and Niger, depend on agriculture for their livelihoods while in Senegal and Mauritania the percentage in more than 50 per cent. The projected increases in temperature and changes in rainfall patterns could change the distribution and timing of crop pests and diseases. For example, hotter and wetter climatic conditions increase the risk of mildew, leaf spot and bacterial stem and root rot. On the other hand, borers, aphids, bollworm, whitefly and beetles thrive in hotter and drier environments. The vulnerability of crop production in the subregion is exacerbated by declining soil fertility, low input use, high dependence on variable natural rainfall, small farm sizes that limit adaptive responses to climate change impacts (USAID, 2018).

Coastal Sub-Region

The significant risks to coastal agriculture activities include increasing heat stress, floods, inundation, waterlogging and water stress, coastal erosion and salinization. The main crops grown in the coastal areas include rice, maize, cassava, yam and tree crops like palm, cocoa, and cashew. Warmer and wetter conditions provide conducive environments for pests and diseases such as rice gall midge, rice weevil, and bacterial leaf blight, making rice production vulnerable to projected climate change in the coastal areas. Coastal crops are also at risk of sea-level rise (from a relatively small rise) which could lead to extensive land inundation and dispersion of saltwater inland causing salinization of surface water, aquifers and land negatively affecting crop production. For example, projections indicate that for Ghana, a sea-level rise of 30cm would result in permanent inundation of 20 000 hectares reducing coastal farmland by more than 3 per cent. An estimated 18 000km^2 of West Africa' coastline could be inundated by sea level rise of up to 1m with severe impacts on cropland, transport corridors and livelihoods (USAID, 2018).

Figure 11 presents trends between cereal yields and rainfall in West Africa between 1961 and 2016. The results are similar to those in East and Southern Africa above. Cereal yields indicate marked declines in years that experience very low rainfall.

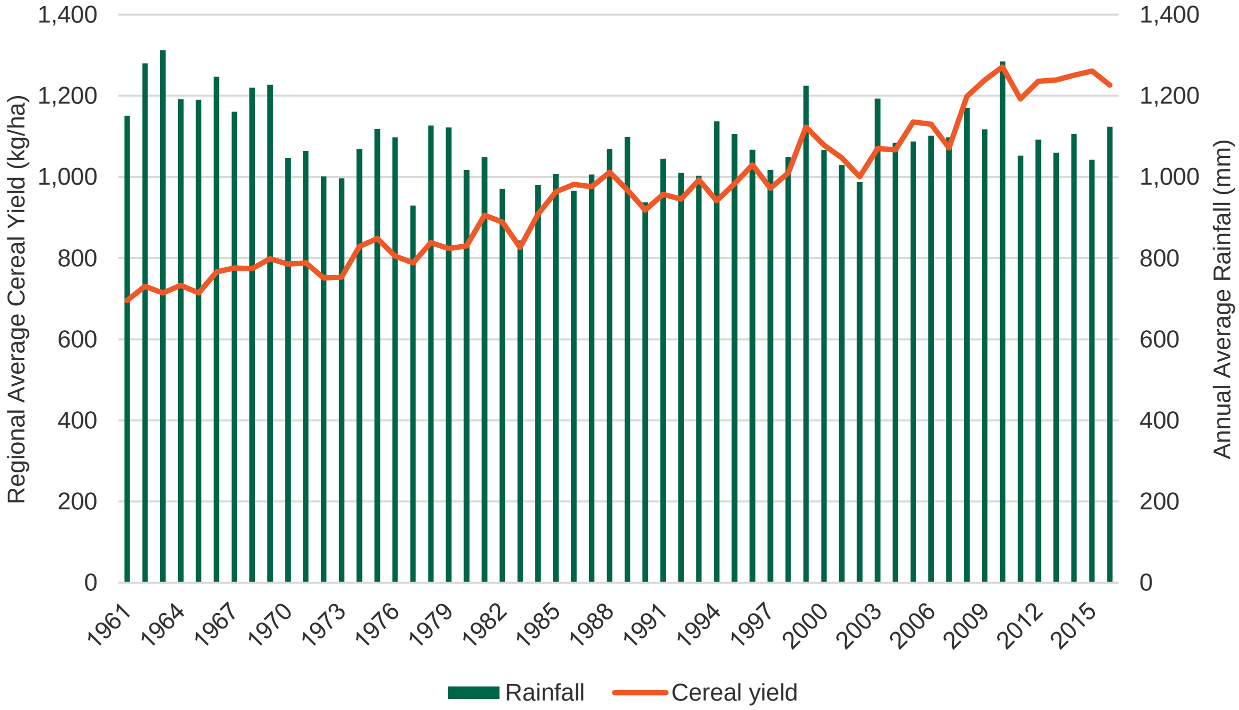


Figure 11: Relationship between rainfall variability and cereal yield, in West Africa

Source: Own construction based on data from World Bank (2020) and FAO (2020)[7]

[7] Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo

4. Climate Change-Related Impacts in Food Value Chains

4.1 Overview of Climate Change Impacts in Food Systems

Climate change directly impacts on the food systems and increases the competition of resources needed for food production through the increased need for adaptation and mitigation (IPCC, 2019). The discussion in this report takes a food systems and value chain approach to understand the key climate change risks and potential measures to adapt, mitigate and build the resilience of food systems through regional food trade interventions. The food systems and value chain approach consider all activities and actors from inputs, production, transport, processing, retailing, consumption and waste of food and the respective impacts on food security, nutrition, health and well-being and the environment (Figure 12).

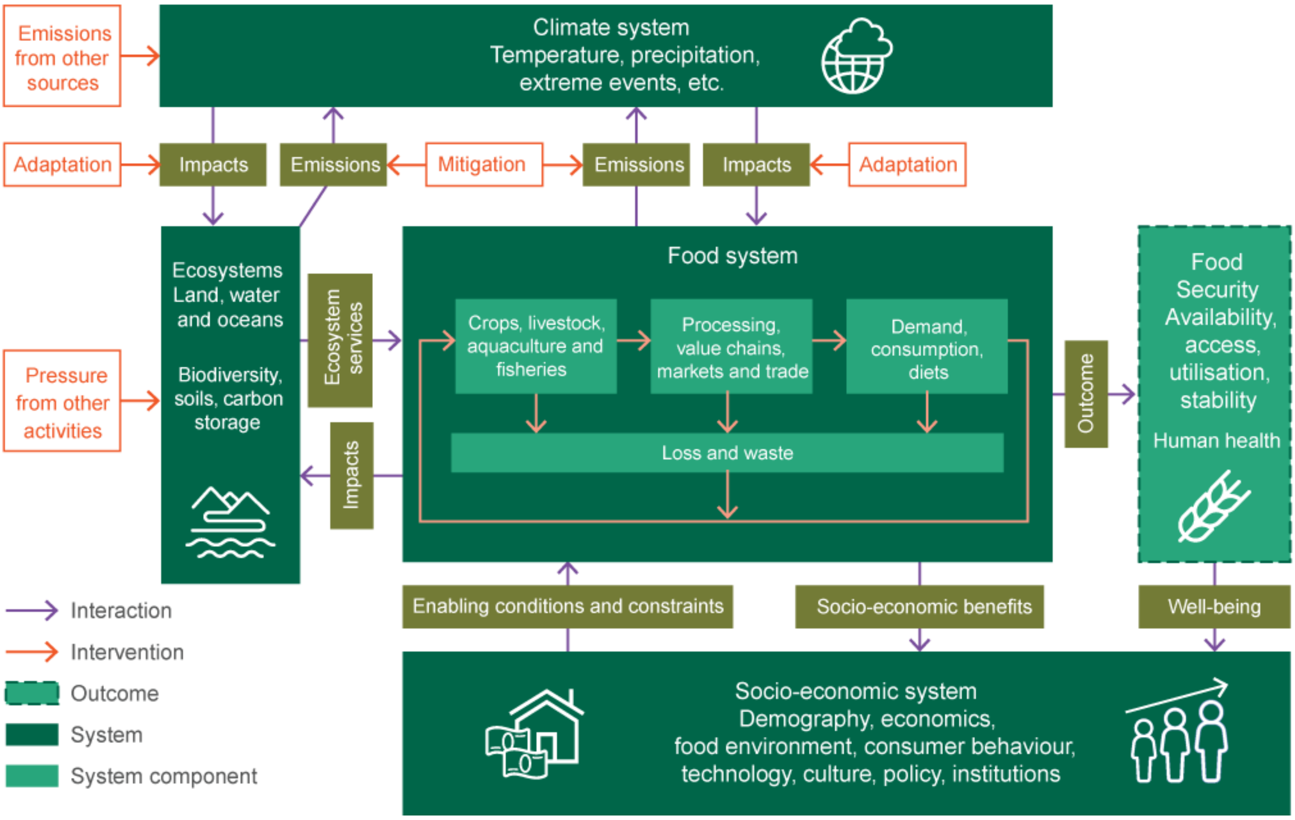


Figure 12: Interlinkages between the climate system, food system, ecosystems (land, water and oceans) and socio-economic system

