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Original Article

Impacts of Climate Change on Agriculture and Water Sector in Kenya and Uganda

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Abstract:
Natural hazards to climate change are increasing in number and intensity. If not addressed climate change will increasingly affect yields and rural livelihoods. They reduce food availability, disrupt access to food and health care, and undermine social protection systems, pushing many affected people deeper into poverty and hunger, fueling distress migration and increasing the need for humanitarian aid. Violent conflict also frequently characterizes protracted crises.

1. Climate change in the Horn of Africa

i) The Horn of Africa (HoA) region have a long-standing history of being prone to climate extreme events such as droughts and floods that exacerbate food, water insecurity and in some cases leading to cross-border conflicts. The economies and livelihoods of the HoA countries (Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan and Uganda) are dependent on rain-fed agriculture that is highly sensitive to weather as well as climate variability and change.

How will climate change affect water resources, agriculture and rural livelihoods?

i) Climate change will incrementally affect all the agricultural sectors. Climate change already has negative effects on crop yields, livestock production and fisheries, particularly in low- and middle- income countries. Such impacts are likely to become even stronger mid and later in this century.

ii) If not addressed, climate change will exacerbate poverty and inequalities. Unaddressed climate change, which is associated, inter alia, with unsustainable agricultural practices, is likely to lead to more land and water use, disproportionately affecting poor people and exacerbating inequalities within and between countries. This carries negative implications for both food availability and food access.

iii) Climate change impacts beyond crop yields decline. Climate change also affects soil quality, fish habitats and stocks, the biodiversity of landscapes, and the epidemiology and antimicrobial resistance of pests and diseases.

ii) In a long run, the IGAD region will experience a general major decline in farm productivity for main cereal yields which majority of its population derive food security. For instance, the wheat yields will decline due to climate change impacts with Ethiopia affected most, followed by Sudan, then Kenya, Uganda, Eritrea and Somalia. Rice yields will also decline, with Uganda recording the greatest reduction. In the case of maize, projections from Special Report on Emissions Scenario (SRES-A), developed by the IPCC indicates that major yield decline will be greatest in Kenya (-488,702.74) followed by Ethiopia (-472,324.41), then Uganda (-174,919.21), Somalia (-33,934.96), Sudan (-7,781.22), Eritrea (-626.40) and lastly Djibouti (-0.39) by year 2080 under SRES, A2 (lies between SSP2 and SSP3) scenario due to climate related stress. This trend is similar under SRES A1FI (RCP8.5 and lies between SSP3 and SSp4)-scenario, with Kenya experiencing (-737,277.28), Ethiopia (-663,998.82); Uganda (-245,903.33); Somalia (-47,706.14); Sudan (-10,938.92); Eritrea (-880.60); and Djibouti (-0.58) tons lost to climate related stress.

1. Climate change and agriculture in Kenya (impacts and vulnerabilities)

i) Recurrent drought, a significant problem, for example, during 2008-2011, an estimated loss of $10.2 billion in livestock and crops were recorded. Higher temperatures are likely to expand production of

maize and beans into higher elevations, but farming in lower elevations is expected to see yield losses of up to 20 percent due to heat stress and shifting rainfall patterns, with some areas (like central Kenya) becoming unsuitable for production. Maize, which accounts for about one-third of caloric intake in Kenya, can be damaged by temperatures over 35^{o}C, which are increasingly common in lowland regions.

ii) Kenya is among world leaders in tea production; e.g. tea accounted for $787 million in exports in 2014 where data was available. Areas suitable for tea production are shifting to higher elevations as temperature increase puts current production areas at risk from heat extremes and increasing pests and diseases. In arid and semi-arid regions, pastoralism is the dominant production system; high temperatures are expected to increase heat stress and pest and disease incidence in livestock.

iii) Some regions of Kenya may see a benefit from a changing climate, specifically the temperate and tropical highlands, the Rift Valley and high plateaus, as projected increases in rainfall and slightly warmer temperatures are likely to raise crop yields. However, the country's large semi-arid and arid land areas are projected to see a significant decline in agricultural productivity and livestock numbers, as water resources become increasingly scarce.

2. Climate change and water sector, Kenya (past and present trends)

i) According to the Government human development report, Kenya, is ranked as water scarce, strained by population growth and severe forest degradation, and could be further stressed by increasing temperatures, evaporation rates and rainfall variability. For example, in 2010 Kenya's water availability was 586 m^3 per person annually, well below the internationally acceptable threshold of 1,000 m^3 per person; this figure is expected to fall to as low as 293 m^3 by 2050.

ii) Urban areas are already highly water stressed; Mombasa regularly implements water rationing. For instance, Mombasa currently has only half of the water required to meet its needs, leading to rationing and the continued use of private sources.

iii) Rising temperature is also leading to glacial loss on Mount Kenya further straining water resources and turning once glacially-fed perennial rivers, such as the Ewaso Ng'iro, to seasonal flows, leading to conflict over water resources between communities upstream and downstream.

4. Climate Change and Agriculture in Uganda (impacts and vulnerabilities)

i) The production of primary food crops such as cassava, maize, millet and groundnuts are projected to decline by mid-century and beyond (2050s) due to climate change impacts. These losses are expected to reach almost US$1.5 billion from available data by 2050.

ii) The rising temperature and shifting rainfall patterns have increased soil erosion, and shorten crop growing seasons. Similarly, it has led to emergence of pests and diseases for crops and livestock.

iii) High temperatures are associated with more incidences of crop pests and diseases such as blast and bacterial leaf blight in rice, aflatoxin in maize, fungal and viral diseases in banana and beans, and coffee rust in coffee trees (MoWE, 2015). Unreliable rainfall patterns leads to higher post-harvest losses and also affect crop yields in maize, beans, coffee and rice.

iv) The yields of major cash crops (coffee and tea) have registered decline, and the trend is predicted to an estimated US$1.4 billion economic losses by mid-century (2050), according to the World Bank (World Bank, 2020:p15; and MoWE, 2015). Climate-induced losses are expected to range from 10–50% yield losses, with the potential to reduce foreign exchange earnings by $15–$80 million per year. In coffee sub-sector alone, the loss estimates could accrue to 50% for Arabica and Robusta coffee combined, which could be about US$1,235 million by 2050.

v) Heat stress has been linked to decline in milk production in dairy cattle and altering breeding patterns for livestock. Extreme heat also affects beef and dairy cattle alike, besides reducing both quality and yields of crops. Estimated impacts on livestock production range between 1 - 2%.

5. Climate Change and Water Resources in Uganda

i) The projections suggest reductions in surface water and groundwater supplies as well as decreased groundwater recharge from reduced precipitation. Conservative estimates suggest that the cost of unmet water demand by 2050 could reach $5.5 billion, with the largest losses expected in the Lake Victoria, Albert Nile, and Lake Kyoga Watersheds (World Bank, 2020). In the past, annual economic losses from droughts have been up to $237 million.

ii) Lake Victoria, the main water body in the region gets its recharge water mainly through rainfall (82%). However, the lake water level has shown a significant downward trend over the last 10 years. For example, in 2006, Lake Victoria had reached an 80-year low; thereby affecting the water levels for Lakes Kyoga and Albert. Furthermore, over the last 10 years, Lake Kyoga levels have also shown a significant downward trend. In 2019-2021, the lake levels went up drastically.

iii) Wetland coverage across the country is in decline, at 15.6% in 1994 and 10.9% in 2008 (World Bank, 2020). These changes have been attributed to massive wetland degradation for rice cultivation and dairy farming, flower farming along the shores of Lake Victoria; especially in Buikwe, Mukono, Wakiso and Kampala districts, with occasional conversion for human settlement. The Lake Victoria catchment also includes wetlands from Bushenyi, Mbale, Mbarara, Ntungamo, Lyantonde, Rakai and Isingiro, which have been adversely impacted by the establishment of dairy cattle keeping in the wetlands along the river Rwizi-Rufuha. This has led to a large loss of wetlands across this major catchment (MoWE, 2014).

6. Climate change impacts/ rising temperatures on labour productivity

i) The heat stress due to rising temperatures is increasingly becoming one of the main factors in labour efficiency and productivity globally. Kenya, a lower-middle income countries and Uganda, a lower-income country the effects are predicted to be affected most, in which case losing an estimated 4% and 1.5% of their GDP by 2030, respectively as a result of high heat levels. The GDP loss is expected to increase by up to 9% for a representative low-income country by end of century (i.e. 2100).

ii) In Eastern Africa, the effects on heat stress on labour productivity will relatively be less compared to other African countries, partly explained by higher attitudes of Kenya and Ethiopia. However, countries like Somalia, Djibouti, Eritrea and Mozambique suffer more loss in productivity to heat stress. For example, in 1995 these countries recorded above 1% of loss working hours due to heat stress (ILO, 2019).

iii) Somalia will suffer most in terms of loss in labour productivity due to rising temperatures. For instance, the ILO estimates that the country lost about 2.8% of total working hours in 1995 alone due to heat stress, but this is expected to reach 5.6% in 2030. Despite these working hours lost seems small in percent point, their ultimate effects on poverty reduction, food security and attaining 2030 Sustainable Development Goals should not be ignored in real terms.

iv) For Kenya, the analyses showed that the country lost an equivalent of 27,000 jobs in full-time or 0.27% of working hours lost in 1995 due to heat stress and expected to reach 147,000 full time job loss equivalent (0.53% of working hours losses) by 2030.

v) Similarly in Uganda, the country lost an equivalent of 20,000 full time jobs (0.24% of working hours lost) in 1995; and this is expected to reach an estimated 212,000 full time jobs loss i.e. 0.75% of working hours loss by 2030, due to heat stress (1.5^{O}C temperature rise).

7. Priority Action Areas for Climate Adaptation

Actions by different stakeholders are needed in the short term to enable responses in the short, medium and long term. Some medium- and long-term responses will need immediate enabling action and planning and immediate implementation of investments especially those investments that leads to building resilience e.g., mobilizing social protection programmes for vulnerable population, Research and Development, investment in resilient agricultural development, enable adaptation through policies and institutions, deepening regional integration and international cooperation, innovation and knowledge transfer.

Introduction

In the coming decades, agricultural sector will continue to face numerous challenges ranging from climate change, rapid population growth, land degradation and loss of farmlands due to increasing urbanization (Rosenzweig and Iglesias, 1999). Whereas there has been a general increase in food production at pace with population growth globally, there are serious regional food deficits, and disproportionate nutritional deficiencies with nearly a billion people affected worldwide. Notably, climate change is big factors behind food production and availability deficits in many parts of the world, particularly those prone to droughts and famines (Rosenzweig and Iglesias, 1999), especially in developing countries. The World

Bank estimates that almost 690 million people (8.9%) of the World's population remains in hunger; and about 70% more food needs to be produced by 2050 in order to feed bulging population which is likely to reach about 9 billion (World bank, 2021) [1]. The big question is, how will this be met, when climate change is threatening agricultural sector and food security at alarming rate? There is now evidence that climate change impacts on agricultural sector have serious consequences on food security (Ciscar et al., 2018). Drought and floods, are not only destructive in themselves, but also catalyze disease vector and pest spreading conditions, foster vector-breeding and intensify disease transmission (FAO, 2021); leading to loss farm productivity and agricultural performance.

Box 1

"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (World Food Summit, 1996). This definition gives rise to four dimensions of food security: availability of food, accessibility (economically and physically), utilization (the way it is used and assimilated by the human body) and stability of these three dimensions.

According to FAO, climate change threats could reverse the past gains made the fight against hunger and malnutrition (Gitz et al., 2016; see also FAO, 2016). Available highlights from the Intergovernmental Panel on Climate change (IPCC), climate change reinforces and intensifies risks to food security for the most vulnerable countries and population segments. Four in eight key risks induced by climate change identified by IPCC Assessment Report (AR5) relates directly to food security: i.e. 1) loss of rural livelihoods and income, 2) loss of marine and coastal ecosystems, and livelihoods, 3) loss of terrestrial and inland water ecosystems, and livelihoods; and 4) food insecurity and breakdown of food systems.