Source: Adapted from IPCC (2019)

Climate change drivers that impact on food systems include changes in temperature-related and rainfall-related variables and their interactions with other variables. The drivers that impact on food production and availability include modal climate changes (such as shifts in climatic conditions that lead to shifts in cropping varieties that are planted); seasonal changes (such as increases in temperature that lead to the extension of the growing season), extreme events (such as floods, droughts and high temperatures that affect critical growth periods) as well as atmospheric conditions like carbon dioxide concentrations, dust and short-lived climate pollutants (IPCC, 2019). The IPCC projections indicate that the frequency, intensity and duration of extreme weather events will increase in the coming decades (IPCC, 2012; IPCC, 2014; IPCC, 2018). Climate change has complex interactions with non-climatic stressors impacting on food and nutrition security outcomes through impacts on food availability, access, utilization and stability (FAO, et al., 2018; IPCC, 2019).

Climate change affects food value chains across all stages from inputs, production, harvesting and storage, aggregation and trade, processing, distribution to consumption agriculture (IFAD, 2015; Dazé & Dekens, 2016; Lim-Camacho, et al., 2016; USAID, 2018). The different activities along the food value chain impact on food and nutrition security outcomes and generate impacts on the environment. The environmental impacts include greenhouse gas (GHG) emissions, land degradation and loss of ecosystems services. Food security is also indirectly linked with the climate and ecosystems through the socio-economic systems. Adaptation interventions can help minimize climate change impacts on the food systems and ecosystems. In contrast, mitigation interventions help reduce environmental impacts (such as GHG emissions) from the food systems and ecosystems (IPCC, 2019).

Sub-Saharan Africa's population is projected to be most vulnerable to projected increases in drier conditions that are expected earlier in drier regions and to be more severe than in humid regions (Lickley & Solomon, 2018). Smallholder farmers experience high risks at the lower stages of the value chains, especially on inputs, production, harvesting and storage. The impacts of climate change and extreme events on these low stages of the value chain severely impact on the smallholder farmers ability to move their produce up the value chain with detrimental impacts on food and nutrition security, farm incomes and resilience to shocks.

The next section discusses the impacts of climate change-related risks on different stages of the food value chain.

4.2 Climate Change Impacts at Different Stages of the Food Value Chain

4.2.1 Inputs

Climate change and variability affect the quantity and quality of seeds and the impacts cascade along the whole value chain through reduced quantity and quality of crop yields. For example, increased exposure of inputs to extreme weather such as increased warming and flooding affect storage conditions for seed. Excessive humidity, for instance, results in fungus in stored seeds. The quality of stored seeds is negatively affected if there is no proper and adequate storage infrastructure.

Decreasing crop yields as a result of increases in warming, water stress, changes in pests, and disease incidence affect the quality of inputs as well as the demand for and availability of inputs such as seed varieties, pesticides and fertilizers. Seed germination is affected by increases in warming that leads to higher soil moisture evaporation affecting the optimum conditions for seed germination. Also, irregular and unpredictable rainfall may lead to a false start in the rainy season as well as impact the optimum seed germination conditions and the entire growing season resulting in poor yields (USAID, 2017). For example, poor yields due to impacts of climate change on the crop growing conditions affect seed production for the next season.

Extreme rainfall events due to climate change lead to land degradation and loss of soil organic matter resulting in acidic soils that affect seed production and germination that result in low crop yields. Also, extreme climatic events such as cyclones and flooding can destroy infrastructures such as input storage infrastructure and transportation infrastructure, impacting the quality of inputs, timely delivery and access to inputs by farmers. The above climate-related conditions may force farmers to replant, increasing production costs as well as impacting crop production and yields. Increased input costs lead to a reduction in the area planted, which may also impact employment on-farm and at other value chain stages. These impacts have knock-on effects on household incomes as well as food and nutrition security. The limited availability and access to improved inputs such as seeds affect smallholder farmers the most.

4.2.2 Production

Climate change and variability exacerbate the risks in food production in Africa, which is dominated by smallholder farmers with less assets and limited adaptation capacities, lack access to mechanization and markets (UNDP, 2017). The IPCC projects that climate change would lead to crop yield reduction across sub-Saharan Africa ranging from 5% for maize, 14% for rice and 22% for wheat, exacerbating the poverty and vulnerability of already poor populations that depend on agriculture for their livelihoods (IPCC, 2014). Figure 13 presents projected changes in agricultural production in 2050, taking into account changes in climate. The impacts of future climate changes are expected to have devastating effects on agricultural production in many parts of Africa, with the western parts of the continent expected to experience severe declines (FAO, 2018). Producing enough food for a growing population under increased climate change and variability is both a challenge and an opportunity for inclusive economic growth, investment and poverty reduction.

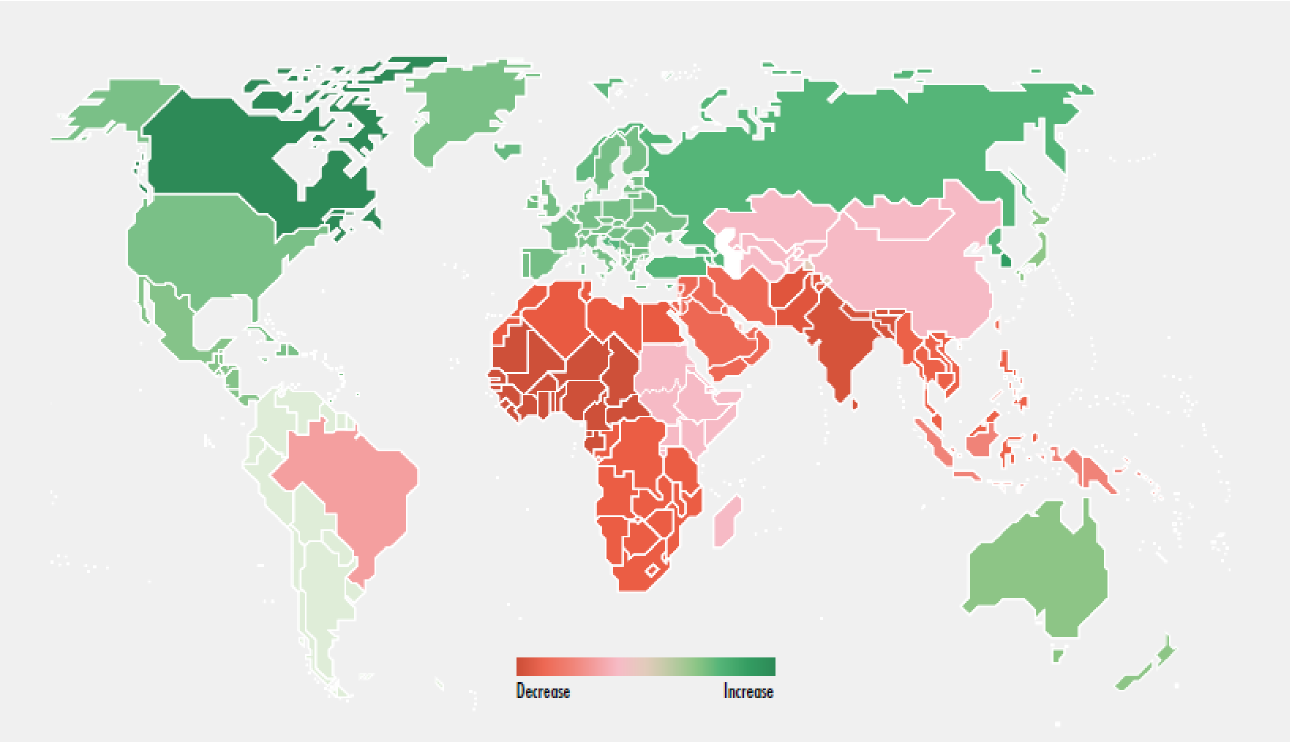


Figure 13: Changes in agricultural production in 2050: climate change relative to the baseline

Source: FAO (2018)

Climate change and variability are already affecting agricultural growing conditions impacting on the suitability of cropping and livestock activities. Changes in climate and variability alter prevailing agro-climatic conditions suitable to existing crop and livestock activities. Changes in agroclimatic conditions even slight changes could lead to some areas becoming unsuitable for current agricultural activities or become less productive of completely disappear (FAO, 2016; Nhemachena, et al., 2016; Benton, et al., 2012). Increases in temperatures and heat stress, damage from heavy rainfall and flooding, soil salinization, loss of arable land from land degradation and erosion are some of the factors that could further reduce areas suitable for crop production in the future. Also, reduced crop productivity due to climate change and variability in the face of increasing population and agricultural expansion increases pressure on already limited land and water resources.

Delayed start of the rain season affect area planted and timing of cropping activities negatively impacting on food production and supply. Droughts, extreme heat, flooding, intense and unreliable rainfall reduce yields and quality of staple and nutritious crops with detrimental impacts on food and nutrition security. For example, heavy precipitation and flooding destroy crops, erodes soil and washes away crop nutrients, lodges crops and leads to poor harvests. Also, increased warming and drying beyond optimum physiological growing conditions of crops results in increased heat stress and reduced yields. Along the coastal areas, sea-level rise will lead to inundation and soil salinization diminishing the suitability of low-lying areas and or ultimately making them unsuitable for crop production. Such impacts can be devastating to farmers who take loans to finance their production activities for the season. The changes in yield quantity and quality affect the prices of the grain impacting on farm incomes and prices for processors and consumers. For instance, bad harvests mean that farm incomes are eroded increasing vulnerability of the affected farmers to shocks (e.g. economic, climate, etc.).

Changes in climate and variability are leading to changes in the incidence, distribution, population size and impacts of pests and diseases for crops and livestock that can either reduce or worsen impacts on food production (IPCC, 2019; Bebber, 2015; Myers, 2017). The increased pest and disease risk due to climate change would increase in some areas that are less prepared for them institutionally and biologically leading to huge adverse impacts of crop and livestock production activities (FAO, 2016). These impacts will have significant implications on food production, food and nutrition security and the resilience of the affected communities and economies.

Overall, the projected increases in temperatures, reduced rainfall and changes in rainfall patterns, increasing frequency and severity of extreme events (droughts and floods) presents risks to crop yields and upstream activities in the value chains. The increases in warming and shifting rainfall patterns could result in a decline in productivity and a shift in the suitability of the current production areas to future crop production.

4.2.3 Harvesting and Storage

Beyond production, the other stages of the food value chains are also at risk of climate change, variability and extreme events. Increasing temperatures, humidity, pests and diseases increase the risk of post-harvest losses for food crops and products (IPCC, 2014). For example, extreme rainfall and flooding can delay harvesting activities and also increase the risks of post-harvest losses where farmers have no appropriate storage facilities. Storage facilities are also at risk of storm and flood damage from intensifying heavy rainfall and extreme weather events, further worsening post-harvest losses. In addition, rising temperatures and humidity increase the risks of harvest spoilage affecting the quantity and quality of food available for trade, processing and consumption. Changes in climate increase the risk of incidence of storage pests and diseases such as fungal and mycotoxin contamination affecting stored grains (Udomkun, et al., 2017; Moses, et al., 2015). The increased risks of contamination of stored grains and food negatively impact the competitiveness of food crops and related products, impacting trade opportunities, incomes, food safety, and food and nutrition security.

4.2.4 Aggregation and Trade

Climate change and variability such as increasing temperatures, heatwaves, intense rainfall, and extreme climatic events can adversely affect transport, aggregation, and trading activities. Similar to the above section, increases in temperatures, shifting rainfall patterns, and extremes lead to a high risk of post-harvest crop spoilage, diseases and quality losses. This negatively impacts the quality of food crops meeting quality requirements for trade (especially in structured domestic, regional and international trade) where quality requirements are important. Extreme events and disasters due to climate change may lead to the destruction of transport and storage infrastructure, affecting the movement of food along the value chain as well as from strategic production areas to deficit areas. The increased logistical risks affect business operations and increases costs due to climate change impact on transport hubs and trade corridors where food crops are aggregated and moved to processing facilities or consumption areas.

4.2.5 Processing

Climate change risks at the processing stage include disruption to business operations triggered by extreme climatic events. For example, extreme rainfall, flooding and cyclones affect transport hubs and corridors, negatively impacting the movement of raw materials from strategic producing areas to processing facilities as well as the movement of processed food products to consumptions areas (Agrawala, et al., 2011; Lemma, et al., 2015). Challenges in accessing raw materials to processing facilities could result in increased costs of processing. The increases in processing and transportation costs are transmitted in the costs of final food products if cheaper alternative inputs cannot be sourced. This would impact the costs of food, affecting food and nutrition security. Alternatively, if cheaper processing inputs are available from other countries, sourcing the cheaper supplies would negatively impact local production and employment.

Processing and storage facilities are also at risk of storm and flood damage from intensifying heavy rainfall and extreme weather events. Processing activities that require high volumes of clean water face increased risk from reduced or irregular water quantity and or quality as a result of climate change. Water scarcity may negatively impact processing activities and reduce the output of processed food.

4.2.6 Distribution

Increased rainfall intensity threatens the transportation infrastructure, which connects strategic crop production and consumption areas such as cities leading to detrimental impacts on food trade. The transportation infrastructure and corridors are essential for the movement of inputs and food products within and across countries. Increased flooding and landslides may make some key transport corridors or roads and bridges seasonally or permanently impassable. Unpaved feeder roads in crop-producing rural areas are vulnerable to flooding that negatively impacts the movement of agricultural inputs and products. The lack of interconnected road networks in many agricultural communities means an impassable road in one area can cut off the accessibility of large areas. For example, in West Africa, increases in rainfall intensity elevate the risk threatening the West-East Trans-Sahelian highway connecting Dakar and Ndgamena, and sea-level rise, coastal erosion and inundation negatively affect roads along the Trans-Coastal highway between Dakar and Lagos (USAID, 2018).

Distribution risks include rising transport costs and increased risk of spoilage due to temperatures as well as variable and intense rainfall. Extreme conditions also threaten food exports at ports. Extreme weather events can result in an increased risk of damage to food crops and products during transportation. Climate change, particularly extreme events, interrupt food distribution activities leading to high inefficiencies and or delays in the food supply chains. In addition, distribution businesses face high reputational risks due to delayed deliveries and increased risk of product quality due to extreme weather events (Agrawala, et al., 2011; Lemma, et al., 2015; Benton, et al., 2012).

4.2.7 Consumption

The increased intensity and frequency of extreme climatic events disrupt food production and supply as well as transport logistics leading to market volatility through food price spikes for traded commodities (IPCC, 2019; FAO, 2016). The impacts of climate change on food prices are driven by the negative impacts of climate change on food supply, as well as other factors such as rising demand due to population growth and rising incomes. The IPCC special report on climate change and land reported with high confidence that projections from Shared Socioeconomic Pathways (SSPs) 1, 2 and 3, global crop and economic models indicate 1-29% increase in cereal prices in 2050 as a result of climate change (Representative Concentration Pathway (RCP) 6.0) impacting global food prices although regional impacts would vary (IPCC, 2019).

The inelasticity of food demand and short-term supply and variability of supply due to changes in climate leads to price volatility. Any shock in supply (or demand) leads to relatively large fluctuations in food prices due to the low elasticity of demand and supply (Benton, et al., 2012). In the absence of substitutes for main staples for many poor households, food price spikes would have severe impacts on food and nutrition security. The increase in food costs triggered by climate change impacts on food supply reduces the purchasing power of consumers, and low-income consumers are severely affected by food price increases (Nelson, et al., 2018). This will result in increased consumption of less healthy diets characterized by low levels of important micronutrients.

The behavioural response of policymakers and consumers to food market shocks impact the resilience of the whole systems. Panic measures, for instance, export bans by policymakers or hoarding by consumers, are likely to exacerbate the impacts of a shock on food prices. Fuel price shocks also threaten the stability of food price, and in recent years energy shocks have led to food price shocks and volatility (FAO, 2016).

Climate change also causes food loss and waste due to a lack of adequate and appropriate storage facilities and packaging equipment to store food in the face of changing conditions. Food loss and waste (an estimated 25-30% of the total food produced) negatively affect food security (medium confidence) (IPCC, 2019). In addition, climate change and variability can impact the nutritional value and food safety of crops and processed food products. This can be mainly through increased incidence and prevalence of food-borne diseases due to changes in transportation and storage conditions triggered by climate change and variability. For example, higher temperatures are likely to negatively impact crop yields and reduce the micronutrient content of staple grains, adversely affecting food and nutrition security. According to USAID, 10 million more children under the age of 5 will be at risk of stunting by 2050 due to impacts of rising temperature on yields and micronutrient of staple grains (USAID, 2017).