The groups being impacted most are the most vulnerable countries and populations, including arid and semi-arid areas, landlocked countries and Small Island developing States (SIDs) (Gitz et al., 2016 and FAO, 2016). In addition, climate change broadly will impact trade flows both within and across countries, destabilizing food markets and price stability and likely to bring new/emerging risks to human health. Towards, this scourge, expanded efforts are needed to respond to climate change urgently though improved governance, innovative partnerships to safeguard the capacity

https://www.worldbank.org/en/topic/climate-smart-agriculture#:~:text=On%20farms%2C%20climate%20change%20is,cereals%2C%20and%20lowering%20livestock%20productivit of food systems, and IGAD relented commitment towards this direction.

The challenges in food production are being intensified by climate change, making agricultural sector very vulnerable. This is even more complicated in developing countries, where majority of the people are smallholder farmers; agriculture is predominantly rain-fed and hence yields are closely linked to weather patterns. Less developed countries where majority of the population is income poor, base their livelihoods on rain-fed agricultural system, the lower social groups are more susceptible to changes and volatilities in food prices driven by climate change (Ciscar et al., 2018; and Hertel et al., 2010).

Globally, negative impacts of climate change are already being felt, in the form of increasing temperatures, rainfall variability, shifting agroecosystem boundaries, invasive crops and pests, and more frequent extreme weather events. On farms, climate change is reducing crop yields, the nutritional quality of major cereals, and lowering livestock productivity. Disasters may have stronger socio-economic impacts on women – the custodians of household security – than on men, especially in agriculture, where women already face greater challenges (FAO, 2021). Therefore, substantial investments in adaptation will be required to maintain current yields and to achieve production and food quality increases to meet the growing food demand.
The incidences of high temperatures, affects precipitation levels; and also the increased frequencies in form of weather extremes (droughts and floods) are associated with suppressed yields and increased uncertainties and production risks in many parts of the World (Tubiello and Fischer, 2007). This trend is likely to accelerate household poverty and inequality between the poor and rich countries, as well populations in different social-economic segments within countries alike (IPCC, 2001).

The IGAD region is not exceptional, climate variability, including unpredictable, intense and at times extreme weather events such as droughts, floods and landslides, is already threatening ecosystems and livelihoods. The region has experienced an increase in the frequency and intensity of droughts and floods in recent years. In response to the growing concerns to these sub-optimal environmental conditions that affect its member states, Intergovernmental Authority on Development (IGAD) through the IGAD Climate Prediction and Applications Centre (ICPAC); an entity accredited by the World Meteorological Organization (WMO) has intensified efforts to tackle the effects of climate change through providing a number of climate services (CS)/ instruments to users ranging from climate data, climate monitoring, climate forecasting, dissemination and communication of climate information, technical assistance to disaster risk reduction management, environmental monitoring, agriculture and food security monitoring, water resources monitoring, and capacity building in the 11 East African countries under its mandate, aimed at creating resilience in a region deeply affected by climate change.

In line with IGAD Regional Climate Change Strategy (IRCCS), one way of adaptation responses is to conduct routine cross country assessments in the member states to keep up-to-date with development issues such as understanding the potential impacts of climate change on key sectors of economy to guide policies, and support resource mobilization at different levels. In cognizant of above call, IGAD through ICPAC, under the current 11th European Development Fund portfolio to Intra-ACP Climate Services and Related Applications (ClimSA) project, has sought the services of a consultant to conduct an evidence based assessment on the social economics of climate services in two pilot countries (Kenya and Uganda), geared towards one of the outputs, i.e. documenting the impacts of climate change on agriculture and water sectors. The technical output(s) needed from the consultant was to estimate the effects of climate change proxy by changing temperature and precipitation regimes and increased CO_2 concentrations on agricultural production and water sector; and its economic implications in order to guide policy decisions along adaptation and mitigation responses in the region. The study makes attempt to document both qualitatively and quantitatively the potential climate change impacts on agricultural production (majorly crops), including yield changes of major food, cash and industrial crops, prices, loss in labour productivity, trade and risk of hunger; and also in water sector.

The results from the study could provide policy makers and international development partners in IGAD region with the evidence base on the economic impacts of climate change in order to mobilize resources, increased investment for adaptation e.g. climate services in climate-sensitive sectors. In addition, the study could also help increase the capacity of government officials to use the evidence on the economic impacts of climate change in development and investment planning. The detail discussions on the ClimSA project and assessment objectives are provided in the subsequent sections that follow.

Overview of Climate Change in the Horn of Africa (HoA) and how ClimSA project aligns to the challenges.

The Horn of Africa (HoA) region have a long-standing history of being prone to climate extremes events such as droughts and floods that exacerbate food, water insecurity and in some cases leading to cross-border conflicts. The economies and livelihoods of the HoA countries (Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan and Uganda) are dependent on rain-fed agriculture that is highly sensitive to weather as well as the climate variability and change. Rainfall has strong bearing on agricultural production and also linked to economic and social well-being of the rural communities in the region. Evidently, climate change in the region could result in an increase in the frequency and intensity1. of extreme weather /climate events, leading to more intense flash floods and more recurrent, severe and prolonged drought leading to water scarcity. Climate risks impacting the livelihoods and food security situation of pastoralists and agro-pastoralists are also increasingly associated with resource-based conflicts in countries such as Kenya, Somalia, Ethiopia, Uganda, Sudan, and South Sudan that could lead to a further deterioration in vulnerability of the affected populations in the region.

It was in this context that the Intra-ACP Climate Services and Related Applications (ClimSA) project was initiated under the 11th European Development Fund (EDF) multi-year funding to support IGAD/ICPAC towards strengthening climate information services. Part of the initiative includes supporting IGAD with technical and financial assistance and infrastructure and capacity building to improve wide access and use of climate information, and to enable and encourage the generation and use of climate services and applications for decision-making processes at all levels. ClimSA provides tools to bridge climate services stakeholders and users in climate sensitive sectors to resources and implement Global Framework for Climate Information Services (GFCIS) at all levels.

In this portfolio, ClimSA actions are envisioned to contribute to six (6)Sustainable Development Goals i.e. SDGs 1, 2, 5, 7, 13 and 15 in the following ways: 1) building the resilience of the poor and vulnerable people and minimizing the risks to climate related extreme events and early warning; 2) enhancing food security tailored climate services through engagements of the regional multi-stakeholder Food Security and Nutrition Working Group (FSNWG), by closely working with IGAD Secretariat and its other implementing regional bodies especially the IGAD Drought Disaster Resilience and Sustainability Initiative (IDDRSI) and Cross-Border Cooperation Working Group and international organizations; and 3) enhancing cooperation between institutions to tackle a major issue of common concern i.e. supporting improvements and capacity building on the use of climate services for improved adaptation planning from regional down to national and local levels.

13. Ultimately, the Action complements both the IGAD Strategic Plan (2021-2025) and ICPAC's Strategic Plan 2016-2020 of enhancing the livelihoods of the people of the region in order to mitigate climate-related risks and disasters. ClimSA portfolio target five results chains: (1) ensure improved interaction between the users, researchers and climate service providers in the IGAD region through structured and strengthened User Interface Platforms (UIPs), (2) guarantee the provision of climate services at regional and national levels, (3) expand access to climate information; (4) enhance the capacity to generate and apply climate information and products; and (5) mainstream climate services into policy processes at regional and national levels.

Objectives of the study

The main objective of the study was to provide technical support on social economic impact assessment of the climate services in the IGAD region targeting Kenya and Uganda; where possible to apply the results broadly across the region.

Specific objectives

More specifically, the consultancy addressed two objectives: (1) to estimate the economic value of climate services supported by ICPAC through Intra ACP ClimSA project; and (2) to come up with specific impacts of climate change for example in agriculture and water sectors. The output 1, has now been completed; and the sector report is expected to respond to output 2, of the specific objectives.

The Organization of the Report

The report is organized as follows. Section I, is the introduction and literature review chapter that gives an overview of climate change and associated impacts to the global economy and the Horn of Africa region; how the trend is evolving, and extent to which it has shaped rural livelihoods. Here, objectives and the description of the project (ClimSA) are also discussed. Then section 2, provides overviews of the climate change impacts on agriculture and food security globally; the state of agricultural and water sector in both countries. It also discusses the country specific climate change impacts in these two sectors and provide policy options needed for adaptation. Section 3, presents the study area, data and the methodology. Research results are presented in section 4, while section 5 presents conclusions, discussion and recommendations. References cited and supporting annexures (appendices) are presented at the end of the research work.

Literature Review

State of the Knowledge of Climate Change and Food Security

Box 2

How will climate change affect agriculture and rural livelihoods?

i. Climate change will incrementally affect all the agricultural sectors. Climate change already has negative effects on crop yields, livestock production and fisheries, particularly in low- and middle- income countries. Such impacts are likely to become even stronger in mid and late century.

ii. If not addressed, climate change will exacerbate poverty and inequalities. Unaddressed climate change, which is associated, inter alia, with unsustainable agricultural practices, is likely to lead to more land and water use, disproportionately affecting poor people and exacerbating inequalities within and between countries. This carries negative implications for both food availability and food access.

iii. Climate change impacts go well beyond crop yields. Climate change also affects soil quality, fish habitats and stocks, the biodiversity of landscapes, and the epidemiology and antimicrobial resistance of pests and diseases. There are great uncertainties about the combined effects of these impacts.

Source: FAO, 2018

Climate change is expected to bring many challenges in future related to water availability and food security in many regions of the world (Gitz et al., 2016 and FAO, 2016). It is associated with reduced precipitation, escalate water runoff and snow/ice melt, with detrimental effects on hydrological systems, water quality and water temperature, as well as on groundwater recharge (FAO, 2016; see also Gitz et al., 2016). The incidences of increased water scarcity under climate change is challenging for climate adaptation and mitigation efforts. Climate change effects such as sea-level rise will also affect the salinity of surface and groundwater in coastal areas. The changes in frequency and intensity of weather extreme events (droughts, floods and storms etc.) impacts agricultural sector highly.

Climate change impacts agricultural sector both directly and indirectly. For example, directly, it modifies the physical conditions (temperatures, rainfall patterns and distribution) altering agricultural/farming systems. Indirectly, it alters insect species affecting crop pollination; emergence of pests and disease vectors and invasive species which are detrimental to farming through increasing production costs due to need for extra inputs; or they lower productivity. Whereas there are noticeable changes, the negatives outweighs the positive sides associated with climate change impacts (Gitz et al., 2016; see also FAO, 2016). It is now clear that crop production has negatively impacted cereal supply chains (wheat and maize) both regionally and worldwide. For example, the IPCC in its fifth assessment report (AR5) associates the yield drops of major world crops (coarse grains, oil seeds, wheat and rice) which overall accounts for 70% of global food production, are predicted to decline by 17% by 2050 under business as usual sceanrio linked to climate change (Gitz et al., 2016 an; see also FAO, 2016).

19. In livestock, climate change affects animal productivity through altered breeding, animal ill-health, lowered forage yield and fodder crops. For example during the past decades, Sub-Saharan Africa recorded on average of 20-60% losses in animal numbers during periods of major droughts in the region (Gitz et al., 2016 and FAO, 2016). Similarly in France, in 2003, it experienced a 60% fodder deficit due to heatwave during summer period.

In forestry, climate change is causing decline in forest cover yet nearly 1.6 billion of world's population derives livelihoods from this sector. Droughts and increasing temperatures are causing disappearances of tree species, wind and water erosion, more storms escalating incidences of bush fires, increasing incidences of pests and disease outbreaks, land and mudslides, saltwater intrusion and sea-level rise, and damage from coastal storms. This has reduced forest role as carbon sink in climate /weather regulation. In fisheries, climate change is altering sea and inland water surface temperature, ocean circulation, (waves and storm systems) and chemical changes (salinity content, oxygen concentration and acidification) of the aquatic environment leading to fish migration from tropics to Mediterranean region. For example, Tropical Ocean has experienced decrease of up to 40% in fish population, and an increase of 30-70% in high-latitude regions (Gitz et al., 2016 and FAO, 2016). For a more detail framework on how climate change affects agriculture, refer to Figure 1.

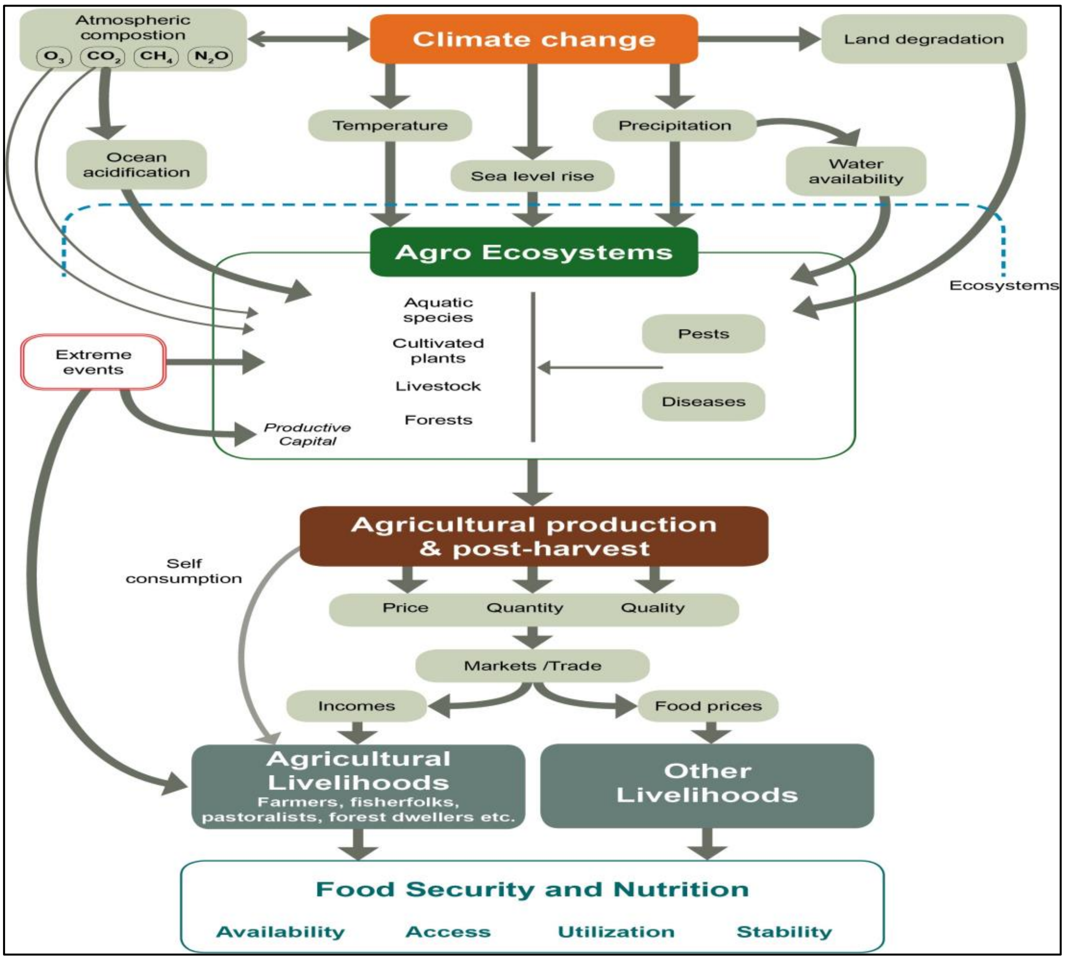


Figure 1: A Framework for climate change impacts on food security and nutrition
Source: Adopted from Gitz et al., 2016; see also FAO, 2016: vii

The resultant effect is that lowered production in those sectors leading to more poverty, increased inequality and reduced quality of lives of the poor population. At household level, climate change leads to reduced income due to low productivity and increased costs of production and food prices. Households may respond by selling productive capital assets (cattle, and land etc.) exposing themselves to 'climate-poverty trap' i.e. in a vicious cycle of poverty. Increased shocks/stresses lowers propensity to save and invest among households. A lowered agricultural income also affects health and education outcomes.

At national level, exposure to climate risks can trigger shocks on agricultural production and food availability, with risks of market disruptions, effects on supply and storage systems, as well as increases in agricultural commodity prices (food and feed), impacting accessibility and stability of food supplies for the entire population, particularly in countries with significant shares of the population spending a large part of their income on food. This triggers macro-economic effects for countries where agriculture is an important part of GDP and/or constitutes an important source of employment. Climatic risks can also hinder agricultural development by discouraging investments.

At global level, climatic shocks impacting areas of global importance for food supplies can have remote impacts through effects on: (i) supply flows and food price spikes, with increased market volatility; and (ii) impacts on bilateral contracts and/or import/export behaviour, with disruption of trade patterns. Trade is expected to play a major role in adjusting to climate-change-driven shifts in agricultural and food production patterns. Recent experience indicates that climate change effects on food price volatility are greatly influenced by domestic policies, with export bans contributing to price fluctuations. Ultimately, global markets will not be accessible to the poorest countries and the poorest populations without sufficient purchasing power (Gitz et al., 2016 and FAO, 2016)

Climate change impacts on the dimensions of food security

Climate change affects all the four (4) dimensions of food security i.e. access, availability, utilization and stability. For example, reflecting on Figure 1, climate change affects food availability through lowered food production. Subsequently, impacting the livelihoods and income of smallholder food producers. In addition, there are associated price increases for food and volatility and the livelihoods of net food buyers will affect the dimensions of accessibility to adequate food and balance diets.

In terms of impacts on nutritional quality, this has been less studied but scanty evidences shows that there are likely reduction in the consumption of protein, vitamins and mineral rich diets, explained by more concentration of CO_2 in major cereals and starchy food like cassava (FAO, 2016); and perhaps the lowered incomes of smallholder farmers making such food varieties less affordable. In terms of food safety, climate change has negative effect on drinking water quality, which is a key requirement in proper absorption of nutrients during digestion. There have been reported cases of more incidence and prevalence of food-borne diseases due to climate change. Therefore, increased climate variability, increased frequency and intensity of extreme events as well as slow ongoing changes will affect the stability of food supply, access and utilization at all levels.

Where are the disproportionate climate change impacts?

The net effects of climate change on food security and nutrition depend on the vulnerabilities of the affected populations and food systems. For example, at each stage of food supply systems, climate change impacts are expected to amplify vulnerabilities and net impacts vice versa. Also, repeated shocks/stresses from climate change on vulnerable population will increase over time through eroding their livelihoods and productive assets needed for production. Their capacity to respond and adapt to climate change are also reduced. Ultimately, the population whose livelihoods are agricultural and natural resources based typical of developing countries where Kenya and Uganda lie, are more exposed to climate change impacts and thus are most at highest risks; due to their limited capacity to adapt.

In regions with high levels of food insecurity and inequality, increased frequency of droughts will particularly affect poor households and may disproportionately affect women, given their vulnerability and restricted access to resources. Gender and social differences discriminate people's access to adaptation options, or even information, such as weather and climate data. Indigenous peoples, who depend on the environment and its biodiversity for their food security and nutrition, are at high risk especially those living in areas where significant impacts are expected such as mountain areas, the coastal and other low-lying areas. Fishers, fish farmers, post-harvest workers and their dependent communities and infrastructure are particularly exposed.

Overview of Agricultural sector in Kenya

Agricultural sector is critical to Kenya's economy and food security and is considered to be one of the most vulnerable to climate risks (World Bank, 2021). The sector contributes approximately 28% of Kenya's GDP and accounts for more than 65% of exports, with crop, livestock, and fisheries sub-sectors contributing approximately 78%, 20% and 2% to the agricultural GDP, respectively (World Bank, 2021)[2]. As of 2015, the agricultural sector provides about 80% of total employment and supports over 80% of the rural population (World Bank 2015; see also CIAT, 2015). Four sub-sectors are recognized: crops, livestock, fisheries and forestry (MALF, 2017). The country's reliance on agriculture and dependence on imports (especially of wheat, maize, and rice, among others) underscores the need for sustainable, resilient increases in agricultural productivity for food security and economic growth (World Bank 2015; see also CIAT, 2015), as well as a need for radical adaptation programmes to safeguard the country against further deteriorations to already fragile food security situation.

Climate change and agriculture in Kenya (impacts and vulnerabilities)

Kenya's agriculture is 98% rain-fed and highly sensitive to changes in temperature and variability in rainfall. Agriculture accounts for more than 30% of GDP and is the primary livelihood for 60% of population (USAID, 2018)[3]. Small-scale farms account for 75% of production with maize, beans, tea and potatoes as the most important

crops, and sheep and goats dominate livestock production (GoK, 2015 and IFPRI, 2012).

Recurrent, prolonged and intense droughts pose a significant problem, example during 2008-2011, an estimated of $10.2 billion loss in livestock and crops were recorded (GoK, 2012).

Higher temperatures are likely to expand production of maize and beans into higher elevations, but farming in lower elevations is expected to see yield losses of up to 20% due to heat stress and shifting rainfall patterns, with some areas (like central Kenya) becoming unsuitable for production. Maize, which accounts for about one-third of caloric intake in Kenya, can be damaged by temperatures over 35^{o}C, which are increasingly common in lowland regions (Kabubo-Mariara et al., 2016). Kenya is among world leaders in tea production; e.g. tea accounted for $787 million in exports in 2014. Areas suitable for tea production are shifting to higher elevations as temperature increase puts current production areas at risk from heat extremes and increasing pests and diseases (CIAT, 2011). In arid and semi-arid regions, pastoralism is the dominant production system; high temperatures are expected to increase heat stress and pest and disease incidence in livestock.

Climate change poses a serious negative impact on agriculture-based livelihoods in Kenya, challenging the sustainability of current arable, pastoral and fishing practices. The majority of Kenyan agriculture relies on seasonal rains for production and the projected changes in precipitation patterns are expected to directly increase the likelihood of short-term crop failures and long-term production declines.

The high inter-annual variability of rainfall is already having devastating consequences on rural livelihoods, with droughts and floods, a frequent occurrence in both the arid and semi-arid lands and key agricultural zones. Additionally, indirect impacts, such as increased rates of runoff and soil erosion, and increased crop losses from wildlife migrations, rising and novel infestations from insects, diseases and weeds, could significantly magnify production losses (NEMA, 2015).

[2]World Bank (2021). Climate Risk Country Profile, Kenya

[3]USAID, Climate risk profile, Kenya

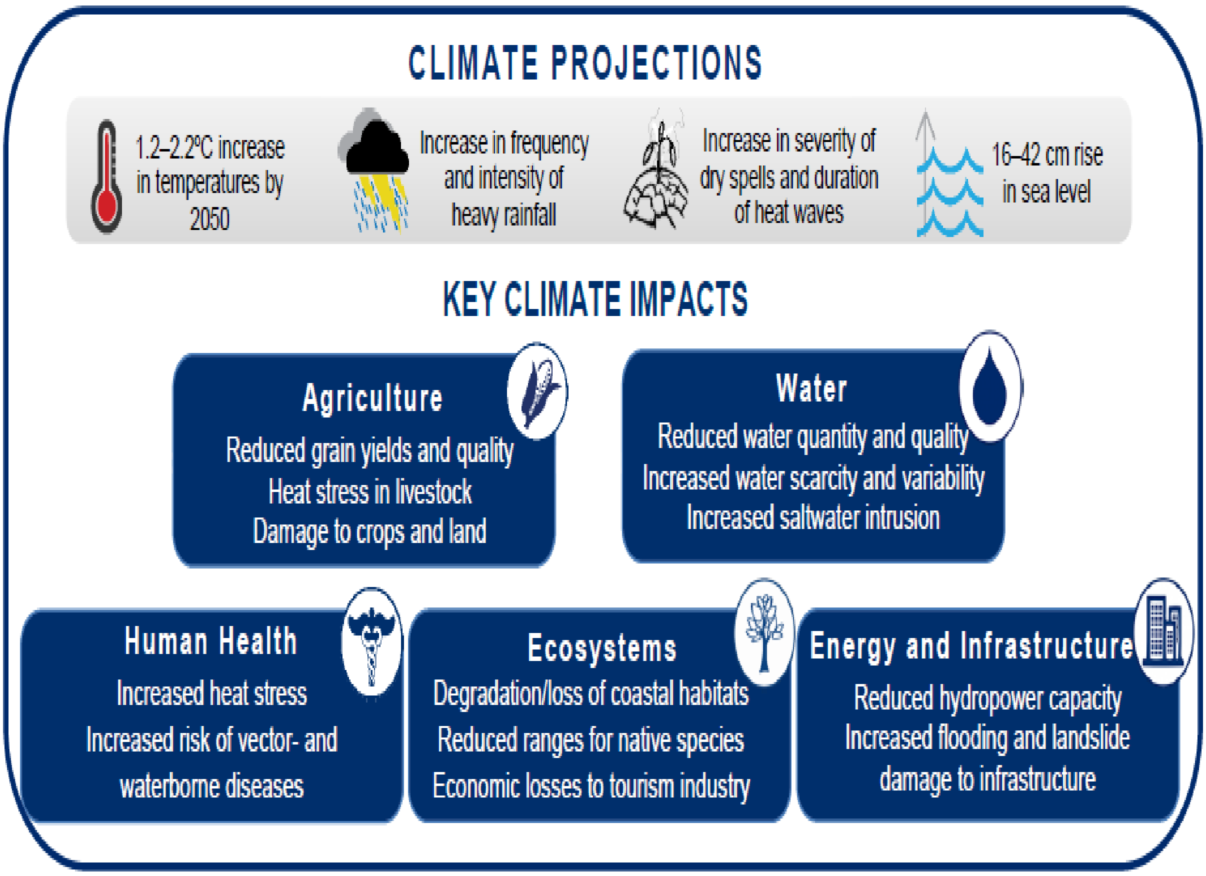


Figure 2: Climate change projections and associated impacts in water and agricultural sector (Kenya)