4.3 Summary Table: Impacts of Climate Change at Different Stages of the Food Value Chain

Table 12: Summary of climate change impacts at the different stages of the food value chain

Value chain stage	Potential climate change impacts
Inputs	• Irregular and unpredictable rainfall resulting in destruction and germination failures (increased costs of replanting). • High and extreme temperatures affect seed and input storage, transportation and packaging conditions that negatively impact the quality and potency of seeds and other inputs. • Poor growing season conditions affect seed production for the next season. • Humidity may result in increased fungus in stored seeds. • Extreme climate-related events may disrupt transport infrastructure affecting timely delivery and access to inputs. • Increased input costs. • Reduced quantity and quality seeds produced. • Reduced seed production for the next cropping season. • Delayed deliveries of inputs (e.g. when infrastructure is destroyed). • High humidity and warm conditions increase the risk of seed deterioration and loss of seed vigour and germination especially during storage. • High-yield varieties may perform poorly under higher temperatures, humidity and salinity.
Production	• Changes in yield and quality of crops. • Higher incidence, distribution, population size and impacts of pests and diseases for crops, for example, maize stem borer, tomato flies, cassava mealybug) and livestock (e.g. cattle ticks). • Shifting of planting and harvesting seasons for crops affecting productivity. • Changing crop growing conditions and seasons.

Value chain stage	Potential climate change impacts
	• Low crop productivity. • Reduced crop yields. • Reduced quality of crop yields. • High production costs. • Environmental and agro-ecosystem degradation. • Emergence of new pests and diseases. • Increased incidence of pests and diseases. • Loss of ecosystems services. • Land degradation.
Harvesting and storage	• Destruction of crops due to extreme weather conditions and events. • Rising temperatures and humidity increase the risk of high post-harvest loses. • Reduced quality of harvests.
Aggregation and trade	• Extreme weather events increase the physical risk to business operations (e.g. destruction of equipment, vehicles etc.). • Risk of the overflow of storage due to increased rainfall. • Logistical risks - risks to the transport corridors and transport hubs from where raw materials are processed and exported: ○ Transportation challenges. • Increased temperatures and humidity could also increase the growth of fungus, causing severe damage to harvests and increasing post-harvest losses. • Increased post-harvest risk of spoilage and diseases. • Possible loss of quality. • Increased costs, e.g. due to disruptions in transport infrastructure. • Destruction of transportation routes. • Product losses due to rotting. • High transportation costs due to the destruction of the road network. • Extreme climate events (heatwaves, storms, floods) may make it difficult to comply with “just-in-time” requirements.
Processing	• Climate risks on transport corridors and hubs negatively impacting on the movement of raw materials to processing facilities as well as the movement of processed food products to consumptions areas: ○ Disruption to the transportation of labour, capital or finished goods and services. • Processing areas hit by unpredictable rain patterns. • High post-harvest losses. • Changes in processing technologies and costs due to the abundance of new crops. • Increased transportation costs. • Increased risk of spoilage. • Reduced quantity of crop yields available for processing. • Poor quality of crop yields. • Delayed deliveries. • Transportation challenges. • Damage to facilities, buildings, equipment and products involved in the food production process. • Extreme climate events (e.g. heatwaves, floods, storms) may damage processing facilities; and changes in climate may result in some sites becoming redundant.

Value chain stage	Potential climate change impacts
	• Increased warming increases the need for and costs of refrigeration, increase energy requirements as well as greenhouse gas emissions.
Distribution	• Risk of damage to products due to extreme events during transportation. • Roads and trade routes become seasonally or permanently impassable due to extreme rainfall, floods and cyclones: ○ Lack of access to markets. • Supply chain and raw material risks: interruption, inefficiency and delays in supply chains. • Reputational risks: Decrease in product quality affecting reputation and consumers' satisfaction. • Delays, supply disruptions and losses of goods as a result of extreme events such as flooding, landslides and permafrost thawing. • Changes in market routes and transport times. • Destruction of transportation routes. • Product losses due to rotting. • High transportation costs. • Transportation challenges and disruption of logistics due to extreme weather events. • Increased warming increases the need for and costs of refrigeration, increase energy requirements as well as greenhouse gas emission. • Extreme climate events (heatwaves, storms, floods) may make it difficult to comply with "just-in-time" requirements
Consumption	• Food shortages and supply scarcity. • Price increases for available food supply. • Decreased revenues from declines in yields and processed products. • Reduced food availability. • Higher food prices. • High food price fluctuations. • Increase in food and nutrition insecurity.

Source: Benton, et al. (2012); Agrawala, et al. (2011), Bebber (2015), IFAD (2015), Lemma, et al. (2015), FAO (2016), Nhemachena et al. (2016), USAID (2017; 2018), Udomkun, et al. (2017). Zimmermann, et al. (2017), Nelson et al. (2018), Kenya Markets Trust (2019), IPCC (2014; 2019)

5. Interventions to Address Climate Change Risks and Build the Resilience of Food Value Chains

5.1 Overview of Measures to Address Climate Risks

Understanding the climate risks across the value chain stages is essential in designing measures that would help minimize the adverse impacts and enhance the resilience of food systems to sustain food productivity in the face of climate change and other shocks. This section presents measures that can be implemented at the different stages of food value chains to adapt and or mitigate the impacts of climate change and build the resilience of the food systems.

Resilience refers to the capacity to ensure that adverse shocks and stressors do not have long-lasting adverse impacts. Resilience building focuses on three capacities: (a) absorptive capacity that focuses on the use of risk management measures to help people cope with or moderate the impacts of stresses and shocks; (b) adaptive capacity that refers to the ability to make forward-looking changes in behaviour and decisions informed by past experiences and knowledge of future conditions; and (c) transformative capacity that focuses on ensuring an enabling environment such as through regulations/ policies, good governance, improved basic service delivery that support the absorptive and adaptive capacity (USAID, 2019).

Climate change adaptation and climate resilience both involve interventions to address climate risks to reduce and or eliminate the negative impacts. Climate change adaptation and resilience capacity are mutually reinforcing. For example, smallholder farmers can implement irrigation technologies to address drought risks as well as livelihood diversification into non-farm income-generating activities to help them respond to reductions in farm incomes due to drought (USAID, 2019).

The supply-side measures to adapt and build resilience in regional food trade systems focus on the following value chain stages: production, harvesting, storage, transport, processing and food trade (see Table 13 below for examples of measures). On the demand-side, adaptation in food systems include measures to change consumption diets and practices as well as interventions to reduce food loss and waste. Demand-side reduction in food loss and waste contribute to adaptation in food systems through the reduction in additional land and other resources required for food production (IPCC, 2019). Changes in consumption diets provide an effective way to affect land use (Beheshti, et al., 2017) and promote climate change adaptation using food demand. For example, interventions can include advocacy campaigns to promote the consumption of nutritious crop diets (such as legumes) that have both adaptation and mitigation benefits. Also, demand-side adaptation interventions can focus on improving efficiency at all stages in the food value chain and reduce waste. The adoption of diets that are low in animal-sourced products and reducing waste at all stages of the value chain help reduce demand for food and land (IPCC, 2019).

Attaining sustainable food security in the face of climate change requires both supply-side and demand-side adaptation measures (Springmann, et al., 2018; Creutzig, et al., 2016). The 2019 IPCC Special Report of Climate change and Land reported with high confidence that combining supply-side measures such as improvements in efficiency in production, transport and processing with demand-side measures such as reduction of food loss and waste and modification of food choices can help reduce GHG emissions and enhance the resilience of the food system. Combined measures enable the implementation of adaptation and mitigation measures without threatening food security as a result of increased competition for land for food production and higher food prices (IPCC, 2019). The measures to address climate change adaptation and mitigation while simultaneously reducing land degradation, desertification and poverty include payment for ecosystem services, integrating environmental costs in food prices and improving access to markets.

Effective interventions to build climate resilience in food value chains include the following elements: (a) diversification of value chain activities: risk management strategy that involves many options to improve farmers, livelihood, farming and environmental management portfolios; (b) measures to make food value chain stages climate-resilient and generate improved livelihood and resilience benefits for farmers; and (c) supply chain efficiencies: interventions that improve efficiencies across food value chain stages such as waste reduction that generate higher returns and profits for value chain actors such as farmers and SMEs as well as mitigation co-benefits (IFAD, 2015).