Source: USAID, 2018

Table 1: Climate Stresses and Risks in Agricultural Sector, Kenya

Stressors	**Risks**
Rising temperatures & evaporation rate Increased intra-seasonal rainfall variability Increased frequency & intensity of heavy rainfall Sea level rise	Reduced grain yields and quality due to heat and water stress
	Heat stress in livestock, leading to reduced reproduction, growth rates and milk production
	Crop damage and degraded crop and pasture land
	Increased incidence of pests and diseases for crops and livestock
	Saltwater intrusion and storm surges, impacting coastal production, particularly of mango, cashew and coconut

Source: USAID, 2018

Some regions of Kenya may see a benefit from a changing climate, specifically the temperate and tropical highlands, the Rift Valley and high plateaus, as projected increases in rainfall and slightly warmer temperatures are likely to raise crop yields. However, the country's large semi-arid and arid land areas are projected to see a significant decline in agricultural productivity and livestock numbers, as water resources become increasingly scarce (NEMA, 2015).

Rising temperatures are likely to alter the mix and distribution of agriculture and livestock pests, while the increased incidence of droughts, coupled with projections of reduced rainfall for the arid and semi-arid regions, is expected to reduce yields in key crops: maize, wheat, rice, livestock and fisheries. Key cash crops such as coffee and tea are also likely to be highly affected due to temperature increases as well as the increased presence of pests and diseases (MoENR, 2016). Reduced water availability could also reduce yields and reduce soil moisture availability, potentially altering the distribution of areas suitable for agriculture or the production of specific crops (World Bank, 2021).

Climate change in water sector, Kenya (past and present trends)

According to the Government of Kenya, the country is ranked as water scarce, strained by population growth and severe forest degradation, and could be further stressed by increasing temperatures, evaporation rates and rainfall variability (GoK, 2015). The country relies predominantly on surface water sources, but key rivers and lakes are highly susceptible to climate change (USAID, 2018)[4]. For example, in 2010 Kenya's water availability was 586 m^3 per person annually, well below the internationally acceptable threshold of 1,000 m^3 per person; this figure is expected to fall to as low as 293 m^3 by 2050 (GoK, 2015). Increasingly severe droughts and flooding will impact water availability and diminish water quality, with implications for irrigation and domestic water supply and sanitation, which combined account for 87% of current use.

Freshwater resources in Kenya are already highly subject to the large inter-and intra-annual rainfall variability, including the extremes of floods and droughts (World Bank, 2021). Urban areas are already highly water stressed; Mombasa regularly implements water rationing. For instance, Mombasa currently has only half of the water required to meet its needs, leading to rationing and the continued use of private sources (World Bank, 2021). The rising temperatures and more variable rainfall will complicate these situations (World Bank, 2021; and GoK, 2013). Rising temperatures is also leading to glacial loss on Mount Kenya further straining water resources and turning once glacially-fed perennial rivers, such as the Ewaso Ng'iro, to seasonal flows, leading to conflict over water resources between communities upstream and downstream (Wesangula, 2017).

Table 2: Climate Stresses and Risks in Water Sector, Kenya

Stressors	Risks
Rising temperatures & evaporation rate	Increased water scarcity and variability for irrigation, domestic use, hydropower and industry
Increased rainfall variability	Accelerated glacial loss; reduced river flows from Mt. Kenya
Increased frequency and intensity of heavy rainfall Sea level rise	Increased flood damage to water supply and sanitation infrastructure
	Saltwater intrusion into coastal aquifers (supplying a population of 3 million); decreased water quality

Source: USAID, 2018:p3

Climate Change and Agriculture in Uganda

The rain-fed agriculture is the dominant farming system in Uganda, and food security and livelihoods of the population depend majorly on the sector. Agriculture employs nearly 70% and contribute about 25% of the Gross Domestic Product (GDP) (MAAIF, 2015). The production of primary food crops such as cassava, maize, millet and groundnuts are projected to decline by mid-century and beyond (2050s) due to climate change impacts. These losses are expected to reach almost US$1.5 billion from available data (World Bank, 2020).

The fisheries sub-sector is another main source of livelihoods in the country, where nearly 1.2 million people; employing almost 8% of the labour force (World Bank, 2020). Climate change inform of reduced water availability and watershed re-charge, will continue to impact fisheries significantly, destabilizing peoples' livelihoods and impacting severe economic losses

[4]USAID, 2018: Climate risk profile, Kenya

to many (Future Climate for Africa, 2016). Weather extremes affecting the country manifests majorly inform of droughts, floods, storms, and pests and diseases.

The rising temperature and shifting rainfall patterns have increased soil erosion, and shorten crop growing seasons. Similarly, has led to emergence of pests and diseases for crops and livestock. High temperatures are associated with more crops pests and diseases such as blast and bacterial leaf blight in rice, aflatoxin in maize, fungal and viral diseases in banana and beans, and coffee rust in coffee trees (MoWE, 2015). Unreliable rainfall patterns leads to higher post-harvest losses and also affect crop yields e.g. in maize, beans, bananas, coffee and rice (MoWE, 2015). The districts of Buikwe, Gulu and Mbale are the main risks prone to these hazards in the country. Increasing dry period trends and land/soil degradation have affected agricultural practices, and reservoirs affecting food security.

The yields of major cash crops (coffee and tea) have registered decline, and the trend is predicted to an estimated US$1.4 billion economic losses by mid-century (2050), as from the World Bank. Climate-induced losses are expected to range from 10–50% yield losses, with the potential to reduce foreign exchange earnings by $15–$80 million per year (World Bank, 2020:p15; and MoWE, 2015). Agricultural sector in the country predominantly relies on ground and surface water supply but experiencing reducing recharge and quality from reduced precipitation and increased evaporation due to rising temperatures.

The rainfall amounts received during peak rainy season are on declining trends negatively impacting agricultural production, and water quality especially in semi-arid parts of the country. More incidences of pests and disease outbreaks are common in water logged areas and during drought periods affecting crop yields and livestock performance. Also unreliable and often heavy rainfall is leading to more soil erosions and loss of soil fertility.

The heat stress has been linked to decline in milk production in dairy cattle and altering breeding patterns for stock. Extreme heat also affect beef and dairy cattle alike, besides reducing both quality and yields of crops. The projected increased heat has been documented to increase stress on crops and also alter the length of crop growing seasons (World Bank, 2020). Decreased water availability is likely to reduce yields and the reduction in soil moisture may alter suitable areas for agriculture or the production of specific crops. Increased heat and water scarcity conditions are likely to increase evapotranspiration, expected to contribute to crop failure and overall yield reductions (MAAIF, 2015).

Climate change and water sector in Uganda

Uganda is endowed with water resources in both surface and ground water. Extremes due to climate change and variability are already affecting the availability of water in Uganda, with this trend expected to not only continue but increase, affecting primary sectors such as agriculture and livestock, fisheries, aquaculture, forestry and tourism (MAAIF, 2015). Surface water resources in the form of streams, rivers, lakes and wetlands are divided into eight water catchment basins (USAID, 2013). However, the projected ranfall and temperature trends in conjunction with existing infrastructure and population growth indicate that water stress is considered highly likely for much of Uganda's population (World Bank, 2020).[5]

The projections suggest reductions in surface water and groundwater supplies as well as decreased groundwater recharge from reduced precipitation. A substantial section of Uganda households utilize groundwater as their source of domestic water. Conservative estimates suggest that the cost of unmet water demand by 2050 could reach $5.5 billion, with the largest losses expected in the Lake Victoria, Albert Nile, and Lake Kyoga Watersheds (World Bank, 2020). In the past, annual economic losses from droughts have been up to $237 million. Similarly, future droughts will likely have significant negative effects on water supply in Uganda (Future Climate for Africa, 2016).

Climate change impacts on swamps and lake basins in Uganda

The country's largest lake, Lake Victoria, gets its recharge water mainly through precipitation (82%) across the catchment with the balance coming from the two main seasons of rain water (March to May and September to December) that give it about 2,100 mm annually. However, the

[5]World Bank, 2020: Climate Risk Country Profile, Uganda

lake water level has shown a significant downward trend over the last 10 years; and again increased drastically displacing many people during the period 2019 to 2021. In 2006, Lake Victoria had reached an 80-year low; thereby affecting the water levels for Lakes Kyoga and Albert. Furthermore, over the last 10 years, Lake Kyoga levels have also shown a significant downward trend (USAID, 2013).

The wetlands provide a large array of ecosystem services for both urban and rural areas in the country. They are used for farming, fishing, and livestock grazing, and are primary supplies for water for many rural households. Wetlands also play a crucial role at a regional level by filtering pollutants and regulating water flow. Wetland coverage across the country is in decline, at 15.6% in 1994 and 10.9% in 2008 (World Bank, 2020).

These changes have been attributed to massive wetland degradation for rice cultivation and dairy farming, flower farming along the shores of Lake Victoria; especially in Buikwe, Mukono, Wakiso and Kampala districts, with occasional conversion for human settlement. The Lake Victoria catchment also includes wetlands from Bushenyi, Mbale, Mbarara, Ntungamo, Lyantonde, Rakai and Isingiro, which have been adversely impacted by the establishment of dairy cattle keeping in the wetlands along the river Rwizi-Rufuha. This has led to a large loss of wetlands across this major catchment (MoWE, 2014).

The country has made good steps in ensuring safe water coverage, improving from 61% to 65%, with sanitation coverage improved from 51% to 70% between 2005 –2014, and piped sewerage is estimated at 6% nationally (World Bank, 2020). However, the decreased availability and/or compromised quality of surface water supply will heighten the vulnerability of populations depending on these sources for daily activities; more intense and frequent storms and flooding may cause storm water flows, will increase water contamination of both surface sources and shallow wells (GoU, 2014). This is a particularly serious concern for people relying heavily on surface water when wells dry up. Increased temperatures and intense rainfall are putting greater pressure on the water and sanitation sector, with potential to further impact development gains.

The rainfall and evaporation changes also impact rates of surface water infiltration and the recharge rates for groundwater. Low-water storage capacity increases the country's dependence on unreliable rainfall patterns. Changes in rainfall and evaporation translate directly to changes in surface water infiltration and groundwater re-charge. This has the potential for further decreased reliability of un-improved groundwater sources and surface water sources during droughts or prolonged dry seasons. Increased strain on pumping mechanisms leading to breakdowns if maintenance is neglected and the potential for falling water levels in the immediate vicinity of wells or boreholes, particularly in areas of high demand.

50. In addition, temperature increases have the potential to result in increased soil moisture deficits even under conditions of increasing rainfall. Rising temperature has negative bearings on quantity and quality of supply of water for human consumption, agriculture use and the energy sector as reductions in water availability impacts river flow and the hydropower generating capabilities. However, in overall the country is projected to maintain its current level of wet conditions, with some areas of the country experiencing heightened wetness, other areas are expected to experience significant increases in aridity by the end of the century (World Bank, 2020).

Data and Methodology

The evaluation of climate change impact at country specific sector levels was based on the literature review of both past trends and future projections from the International Labour Organisation (ILO) loss productivity estimates associated to heat stress; together with the latest estimates using Representative Concentration Pathways (RCPs) developed as part of the Fifth Assessment Report (AR5) under the Intergovernmental Panel on Climate Change (IPCC). The IPCC categorically ranks CO_2 emissions pathways along RCP2.6, RCP4.5, RCP6 and RCP8.5, which means four different increases in mean global temperature by the end of the century (1°C, 2°C, 3°C and 4°C respectively). The representative Concentration Pathways (RCPs) have been updated to Shared

Socio-economic Pathways (SSPs) as shown in Figure 3.

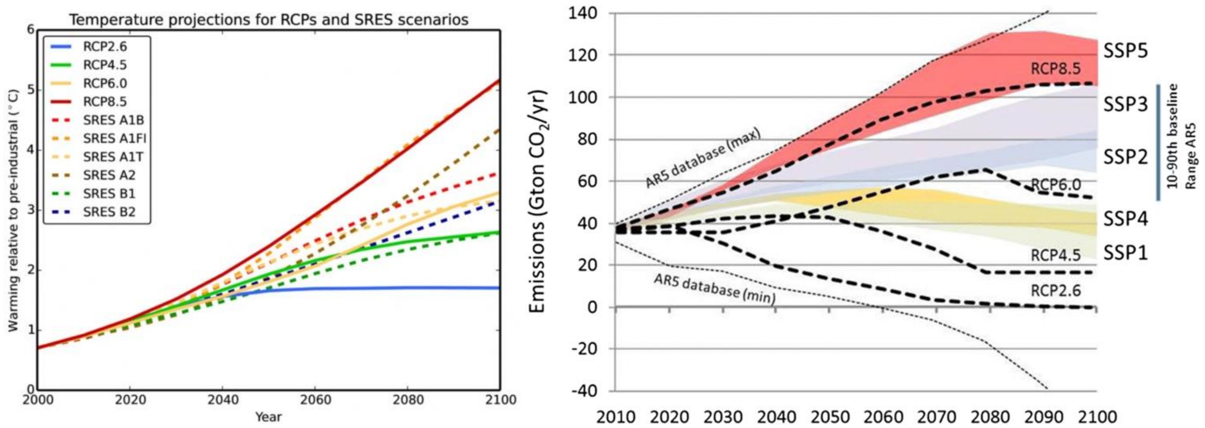


Figure 3: IPCC socio-economic scenarios (SRES, RCPs and SSPs) and their linkages

The climate change policies under different Representative Concentration Pathways (RCP) shown in Figure 3 are defined as:

1) The case of 1°C is likely to reflect the lowest emission scenario with the most stringent mitigation policies (or approximately RCP2.6); the warming level of this scenario family is well under that of SRES B1 and SSP1.

2) Implementation of a climate change agreement (e.g., the Paris Accord) would slow global warming to around 2°C by 2100 (or approximately RCP4.5); this scenario is close to SRES B1 and SSP1.

3) A medium baseline case with less stringent mitigation policies will push global surface temperatures up to 3°C by 2100 (approximately RCP6); This approximates SRES B2 and lies between SSP2 and SSP4 and also approximates SRES A1T

4) Without any countervailing action to reduce emissions, global warming could increase up to 4°C (or approximately RCP8.5). This closely matches SRES A1FI and lies between SSP3 and SSP5.

Climate change is affected by various factors ranging from regional characteristics, socioeconomic variable and meteorological variables, and the future trends will depend on the development pathways, countries adopt globally. The IPCC elaborates on these future Greenhouse Gas emission scenarios based on the demographic and socioeconomic development adopted by each country, with likely consequences to economic performance of different sectors. This is presented in its Special Report on Emissions Scenario (SRES), with four likely pathways adopted i.e. mainly (A1, A2, B1, and B2, See Figure 3 for the linkages between SRES, RCPs and SSPs); and others (A1F, A1T, A1B See Figure 3 for the linkages between SRES, RCPs and SSPs), as modification for technologies countries use in the A1 (Scenario, to predict the level of economic growth. For detailed explanations on each scenario, make reference to the framework provided in Figure 4.

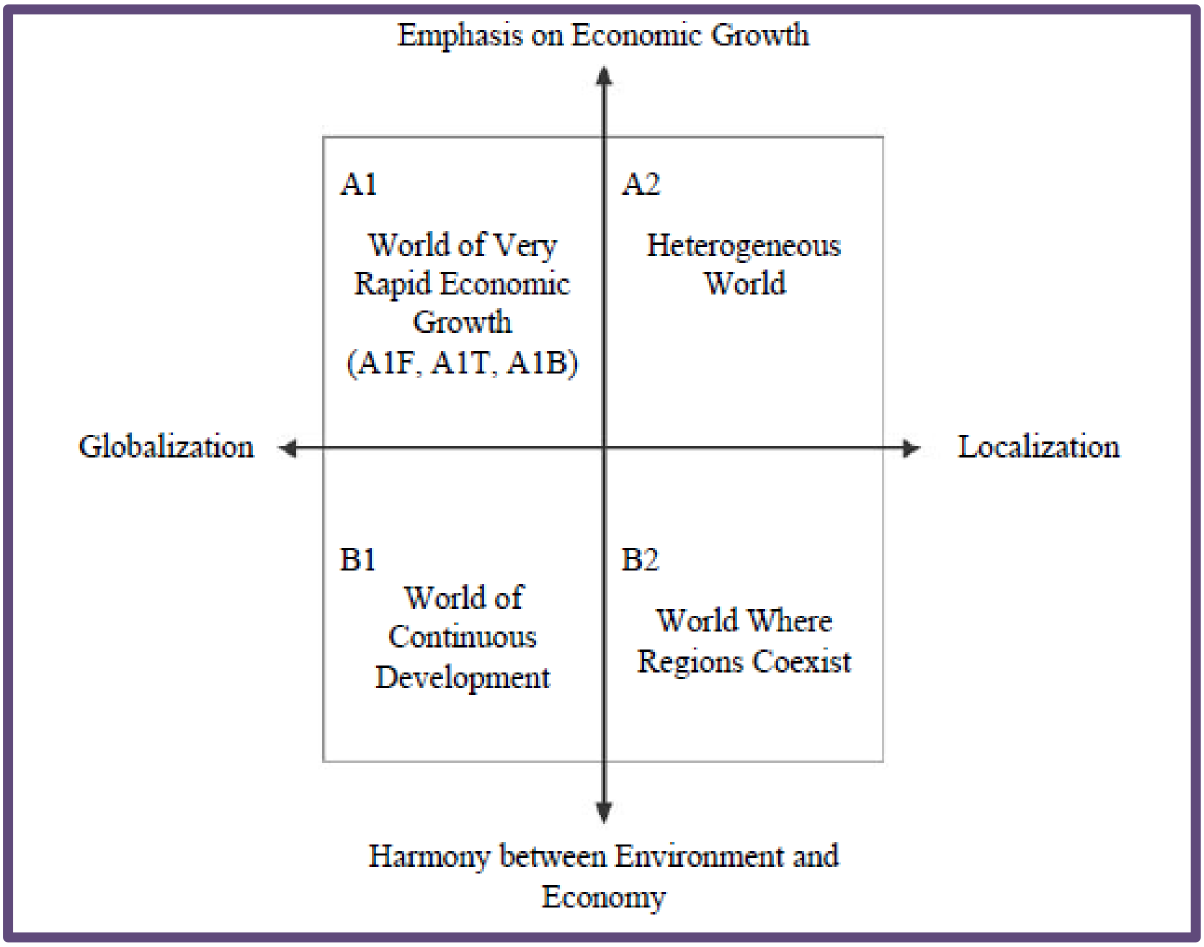


Figure 4: A Framework of GhG scenarios for estimating climate change impacts
Source: Kim, Chang-Gil and et al. (2009), p.21.

A1 scenario assumes a very-rapid economic growth, in which the rapid growth of the global economy and population peaks in 2050 and declines thereafter, in which then new efficient technologies are introduced. It is divided into three groups according to the alternative development of energy technology. The three scenarios are the fossil intensive scenario (A1FI, RCP8.5 and lies between SSP3 and SSP5), non-fossil energy scenario (A1T), and balanced-energy source scenario (A1B).

SRES A2 is the scenario for a heterogeneous world with a high population growth rate, a low economic growth rate, and the most diversified but slowly developing technologies. The SRES A2 scenario family lies between RCP6.0 and RCP8.5; also can fall between SSP2 and SSP3.

The B1 scenario assumes the same population growth rate as that of the A1 scenario but at a lower economic growth rate. In this scenario, the economic structure changes toward a service and information economy and sustainable development is pursued with an emphasis on clean and resource- efficient technologies. B2 (RCP6.0 and lies between SSP2 and SSP4) is a scenario for a world where regions coexist with each other in harmony. This scenario assumes the intermediate level of population and economic growth between A1 and B1, and focuses on regional solutions for economic, social and environmental sustainability. This scenario family approximates RCP4.5 and SSP1.

Data Sources

The study uses data from various sources, which included: 1) relevant literature providing climate change impacts both regionally and country levels as shared in the section of Literature Review, section 2) data on the impact of heat stress on labour productivity and decent work, developed by the International Labour Organization (ILO, 2019); 3) data on renewable freshwater resources per capita provided by the "Our World in Data"[6];

[6] https://ourworldindata.org/water-use-stress

and 4) data on yield changes on major World cereals (wheat, rice and maize) due to differences in CO_2 levels, indicated by the amount of CO_2 concentration measured in parts per million volume (ppmv) for different time horizons (1990s, 2020s, 2050s and 2080s), under different SRES emissions and socio-economic scenarios (A1FI, A2, B1 and B2, See Figure 3 for the linkages between SRES, RCPs and SSPs). The change in yield due to CO_2 effects does not reflect the effect of changes in any other variables in the climate change scenarios, i.e. do not reflect the effects of changes in temperature or precipitation.

We need to know that to have sustainable levels of water resources, the rates of water withdrawals must be kept below freshwater replenishment. The renewable internal freshwater flows refer to internal renewable resources i.e. the internal river flows and groundwater from rainfall in the country. Measuring climate change impacts was conducted indirectly through available renewable freshwater resources per capital as it a strong indicator water security or scarcity in the country. It must take note that in a country where the rates of freshwater withdrawal exceeds renewable flows, then resources begin to decline.

This per capita renewable fresh water resources is affected under two factors: a) the total quantity of renewable flows, and 2) the population size. The renewable fresh water resources /flows is on decline especially in countries with large annual variability in rainfall, such as experiencing frequent droughts, making per capita renewable withdrawals to fall. Similarly, if total renewable sources remain constant, per capita levels can fall if a country's population is growing. The results of the renewables fresh water resources in the two countries (Kenya and Uganda) are presented in section (4).

Findings and Main Results

Climate change impacts/ rising temperatures on labour productivity

The heat stress due to rising temperatures is increasingly becoming one of the main factors in labour efficiency and productivity globally. Increasingly, heat waves are the cause of injuries and merging pests/diseases as well as a decline in work ability and productivity. Heat stress and rising mean temperatures affect different occupations differently. For examples, occupations that require a lot of physical activity and/or prolonged time spent outdoors are particularly affected. In terms of labour loss productivity, farmers and construction workers are expected to be particularly affected by climate change and thus more vulnerable to climate change impacts due to rising temperatures. According to UNDP, rising temperatures in place of work will negatively affect the attainment of 2030 Sustainable Development Agenda (SDGs) in 9 areas; ultimately affecting food security outcome (UNDP, 2016). More elaboration on this is provided in Table 3.