5.1.1 The Role of Trade in Contributing to Addressing Climate Change Risks

Adaptation to climate change affects food availability, food access, food utilization, and the stability of food security for millions of poor people around the world. Trade plays an essential role in helping adjust shifts in agricultural and food production patterns due to climate change. Trade help facilitates the movement of food from areas of strategic production to deficit areas. It contributes to food and nutrition security by ensuring food access, utilization (through increased diet diversity), and stability (through pooling production risks across individual markets) (Brooks & Matthews, 2015). Trade helps ensure that sufficient and nutritious food is available and accessible to those experiencing shortages due to impacts of climate change and other shocks (Brown, et al., 2017). Through stabilizing food prices under shocks such as climate change, trade contributes to improving access to food by millions of poor households (Wiebe, et al., 2015; Brown & Kshirsagar, 2015). Cross-border trade also helps contribute to building the adaptive capacity of food systems to climate change by facilitating the movement of climate-smart agricultural inputs and technologies such as improved inputs and livestock breeds across borders (Figure 14).

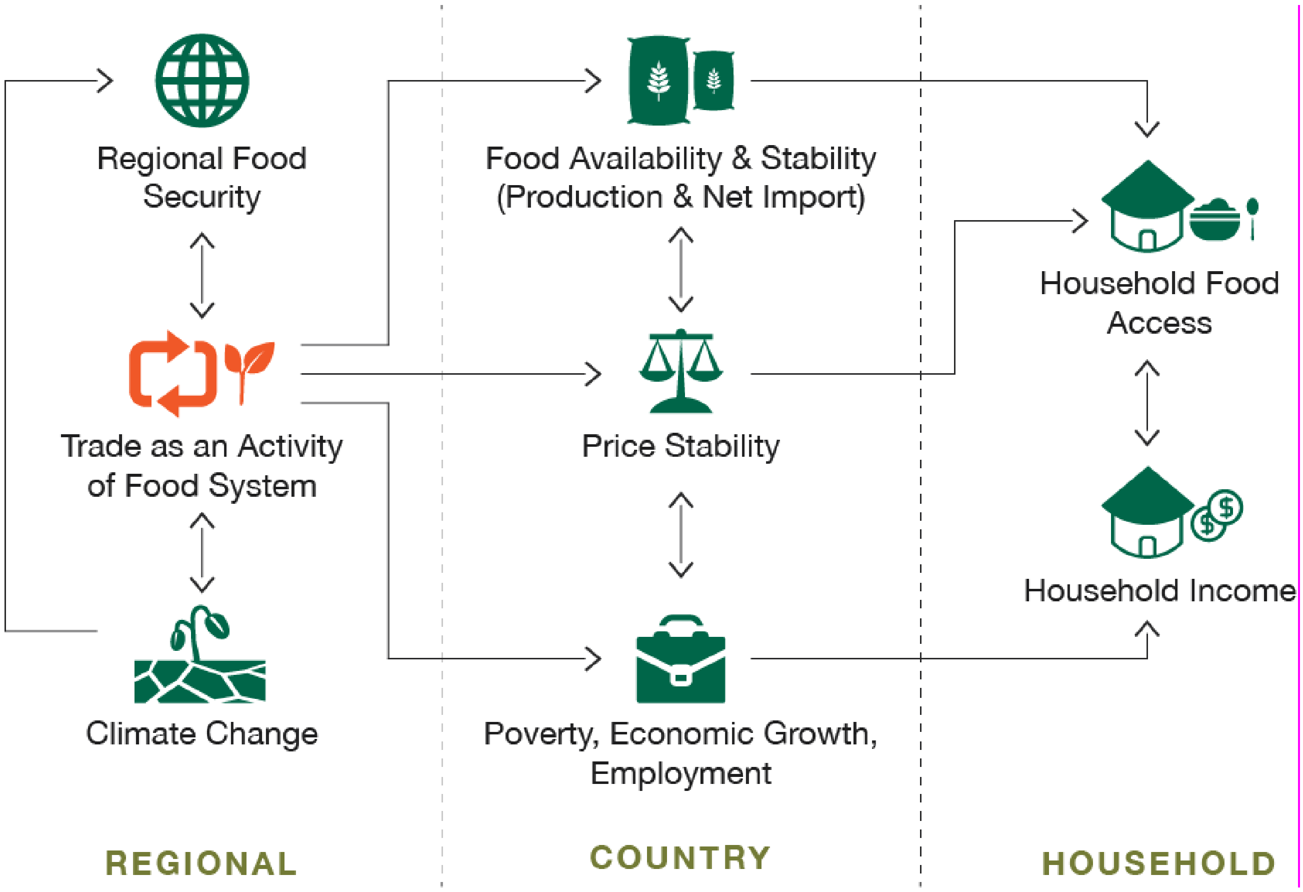


Figure 14: Regional, country, and household climate impacts

Source: Adapted from Brown et al. (2017)

5.2 Summary Table: Potential Measures to Address Climate Change Risks in Food Value Chains

Table 13: Potential adaptation and resilience-building measures at the different stages of the food value chains

Value chain stage	Potential adaptation and resilience-building measures

Inputs	• Seed companies should develop varieties that are better adapted to drier and hotter conditions as well as address challenges of new and existing pests and disease outbreaks.
	• Ensure diversity of climate-resilient inputs through seed banks and buffer stocks.
	• Invest in climate-friendly seed management infrastructure (storage, transportation and packaging) to withstand harsh conditions and maintain the quality of seeds:
	    ○ Improve seed storage and packaging of seeds such as the use of hermetically sealed storage bags.
	    ○ Promote proper drying and storage to avoid fungus contamination.
	• Seed companies invest in wider networks with agro-dealers (particularly those located close to smallholder farming communities) to increase timely supply and access to climate-resilient inputs for farmers.
	• Awareness-raising and advocacy campaigns, including capacity building initiatives to farmers on climate risk management and decision support tools to promote use and adoption of climate-resilient inputs and contribute to improve incomes for agro-dealers and farmers:
	    ○ Seed companies promote awareness of climate-resilient seeds and facilitate needs assessments of farmers, including acting as channels of climate information and assist agrodealers to adjust their products and services to changing climatic conditions.
	    ○ Increased awareness of climate-resilient inputs by agro-dealers and smallholder farmers.
	    ○ Promote the use and adoption of fast maturing and high yielding varieties.
	• Enable farmers' (especially smallholder and women farmers') access to geographic-specific climate-adapted varieties and encourage farmers to plant new climate-resilient varieties such as drought-tolerant, early maturing.
	• Facilitate increased linkages between service providers and farmers (especially smallholder and women farmers).
	• Organize farmers into groups that can help facilitate collective procurement of climate-resilient inputs, link farmers with outlets of input companies.
	• Support access to climate-resilient inputs (e.g. seeds).
	• Smallholder farmers are supported to make informed decisions about climate-resilient inputs and how to use them.
	• Strengthen collaboration on dissemination, utilization and adoption of the use of improved certified climate-resilient seed varieties.
	• Support timely access to and use of climate and weather information by smallholder farmers, agro-dealers, extension workers and other key stakeholders.

Production	• Changing planting dates, crop types and or varieties in response to changing agro-climatic conditions. • Promote farmers' awareness and access to climate-smart technologies such as planting climate-resilient and quality seeds such as drought-tolerant, early maturing or short-season varieties. • Promote climate-smart agricultural technologies and practices that ensure optimal yields in the face of climate change and variability. • Promote farm-level climate-sensitive measures such as water-efficient small-scale irrigation systems and technologies. • Promote soil and water conservation measures such as contour bunds, terracing, agroforestry and perennial crops); increase soil carbon and improve the management of soil organic matter; rehabilitate degraded lands, mulching, water harvesting measures. • Promote sustainable soil management methods of farming to improve carbon storage (such as conservation agriculture):