Table 3: Impacts of heat stress on work to 2030 Sustainable Development Agenda

Goal	Focus	Impacts of rising heat in the workplace
1.	1 NO POVERTY	The lowest-income groups, in particular agricultural workers, small-scale and Subsistence farmers, and casual workers in urban areas in tropical and subtropical developing countries are worst affected. Social protection systems in these countries tend to provide only limited coverage.
2.	2 ZERO HUNGER	A reduction in the available working hours, and by implication also in outputs, among small-scale and subsistence farmers is likely to affect household food security.
3.	3 GOOD HEALTH AND WELL-BEING	Large-scale exposure to heat injury and health risks such as heatstroke, exhaustion and even death will thwart efforts to improve health, particularly in countries without universal health-care coverage. Migrants may be especially vulnerable to health risks if they do not have access to health care and occupational safety and health services

		in their destination country.
4.	4 QUALITY EDUCATION	Heat-exposed students and teachers are less likely to receive and provide quality education and learning.
5.	5 GENDER EQUALITY	Many heat-exposed occupational functions involve women and men differently, especially in developing countries. Pregnancy adds to the risks of heat exposure.
8.	8 DECENT WORK AND ECONOMIC GROWTH	New heat extremes affect working conditions, productivity and economic growth. They make it more difficult to comply with international standards and guidelines on the occupational safety and health of workers. The economic consequences are considerable
10.	10 REDUCED INEQUALITIES	High-income temperate regions are affected by heat stress to a far lesser extent than tropical and subtropical developing regions, which counteracts efforts to reduce inequalities.
11.	11 SUSTAINABLE CITIES AND COMMUNITIES	Heat extremes pose a challenge to the built environment (houses and workplaces) and its sustainability. Significantly, heatwaves are more intense in urban areas.
13.	13 CLIMATE ACTION	The impact of climate change on labour is a major challenge to climate resilience that has yet to be effectively recognized or addressed through international and national measures. Source: UNDP, 2016

Besides serious health problems associated with rising temperature, the impact of heat waves on the population is reflected on labour loss productivity among the population of working age (Božanić and Mitrović, 2019). The International Labour Organization (ILO) estimates that by 2030[7], more than 2% of total working hours will be lost globally, due to excessive temperatures which will make it impossible to work or will slow down labour considerably (Božanić and Mitrović, 2019). Table 4, show the degree to which heat stress will cause lost working hours by sector and economy in the Eastern African countries, where Kenya and Uganda lie geographically. According to ILO, the key assumption in this estimation is that agricultural and construction works will take place under the shade and the global mean temperature will increase by 1.5°C by the end of century (2100)[8].

ILO estimates the impact of heat stress on labour productivity by combining climate models and global temperature projections with labour force projections and occupational health data. By GDP atlas methods, Uganda falls in low-income category and Kenya (lower middle) country. The World Bank assigns the world's economies to four income groups—low, lower-middle, upper-middle, and high-income countries. A low-income country is assigned for Gross National Income (GNI) per capita in current USD, Atlas method (US$ < 1,045); Lower-middle income (US$ 1,046

[7] Source: The ILO estimates based on data from the ILOSTAT database and the HadGEM2 and GFDL-ESM2M climate models.

[8] https://blogs.worldbank.org/opendata/new-world-bank-country-classifications-income-level-2021-2022

– 4,095); Upper-middle income (US$ 4,096 - 12,695); and High income (US$ > 12,695)[5].

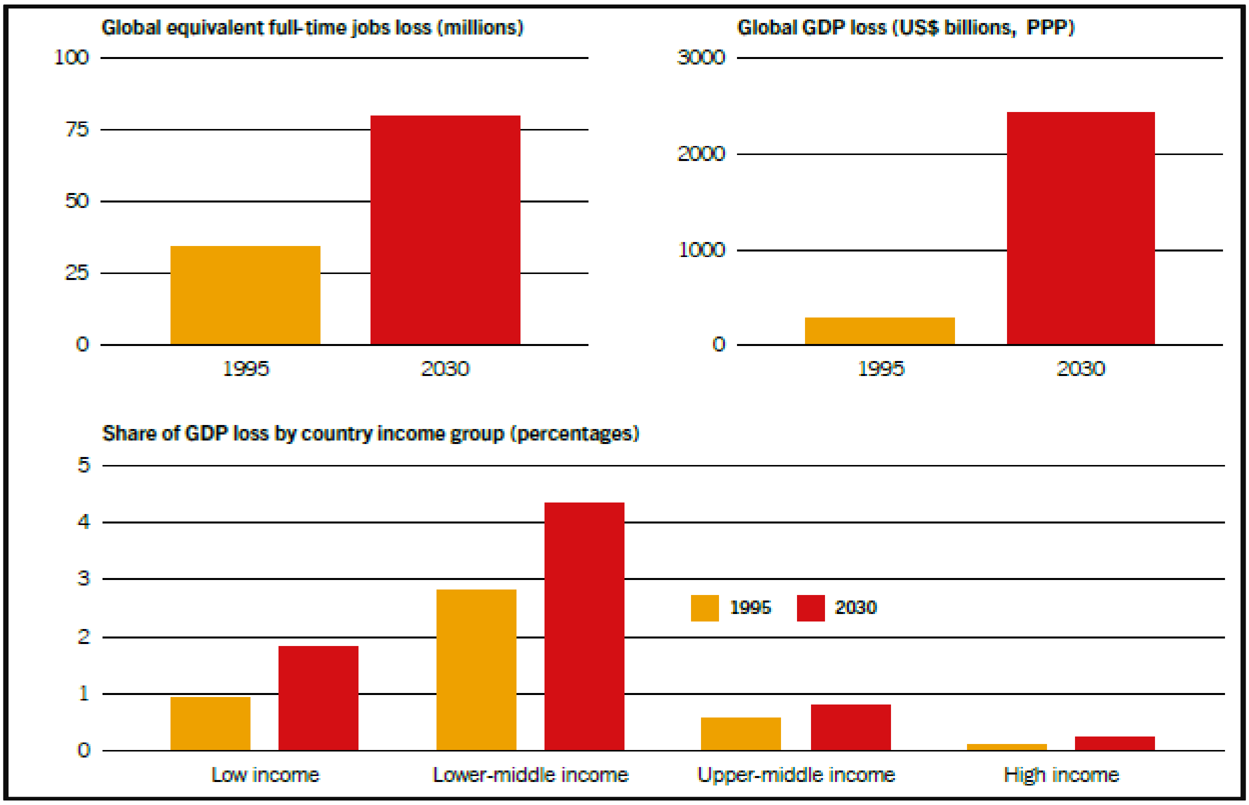


Figure 5: Equivalent full-time jobs and GDP lost to heat stress, global and by country income group, 1995 and projections for 2030
Source: ILO, 2019:p276[9]

Globally, an estimated 1.4% of the working hours got lost in 1995 due to heat stress, approximating to about 35 million full time jobs (ILO, 2019). This approximates to GDP loss of US$ 280 billion, purchasing power parity (PPP). When estimated through combining a global temperature rise of 1.5°C by the close of 21st century i.e. year, 2100; together with trends in labour force, it's predicted that by 2030, the global temperature would have risen by 1.3°C, and the share of working hours lost will rise to 2.2%; which approximates to a productivity loss of about 80 million full-time jobs. When valued in monetary terms, a total loss of US$ 2,400 billion (PPP) is expected by 2030, globally, where 2.2% of the working hours are lost due to heat stress.

The results are even more striking for the lower-middle income countries e.g. Kenya and the lower-income countries e.g. Uganda where the effects are predicted to be affected most, in which case losing an estimated 4% and 1.5% of their GDP by 2030, respectively as a result of high heat levels. The results are in agreement with other studies which reported an estimated losses of about US$ 311 billion (PPP) in 2010 and US$ 2,400 billion (PPP) in 2030 (DARA and Climate Vulnerable Forum, 2012). The GDP loss is expected to increase by up to 9% for a representative low-income country by 2100 (IMF, 2017).

9ILO estimates based on data from the ILOSTAT database and from the HadGEM2 and GFDL-ESM2M climate models (using as input the RCP2.6 climate change pathway, which envisages a global average temperature rise of 1.5°C by the end of the century).

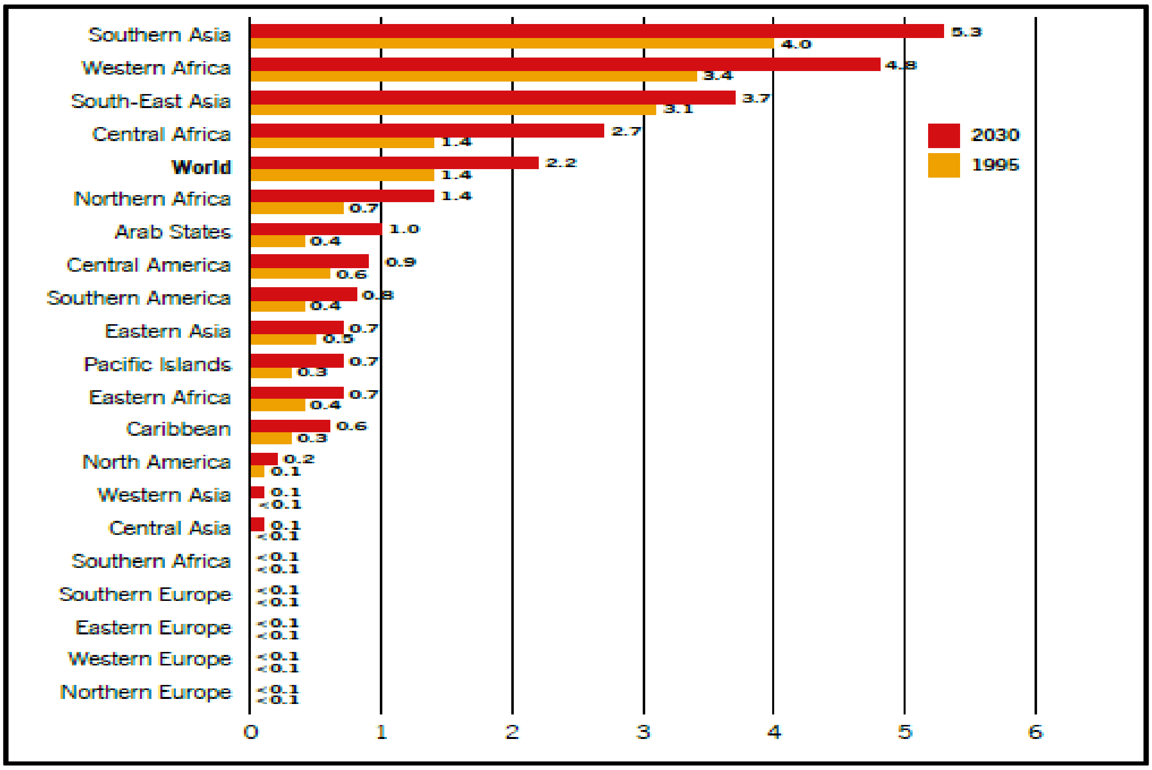


Figure 6: Working hours lost to heat stress (1.5°C temperature rise) by sub-region (%)
Source: ILO, 2019:p27

Heat stress (1.5°C rise) and its effects on labour productivity by sector

According to the ILO report, agriculture and construction sector will be affected most due to heat stress. Take for instance, agricultural sector accounted for 83% and 60% of the total working hours lost to heat stress during 1995 and 2030 respectively, globally. This is linked to most of the activities in the sector taken majorly outdoors; and by nature that it employed the greatest portion of the labour force especially in developing countries, where the effects of climate change inform of heat stress/droughts are expected to affect most in future.

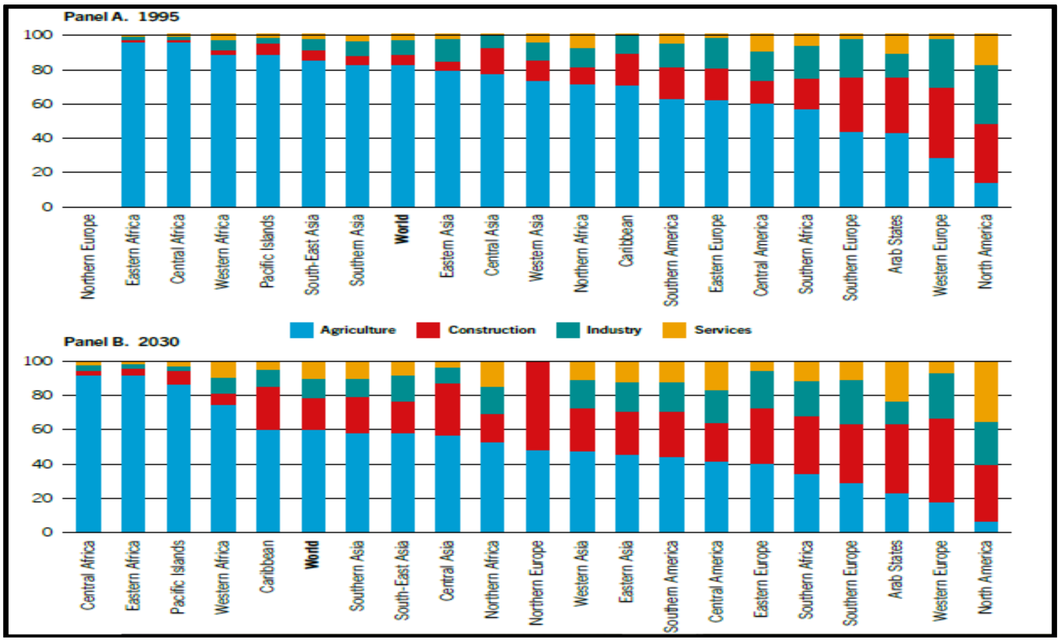


Figure 7: Working hours lost to heat stress (1.5°C temperature rise) by sector (%)
Source: ILO, 2019:p27

Where greater temperature increases are recorded under current "business-as-usual" scenario, some marginal areas would be rendered unproductive completely causing massive human mobility and displacement of workers engaged in agriculture, due to heat stress (ILO, 2019). In construction sector, heat wave accounted for 6% of total working time losses in 1995; and expected to reach 19% by 2030 with difference across sub-regional levels. However, working hours loss to heat stress will affect North America, Western Europe, Northern and Southern Europe and the Arab World where construction sector is dominant than in Sub-Saharan Africa.

Working hours lost to heat stress (1.5°C rise) in Africa and IGAD Sub-region

Many countries in Africa already experience heat-related issues, which are having a negative impact on individuals, the economy, social conditions and the environment. In Eastern Africa, the effects on heat stress on labour productivity will relatively be less compared to other African countries, partly explained by higher attitudes of Kenya and Ethiopia. However, countries like Somalia, Djibouti, Eritrea and Mozambique suffer more in loss productivity to heat stress. For example, in 1995 these countries recorded above 1% of loss working hours due to heat stress (ILO, 2019).

Somalia will suffer most in terms of loss labour productivity due to rising temperatures. For instance, the ILO estimates that the country lost about 2.8% of total working hours in 1995 alone due to heat stress, but this is expected to reach 5.6% in 2030 (ILO, 2019). Despite these working hours lost seems small in percent point, their ultimate effects on poverty reduction, food security and attaining 2030 Sustainable Development Agenda should not be ignored in real term.

The East African region is the host to most population compared to other African region, heat stress is estimated to cause productivity loss to more than 1.6 million full time jobs by 2030 due to rising temperatures. This will affect agricultural sector and construction sector most. However, workers in informal sectors in urban centers will also feel the effects of rising temperatures significantly. More elaboration on working hours lost by sector and country in the sub-region are provided in Table 4.

Table 4: Working hours lost to heat stress (1.5°C rise) by sector, Eastern Africa (%)

Country	1995						2030					
	Agriculture (in shade) (%)	Industry (%)	Construction (in shade) (%)	Services (%)	Total (%)	Total (thousand full-time jobs)	Agriculture (in shade) (%)	Industry (%)	Construction (in shade) (%)	Services (%)	Total (%)	Total (thousand full-time jobs)
Burundi	0	0	0	0	0	0	0.01	0	0.01	0	0.01	1
Comoros	0.02	0	0.02	0	0.01	0	0.32	0	0.32	0	0.20	1
Djibouti	3.17	1.17	3.17	0.11	1.17	2	6.48	3.00	6.48	0.49	2.55	10
Eritrea	1.63	0.72	1.63	0.13	1.06	15	3.24	1.67	3.24	0.40	2.08	95
Ethiopia	0.19	0.07	0.19	0.01	0.11	24	0.44	0.18	0.44	0.03	0.33	190
Kenya	0.38	0.11	0.38	0.01	0.27	27	0.85	0.31	0.85	0.03	0.53	147
Madagascar	0.34	0.07	0.34	0	0.27	17	0.74	0.20	0.74	0.01	0.57	108
Malawi	0.26	0.07	0.26	0.01	0.19	8	0.51	0.15	0.51	0.01	0.36	47
Mauritius	0	0	0	0	0	0	0.09	0	0.09	0	0.01	0
Mozambique	1.32	0.42	1.32	0.04	1.08	63	2.52	0.95	2.52	0.11	1.99	272
Rwanda	0	0	0	0	0	0	0	0	0	0	0	0
Somalia	3.62	1.36	3.62	0.14	2.76	57	7.42	3.38	7.42	0.54	5.59	172
South Sudan	0	0	0	0	0	0	0	0	0	0	0	0
Tanzania, United Rep. of	0.64	0.19	0.64	0.01	0.52	73	1.12	0.36	1.12	0.02	0.76	303
Uganda	0.33	0.08	0.33	0	0.24	20	1.01	0.31	1.01	0.03	0.75	212
Zambia	0.11	0.02	0.11	0	0.08	3	0.30	0.06	0.30	0	0.17	18
Zimbabwe	0.17	0.05	0.17	0	0.11	5	0.38	0.12	0.38	0.01	0.28	26
Eastern Africa	0.50	0.11	0.50	0.01	0.35	313	0.91	0.32	0.91	0.04	0.65	1602

Source: ILO, 2019:p37

For Kenya, the analyses showed that the country lost an equivalent of 27,000 jobs in full-time or 0.27% of working hours lost in 1995 due to heat stress, and expected to reach an equivalent of 147,000 full time job loss i.e. (0.53% of working hours losses) by 2030 (Table 5).

Table 5: Working hours lost due to heat stress (1.5^{o}C rise) by sector, Kenya

Sector	**1995**	**2030**
Agriculture (in shade) (%)	0.38	0.85
Industry (%)	0.11	0.31
Construction (in shade) (%)	0.38	0.85
Services (%)	0.01	0.03
Total (%)	0.27	0.53
Total (jobs loss equivalent)	27,000	147,000

Source: ILO, 2019 with modifications from Author, 2023

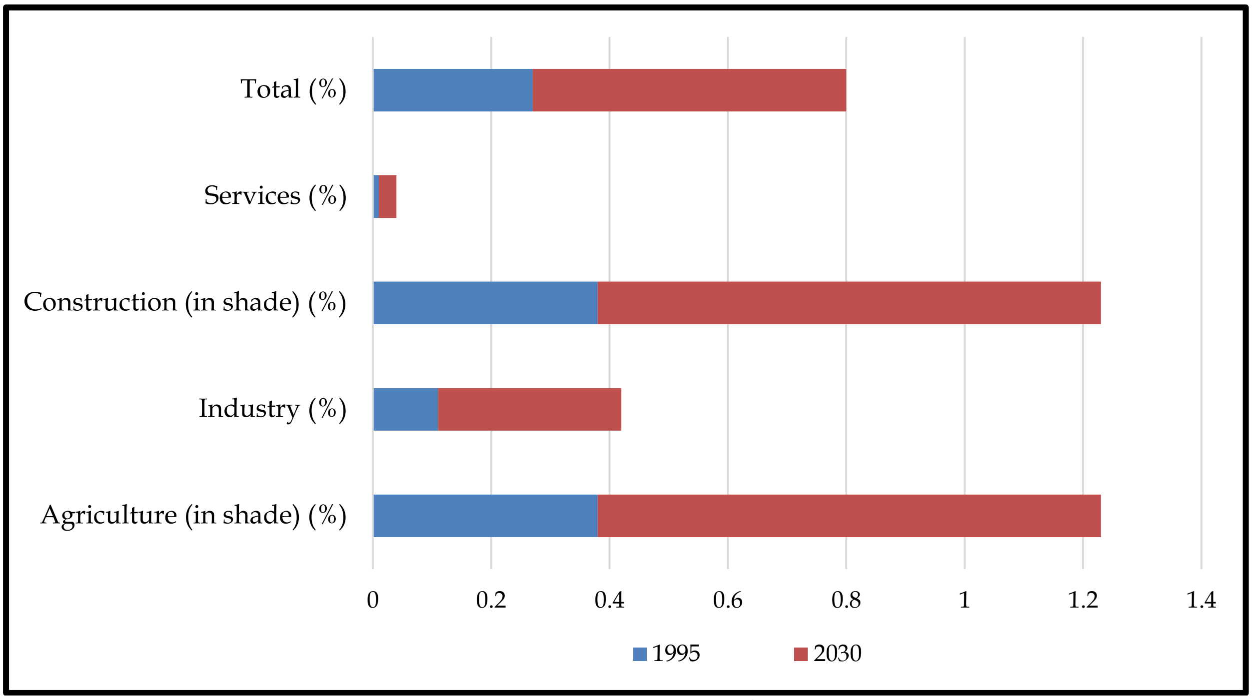


Figure 8: Working hours lost to heat stress (1.5^{o}C rise) by sector, Kenya (%)
Source: ILO Dataset, 2019

Similarly in Uganda, the country lost an equivalent of 20,000 full time jobs (0.24% of working hours lost) in 1995; and this is expected to reach an equivalent of 212,000 full time jobs loss i.e. 0.75% of working hours loss by 2030, due to heat stress (Table 6,).

Table 6: Working hours lost due to heat stress (1.5^{o}C rise) by sector, Uganda

Sector	**1995**	**2030**
Agriculture (in shade) (%)	0.33	1.01

Industry (%)	0.08	0.31
Construction (in shade) (%)	0.33	1.01
Services (%)	0	0.03
Total (%)	0.24	0.75
Total (jobs loss equivalent)	20,000	212,000

Source: ILO, 2019 with modifications from Author, 2023

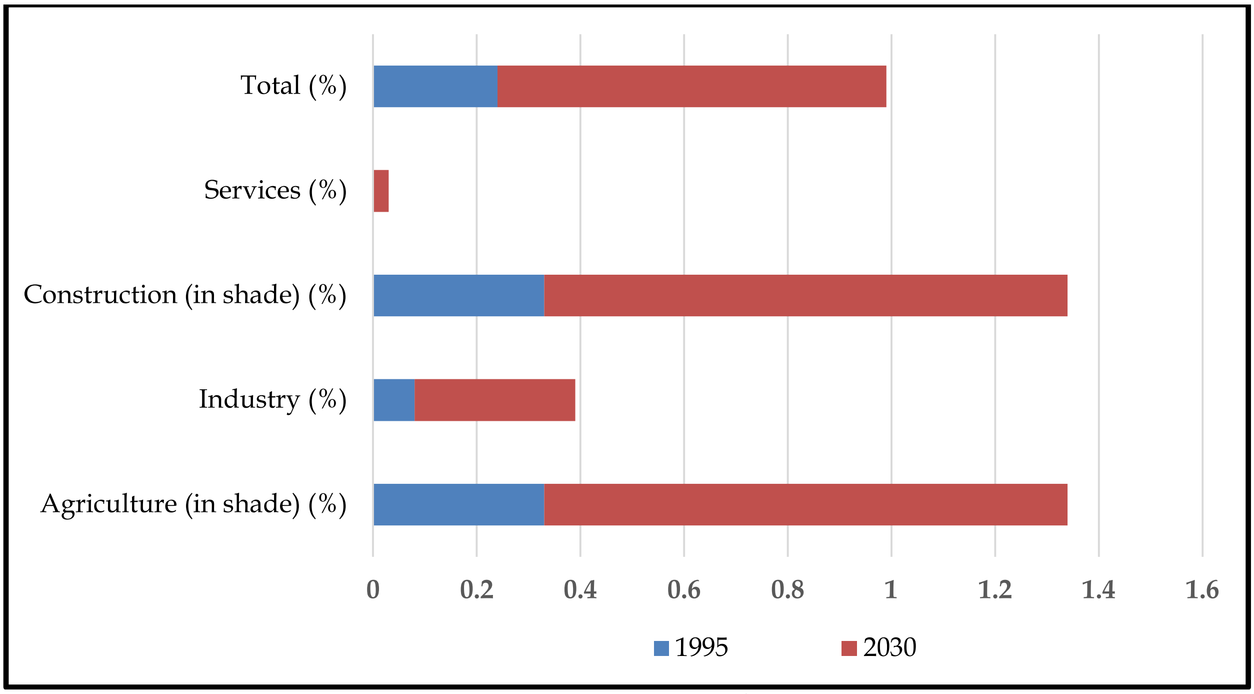


Figure 9: Working hours lost to heat stress (1.5°C rise) by sector, Uganda (%)
Source: ILO Data, 2019

Effects of climate change on food production under different SRES emissions / (RCP and socio-economic scenarios)

The data set used in this analyzes originated from Ana Iglesias of Universidad Politecnica de Madrid and Cynthia Rosenzweig of the NASA Goddard Institute for Space Studies being disseminated by the NASA Socioeconomic Data and Applications Center (SEDAC), and managed by CIESIN at Columbia University.[10]

Brief description of the data

As earlier discussed, this decades and coming ones, the agricultural sector is expected to face many challenges stemming from growing global populations, land degradation, and loss of cropland to urbanization. Although food production has been able to keep pace with population growth on the global scale, periodically there are serious regional deficits, and poverty related nutritional deficiencies affect close to a billion people globally. In this century climate change is one factor that could affect food production and availability in many parts of the world, particularly those most prone to drought and famine.