Value chain stage	Potential adaptation and resilience-building measures
	○ Integrate climate-smart technologies and environmental sustainability practices in production systems. • Promote integrated pest management such as push-pull methods like use of Napier grass. • Diversify cropping, livestock and livelihood activities, for example, mix crop and livestock activities and non-farm income-generating activities to counter any business risks that could arise from impacts of climatic change. • Promote timely dissemination and access to information (weather and market in formats usable and accessible by farmers) for informed decision making on production as well as other activities along the food value chain, for example, provide timely seasonal, daily and 10-day forecasts to help farmers make decisions on when to plant: ○ Improve access to climate and market information targeting women smallholder farmers and women-owned SMEs. ○ Empower women to find solutions to climate variability and disasters through radio messaging, climate forecasting and behavioural change. ○ Develop radio messaging for improved resilience. • Promote the integration of indigenous knowledge such as traditional weather forecasts in production activities. • Promote resilient pest and disease management practices to address challenges of new and existing pests and disease outbreaks. • Promote planting and integration/intercropping of cover crops, to counter excessive water loss through evapotranspiration. • Empower smallholder farmers (especially women farmers) to transition from subsistence to dynamic commercial farmers. • Improve crop productivity through facilitating smallholder farmers' access to climate-smart productivity-enhancing inputs, technologies and services. • Smallholder farmers have timely and adequate access to production inputs. • Raise awareness among smallholder farmers on the benefits of climate-resilient production methods and technologies. • Train and improve the ability of smallholder farmers to use appropriate climate-resilient production methods and technologies, e.g. water harvesting technologies. • Facilitate the availability of affordable climate-smart agricultural technologies. • Promote and train smallholder farmers to use efficiency-enhancing and time-saving technologies. • Capacity building of agricultural extension workers and women lead farmers on the integration of climate-smart production practices in various gender-responsive climate-smart technologies. • Promote the use of cost-effective, participatory and demand-driven farmer-led extension approaches such as using lead farmers. • Promote wide-scale uptake of climate-smart and environmental sustainability practices.
Harvesting and storage	• Design and promote the use of improved post-harvest storage and packaging materials such as hermetic bags. • Investments in post-harvest technologies such as grain drying equipment and eco-friendly storage facilities: ○ Invest in improvements in harvesting techniques, on-farm storage, infrastructure and packaging. • Promote climate-proofing of storage infrastructure such as the flood-resistant design of storage facilities. • Promote appropriate climate-smart harvesting and storage management strategies. • Promote proper drying and storage to avoid fungus contamination. • Build the capacity of farmers and other value chain actors to use post-harvest technologies and practices. • Traders support packaging, storage and marketing of crops from smallholder farmers to processors.

Value chain stage	Potential adaptation and resilience-building measures
	• Support smallholder farmers with drying, winnowing, bagging, bulking and transportation of grains to storage. • Promote the use of improved storage technologies such as the use of hermetic bags. • Raise awareness among smallholder farmers on the benefits of climate-resilient harvesting and storage methods and technologies. • Train and improve the ability of smallholder farmers and traders to use appropriate harvesting and storage methods and technologies to reduce post-harvest loses. • Promote wide-scale uptake of climate-smart and environmental sustainability practices. • Support timely access to and use of climate, weather, market and financial information by smallholder farmers, agro-dealers, extension workers and other key stakeholders.
Aggregation and trade	• Build resilient market systems through enhancing linkages between value chain actors (private sector, government, SMEs, smallholder farmers): ○ Smallholder farmers have access to profitable structured output markets. ○ Facilitate crop aggregation through structured markets. ○ Strengthen institutional linkages in the grain input-output marketing systems. • Invest in improving coordination in food value chains to help reduce transportation distances and costs. • Climate-proof transportation infrastructures such as good drainage roads and bridges in key food trade corridors and rural areas. • Invest in adequate and appropriate infrastructure to reduce food losses • Improve transportation infrastructure and logistics services to facilitate the movement of food from strategic production areas to deficit areas as well as facilitate the movement of inputs to areas of production and processing. • Re-site transport hubs and routes, and develop contingency plans for alternative transport, co-design value addition, storage and transport components of hubs to avoid high-risk routes and seasons. • Traders support packaging, storage and marketing of crops from smallholder farmers to processors. • Promote collective marketing of crops by smallholder farmers. • Support smallholder farmers with grading, sorting, milling, storage and marketing of grains from smallholder farmers. • Train and improve the ability of smallholder farmers and traders to use appropriate aggregation methods and technologies. • Promote and train smallholder farmers and traders to use efficiency-enhancing and time-saving technologies. • Provide timely market information services to smallholder farmers and traders. • Strengthen information systems of agricultural markets and financial services to smallholder farmers. • Promote wide-scale uptake of climate-smart and environmental sustainability practices. • Integrate climate-smart technologies and environmental sustainability practices in marketing systems. • Support timely access to and use of climate and weather information by smallholder farmers, traders, extension workers and other key stakeholders.
Processing	• Build farmers' capacity to diversify into value addition beyond primary food production, for example, through training in financial and business skills and value chain promotion activities. • Promote climate-proofing of processing and storage infrastructure such as the flood-resistant design of processing and storage facilities: ○ Strengthen processing facilities to withstand the potential impacts of climate change (e.g. extreme weather events, pest infestations). • Invest in energy-efficient processing equipment and facilities to reduce energy use, including using renewable energy where possible.

Value chain stage	Potential adaptation and resilience-building measures
	• Invest in appropriate packaging materials that preserve the quality and safety of food, even under extreme climatic conditions. • Use hazard exposure and crop suitability maps to inform siting of processing facilities; retrofit processing facilities with protective features; insure processing facilities against extreme climate events. • Grain processors provide extension/ advisory services to smallholder farmers to secure sufficient and quality crop yields/ grains. • Support smallholder farmers with grading, sorting, milling, storage and marketing of grains from smallholder farmers. • Raise awareness on the need for processors to support smallholder farmers and traders implement climate-resilient and appropriate production, harvesting, storage, aggregation methods and technologies. • Large processors provide technical support and business opportunities for small and medium enterprises. • Foster increased participation of the processors in the provision of services in the selected value chain. • Integrate climate-smart technologies and environmental sustainability practices in food processing such as water and energy efficiency technologies and practices. • Support timely access to and use of climate and weather information by smallholder farmers, processors, extension workers and other key stakeholders.
Distribution	• Climate-proof transportation infrastructures such as good drainage roads and bridges in key food trade corridors and rural areas. • Improve transportation infrastructure and logistics services to facilitate the movement of food from strategic production areas to deficit areas as well as facilitate the movement of inputs to areas of production and processing. • Invest in improving coordination in food value chains to help reduce transportation distances and costs. • Re-site transport hubs and routes, and develop contingency plans for alternative transport, co-design value addition, storage and transport components of hubs to avoid high-risk routes and seasons.
Consumption	• Advocate for change in consumption patterns, such as promote the consumption of nutritious foods. • Advocate and promote the reduction in food loss and waste along the food value chain stages such as processing, food service sector, retail markets. • Encourage sustainable consumption to help reduce food waste, such as at home and in eateries. • Increase diversity of food options and diets to increase the elasticity of demand and reduce food price volatility. • Strengthen and diversify storage to buffer price fluctuations. • Diversify into "offseason" crops. • Invest in social safety nets.
Policy and enabling environment	• Invest in improving access to financial services such as crop insurance. • Use 'grain balance sheet' to track surpluses and deficits in food crops in different countries to inform trade and food and nutrition security decisions that will help avoid food market volatility. • Invest in research for decision-making such as on climate effects on the prevalence and distribution of crop pests/pathogens and links between increased heat and declining protein/ micronutrients in crops. • Invest in climate services to provide both short-term and long-term projections to enable sector-level planning. • Invest in the technical capacity and forecast infrastructure, such as forecasting modelling and weather stations. • Strengthen early warning systems and invest in country-level capacity in scaled-down climate impact modelling and scenario planning.

Value chain stage	Potential adaptation and resilience-building measures
	• Develop transformational solutions to climate variability and disasters • Invest in the development (research and breeding) of climate-resilient varieties such as drought-tolerant, early maturing or short-season varieties. • Government invest in conservation and improvement of genetic resources as well as strategic seed reserve for climate-resilient crops. • Ensure affordable finance and credit services to enable agro-dealers to source and stock large quantities of better varieties and quality seeds that are suitable for specific geographic areas. • Ensure affordable finance and credit services for farmers (especially smallholder farmers) to access climate-resilient varieties and other inputs. • Government support the use and adoption of climate-resilient inputs through designing and implementing enabling policies and providing increased funding to relevant ministries and institutions. • Review national input policies and regulations (such as for seeds) to ensure they respond to changing climatic conditions. • Strengthen agricultural extension delivery policies implementation including mainstreaming climate risk management in extension services (for example, in seed production, processing and marketing). • Capacity building of agricultural extension workers and women lead farmers on the integration of climate-smart production practices in various gender-responsive agricultural activities. • Promote the use of cost-effective, participatory and demand-driven farmer-led extension approaches such as using lead farmers. • Provide capacity building on climate issues and strengthen farmer-based research and knowledge systems as well as ensuring smallholder farmers are actively engaged in policy dialogues and planning activities. • Invest in mobile-based information dissemination on climate and market information as well as appropriate innovative measures that farmers can use and adopt. • Develop shorter documents and translate relevant policies to promote climate resilience into local languages and make them easily accessible to intended users such as smallholder farmers to ensure access to information on climate-related risks as well as adaptation and resilience-building measures. • Improve networking and partnerships for climate risk adaptation along food value chains through strengthening existing structures and platforms across all levels and exploring the role of incentives such as standards. • Government and financial services sector should develop new and flexible financial products and services to support investments in climate-resilient and inclusive food value chains through capacity building and innovative public-private partnerships. • Invest in climate-resilient infrastructures such as irrigation systems, roads, storage facilities and telecommunications to support the development of climate-resilient food value chains. Policy and Regulatory Interventions: • Supporting the development of relevant sanitary and phytosanitary regulations to facilitate easier cross border trade. • Facilitating training and capacity building of Government extensions workers in regional trade-related aspects. • Coordinating relevant donor and regional Government interventions in trade facilitation. • Activities to support effective implementation of the African Continental Free Trade Area (ACFTA). • Supporting regional trade policy dialogue platforms amongst countries. • An enabling policy environment for the development, marketing, distribution, use and adoption of sustainable and climate-resilient technologies and practices. • A predictable food trade policy environment (national and regional). • Support convening of the selected crop value chain and Climate Smart Agriculture stakeholders' platforms. • Invest in climate and market information services to enable better decision making by all actors in the selected value chain.

Value chain stage	Potential adaptation and resilience-building measures
	• Ensure smallholder farmers and other value chain actors have access to affordable, equitable financial and complimentary services. Supporting functions Interventions: • Facilitating access to trade finance by aggregators and traders. • Facilitating access to insurance services for transporters; warehouse providers etc. • Access to climate information; access to regional trade financing information and access. • Facilitating access to logistics and warehousing.

Source: Benton, et al. (2012); IFAD (2015), Bodin et al. (2016), Dazé & Dekens (2016), Nhemachena et al. (2016), Atlin et al. (2017), USAID (2019; 2017), Kenya Markets Trust (2019), Teixeira, et al. (2017), Zimmermann, et al. (2017), Scheba (2017), Omotilewa et al. (2018), IPCC (2019).

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Appendix 1: Climate Resilience Framework for Regional Food Trade and Resilience Programme

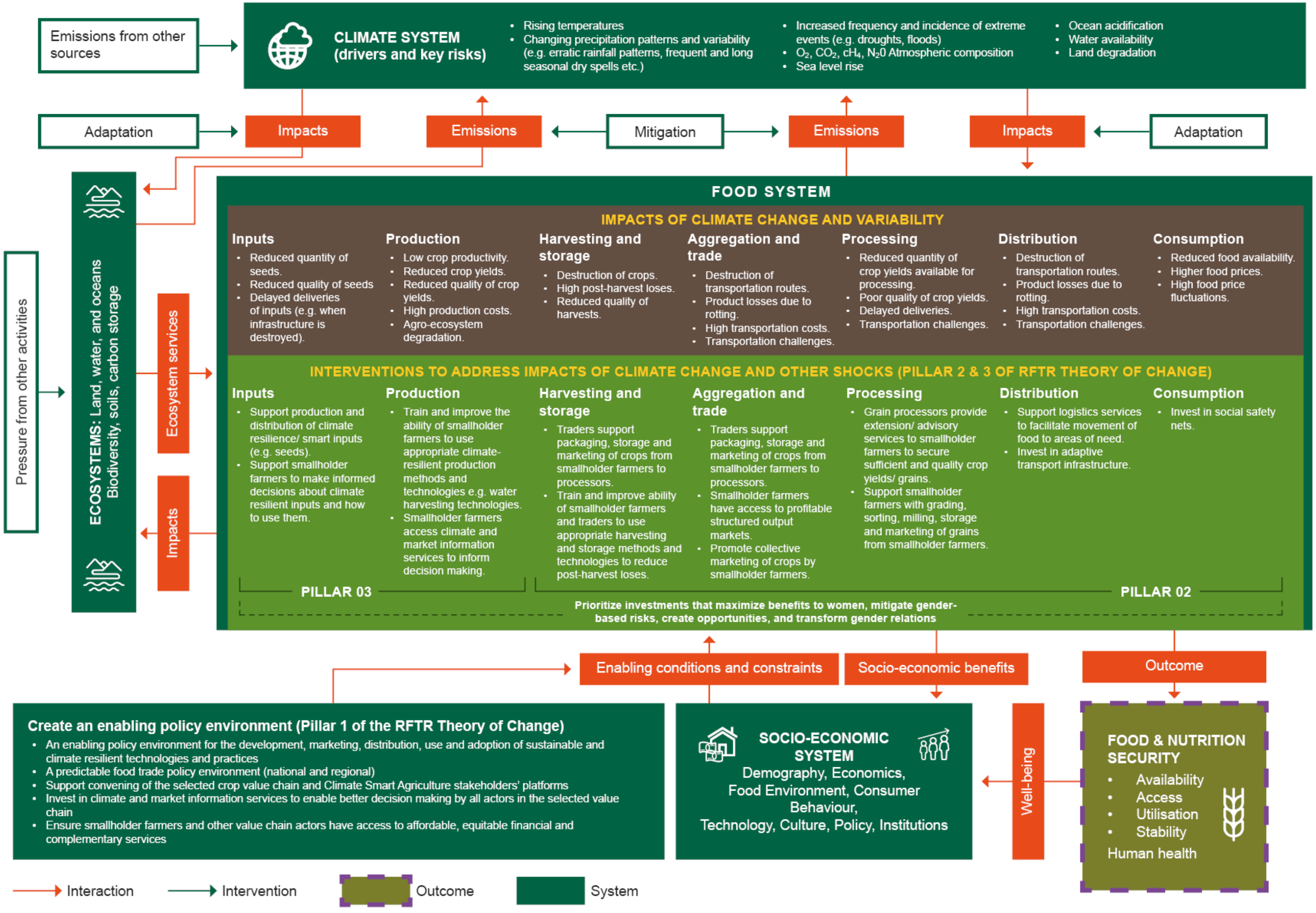

Figure 15: Climate resilience framework for Regional Food Trade and Resilience Programme

Source: Adapted from IPCC (2019)

Table 14: Climate resilience framework for Regional Food Trade and Resilience Programme

Climate System (drivers and key risks)

- Rising temperatures
- Changing precipitation patterns and variability (e.g. erratic rainfall patterns, frequent and long seasonal dry spells etc.)
- Increased frequency and incidence of extreme events (e.g. droughts, floods)
- O2, CO2, cH4, N20 Atmospheric composition
- Sea level rise
- Ocean acidification
- Water availability
- Land degradation

Inputs	Production	Harvesting and storage	Aggregation and trade	Processing	Distribution	Consumption
IMPACTS OF CLIMATE CHANGE AND VARIABILITY						
• Reduced quantity of seeds • Reduced quality of seeds • Delayed deliveries of inputs (e.g. when infrastructure is destroyed)	• Low crop productivity • Reduced crop yields • Reduced quality of crop yields • High production costs • Environmental and agro-ecosystem degradation • Emergence of new pests and diseases • Increased incidence of pests and diseases • Loss of ecosystems services	• Destruction of crops • High post-harvest loses • Reduced quality of harvests	• Destruction of transportation routes • Product losses due to rotting • High transportation costs • Transportation challenges	• Reduced quantity of crop yields available for processing • Poor quality of crop yields • Delayed deliveries • Transportation challenges	• Destruction of transportation routes • Product losses due to rotting • High transportation costs • Transportation challenges	• Reduced food availability • Higher food prices • High food price fluctuations

Inputs	Production	Harvesting and storage	Aggregation and trade	Processing	Distribution	Consumption
	• Land degradation • Degradation of agro-ecosystems					
INTERVENTIONS TO ADDRESS IMPACTS OF CLIMATE CHANGE AND OTHER SHOCKS (PILLAR 2 & 3 OF RFTR THEORY OF CHANGE)						
• Support production and distribution of climate resilience/ smart inputs (e.g. seeds) • Support access to climate resilient inputs (e.g. seeds) • Increased awareness of climate resilient inputs by agro-dealers and smallholder farmers • Smallholder farmers are supported to make informed decisions about climate resilient inputs and how to use them • Raise awareness on climate risks among smallholder farmers and agro-dealers • Promote use and adoption of fast maturing and high yielding varieties • Strengthen collaboration on dissemination, utilization and adoption of use of improved certified	• Improve crop productivity through facilitating smallholder farmers' access to climate smart productivity enhancing inputs, technologies and services • Smallholder farmers plant climate resilient varieties • Smallholder farmers access climate and market information services to inform decision making • Smallholder farmers have timely and adequate access to production inputs • Raise awareness among smallholder farmers on the benefits of climate-resilient production methods and technologies • Train and improve the ability of smallholder farmers to use appropriate climate-resilient	• Traders support packaging, storage and marketing of crops from smallholder farmers to processors • Support smallholder farmers with drying, winnowing, bagging, bulking and transportation of grains to storage • Promote use of improved storage technologies such as use of hermetic bags • Raise awareness among smallholder farmers on the benefits of climate-resilient harvesting and storage methods and technologies • Train and improve ability of smallholder farmers and traders to use appropriate harvesting and storage methods and technologies to reduce post-harvest loses	• Traders support packaging, storage and marketing of crops from smallholder farmers to processors • Smallholder farmers have access to profitable structured output markets • Promote collective marketing of crops by smallholder farmers • Support smallholder farmers with grading, sorting, milling, storage and marketing of grains from smallholder farmers • Raise awareness among smallholder farmers on the benefits of climate-resilient aggregation methods and technologies • Train and improve ability of smallholder farmers and traders to use appropriate aggregation methods and technologies	• Grain processors provide extension/ advisory services to smallholder farmers to secure sufficient and quality crop yields/ grains • Support smallholder farmers with grading, sorting, milling, storage and marketing of grains from smallholder farmers • Raise awareness on the need for processors to support smallholder farmers and traders implement climate-resilient and appropriate production, harvesting, storage, aggregation methods and technologies • Large processors provide technical support and business opportunities for small and medium enterprises	• Support logistics services to facilitate movement of food to areas of need • Invest in adaptive transport infrastructure	• Invest in social safety nets

Inputs	Production	Harvesting and storage	Aggregation and trade	Processing	Distribution	Consumption
climate resilient seed varieties • strengthen information systems of climate resilient input and financial services to smallholder farmers • Support timely access to and use of climate and weather information by smallholder farmers, agro-dealers, extension workers and other key stakeholders	production methods and technologies e.g. water harvesting technologies • Facilitate availability of affordable climate smart agricultural technologies • Promote and train smallholder farmers to use efficiency enhancing and time saving technologies • Capacity building of agricultural extension workers and women lead farmers on the integration of climate smart production practices in various gender responsive climate smart technologies • Promote use of cost effective, participatory and demand driven farmer led extension approaches such as using lead farmers • strengthen information systems of agricultural production and financial services to smallholder farmers • Promote wide scale up take of climate smart and environmental	• Promote and train smallholder farmers and traders to use efficiency enhancing and time saving technologies • strengthen information systems of climate smart harvesting technologies and practices and financial services to smallholder farmers • Promote wide scale up take of climate smart and environmental sustainability practices • Strengthen post-harvest management • Integrate climate smart technologies in crop harvesting and storage • Build capacity of farmers and other value chain actors to use post-harvest technologies and practices • Support timely access to and use of climate and weather information by smallholder farmers, agro-dealers, extension workers	• Promote and train smallholder farmers and traders to use efficiency enhancing and time saving technologies • Provide timely market information services to smallholder farmers and traders • strengthen information systems of agricultural markets and financial services to smallholder farmers • Promote wide scale up take of climate smart and environmental sustainability practices • Strengthen institutional linkages in the grain input-output marketing systems • Integrate climate smart technologies and environmental sustainability practices in marketing systems • Facilitate crop aggregation through structured markets • Support timely access to and use of climate and weather	• Foster increased participation of the processors in the provision of services in the selected value chain • Integrate climate smart technologies and environmental sustainability practices in food processing • Support timely access to and use of climate and weather information by smallholder farmers, processors, extension workers and other key stakeholders		

Inputs	Production	Harvesting and storage	Aggregation and trade	Processing	Distribution	Consumption
	sustainability practices • Integrate climate smart technologies and environmental sustainability practices in production systems • Promote improved water efficient practices and climate-smart technologies • Support timely access to and use of climate and weather information by smallholder farmers, agro-dealers, extension workers and other key stakeholders	and other key stakeholders	information by smallholder farmers, traders, extension workers and other key stakeholders			
Prioritize investments that maximize benefits to women, mitigate gender-based risks and create opportunities and transform gender relations						

INTERVENTIONS TO ADDRESS IMPACTS OF CLIMATE CHANGE AND OTHER SHOCKS (PILLAR 1 OF RFTR THEORY OF CHANGE)

Policy and Regulatory Interventions:

- Supporting the development of relevant sanitary and phytosanitary regulations to facilitate easier cross border trade.
- Facilitating training and capacity building of Government extensions workers in regional trade related aspects.
- Coordinating relevant donor and regional Government interventions in trade facilitation.
- Activities to support effective implementation of the African Continental Free Trade Area (ACFTA).
- Supporting regional trade policy dialogue platforms amongst countries.
- An enabling policy environment for the development, marketing, distribution, use and adoption of sustainable and climate resilient technologies and practices.
- A predictable food trade policy environment (national and regional).
- Support convening of the selected crop value chain and Climate Smart Agriculture stakeholders' platforms.
- Invest in climate and market information services to enable better decision making by all actors in the selected value chain.
- Ensure smallholder farmers and other value chain actors have access to affordable, equitable financial and complementary services.

Supporting functions Interventions:

- Facilitating access to trade finance by aggregators and traders.
- Facilitating access to insurance services for transporters; warehouse providers etc.
- Access to climate information; access to regional trade financing information and access.
- Facilitating access to logistics and warehousing.

Prioritize investments that maximize benefits to women, mitigate gender-based risks and create opportunities and transform gender relations

Guiding Notes for Integrating Climate Resilience in the RFTR Programme

(a) Climate change and variability risks and other shocks:

- Discuss the main climate change and variability risks and other shocks affecting the selected value chain (from inputs, production, harvesting and storage, aggregation and trade, processing, distribution to consumption).

(b) Impacts of climate change and variability risks and other shocks:

- Highlight the key impacts of climate change and variability (and other shocks)/ vulnerabilities on the different stages of the focus value chain (from inputs, production, harvesting and storage, aggregation and trade, processing, distribution to consumption).
- Highlight key impacts of climate change (and other shocks) on women actors/ vulnerabilities at the different stages of the value chain (from inputs, production, harvesting and storage, aggregation and trade, processing, distribution to consumption).

(c) Interventions to address the identified impacts of climate change and other shocks:

- Discuss the direct interventions from the grant that will address climate change impacts identified above (from inputs, production, harvesting and storage, aggregation and trade, processing, distribution to consumption).
- Discuss the indirect interventions through collaborations and partnerships with other actors that will be facilitated by the grant (from inputs, production, harvesting and storage, aggregation and trade, processing, distribution to consumption).
- The discussion should clearly identify the target beneficiary at each value chain stage (from inputs, production, harvesting and storage, aggregation and trade, processing, distribution to consumption).
- Discuss how women will benefit from the proposed interventions (from inputs, production, harvesting and storage, aggregation and trade, processing, distribution to consumption).
- If supported value chain contributes to agro-ecosystem services discuss how the area under production for the target farmers will be captured. The area under production will be used to estimate potential contribution to climate change through carbon sequestration, nitrogen fixation etc.

(d) Interventions to create an enabling environment for inclusive and strengthen supporting functions:

- Discuss how the grant will contribute to:
    - The development of an enabling policy environment for the development, marketing, distribution, use and adoption of sustainable and climate resilient technologies and practices.
    - Strengthen the Knowledge Management of the selected crop value chain/s.
    - Support convening of the selected crop value chain and Climate Smart Agriculture stakeholders' platforms.
    - Invest in climate information services to enable better decision making by all actors in the selected value chain.
    - Ensure smallholder farmers and other value chain actors have access to affordable, equitable financial and complementary services that are appropriately designed for changing climatic conditions.

(e) **Prioritize investments that maximize benefits to women, mitigate gender-based risks, create opportunities and transform gender relations:**

- See Gender Implementation Plan.

(f) **Demonstrate availability in the team of an expert/s who are going to address cross-cutting issues of climate resilience, gender, food and nutrition security, M&E and Knowledge Management:**

- Provide evidence of practical experience in dealing with the above cross-cutting issues.

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