The purpose of this data set is to provide an assessment of potential climate change impacts on world staple crop production (wheat, rice, and maize) with a focus on quantitative estimates of yield changes based on multiple climate scenario runs. The data set assesses the implications of temperature and precipitation changes for world crop yields taking into account uncertainty in the level of climate change expected and physiological effects of carbon dioxide on plant

http://sedac.ciesin.columbia.edu/mva/cropclimate/

growth. Adaptation is explicitly considered and incorporated into the results by assessing the country or regional potential for reaching optimal crop yield. Optimal yield is the potential yield non-limited by water, fertilizer, and without management constraints. Adapted yields are evaluated in each country as a fraction of the potential yield. The weighting factor combines the ratio of current yields to current yield potential and the economic limitation of the economic country's agricultural systems.

The baseline year for crop yield changes is the average yield simulated under current climate (1970-2000 baseline). The resulting yield change data were then fed into trade models to assess impacts on prices and overall food production. (Please note that total production changes need to be treated with caution, since production is determined by many factors.) The overall objective is to calculate quantitative estimates of climate change impacts on the amount of food produced globally and country level, and to determine the consequences to world food prices and the number of people at risk of hunger.

Table 7: Climate Change Impacts on wheat yield change, SRES A1FI (RCP8.5 or lies between SSP3 and SSP5) scenario (tons)

		SRES-A1FI (RCP8.5 or lies between SSP3 and SSP5) Scenario		
Country	2020	A1F-2020	A1F-2050	A1F-2080
Djibouti		0.00	0.00	0.00
Eritrea	7,386.71	10.43	-146.52	-1,072.58
Ethiopia	1,879,935.86	2,655.36	-37,290.34	-272,973.61
Kenya	321,924.86	4,510.93	-13,110.35	-56,044.01
Somalia	987.14	1.39	-19.58	-143.34
Sudan	369,714.29	522.21	-7333.64	-53,683.88
Uganda	14,714.29	20.78	-291.87	-2,136.57

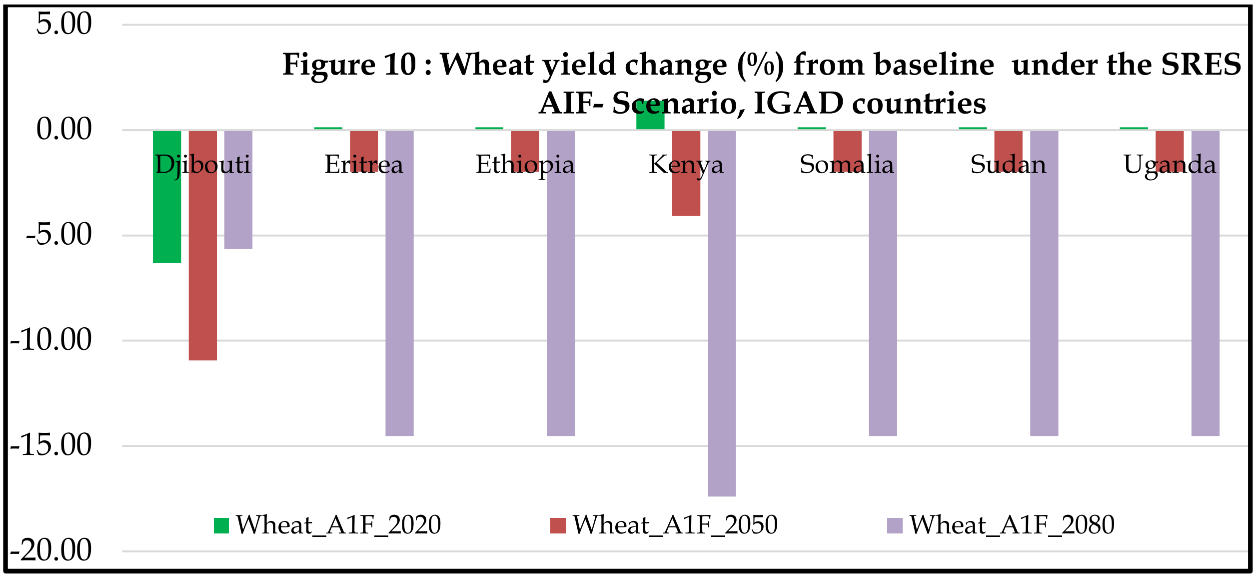
Source: [1] http://sedac.ciesin.columbia.edu/mva/cropclimate/

The estimation was based on wheat total production changes in years 2020s, 2050s, and 2080s through applying the SRES A1FI (RCP8.5 and lies between SSP3 and SSP5) scenario yield change to the 1990 production. The wheat production average 2000 to 2006 in tons was based on FAO data. In general, the overall the prediction points towards negative yield change in the future years due to climate change impacts. The details on yield changes (%) volume are provided in Figure 6, 7, & 8.

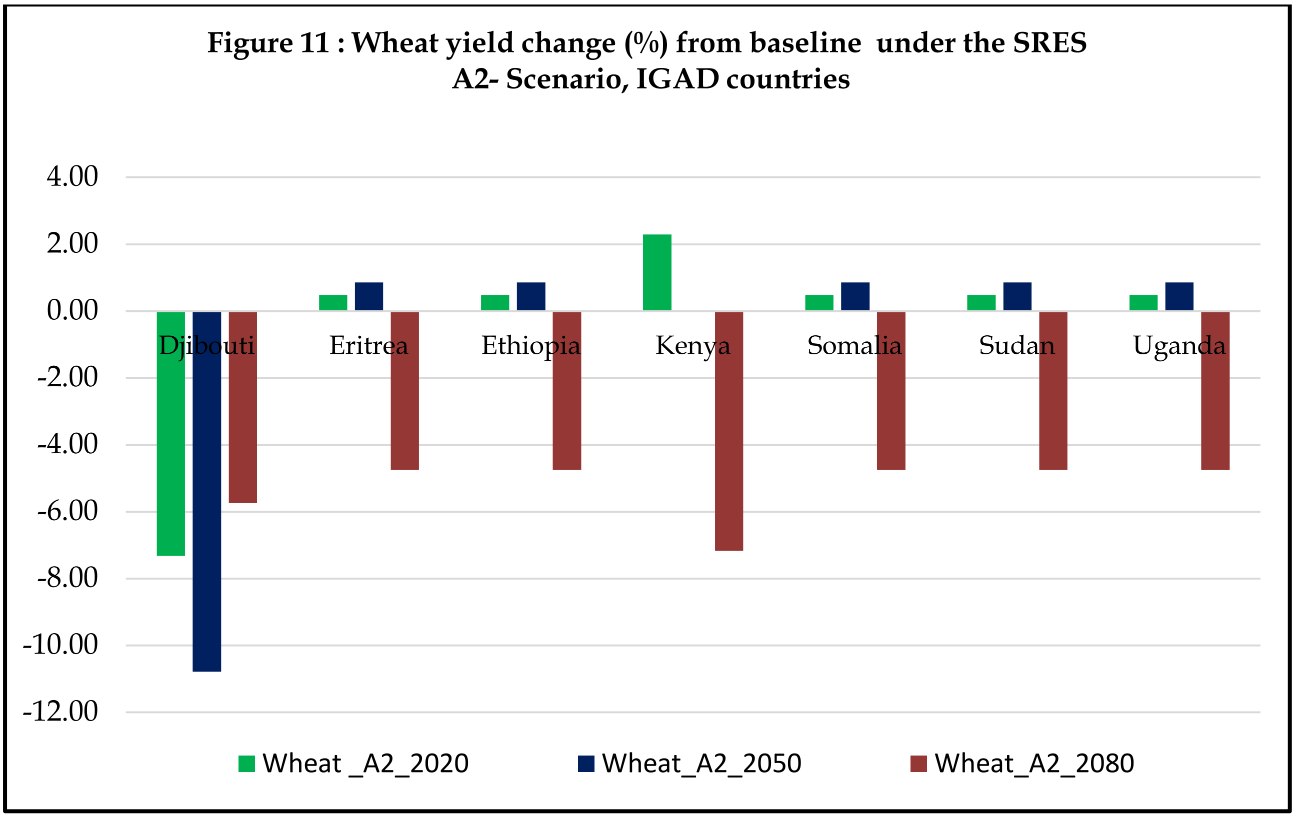
Table 8: Climate Change Impacts on wheat yield change, SRES A2 scenarios (tons)

	SRES-A2 (lies between SSP2 and SSP3 Scenario)		
Country	2020	2050	2080
Djibouti	0.00	0.00	0.00
Eritrea	35.91	63.09	-350.74
Ethiopia	9,138.09	16,056.48	-89,262.95
Kenya	7,366.28	-21.54	-23,075.65
Somalia	4.80	8.43	-46.87
Sudan	1,797.13	3,157.72	-17,554.74
Uganda	71.52	125.67	-698.66

Source: [1] http://sedac.ciesin.columbia.edu/mva/cropclimate/



[Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/](http://sedac.ciesin.columbia.edu/mva/cropclimate/) with author's calculations.



[Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/](http://sedac.ciesin.columbia.edu/mva/cropclimate/) with author's calculations.

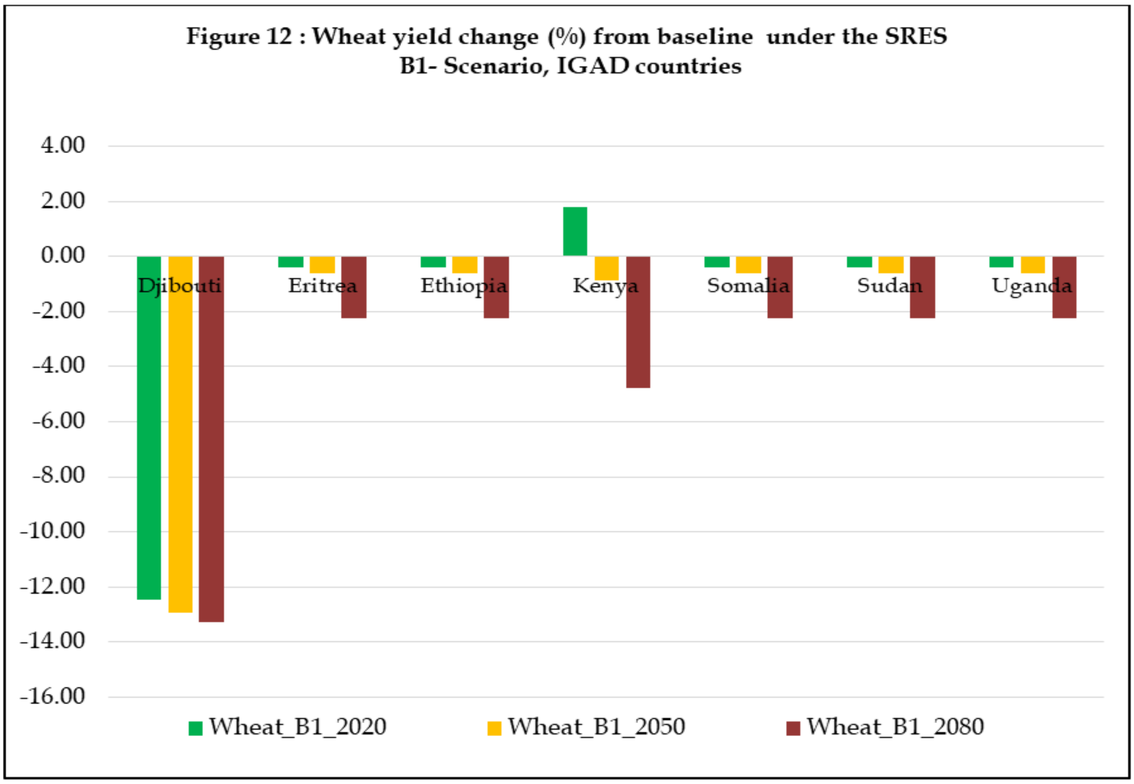
Table 9: Climate Change Impacts on wheat yield change, SRES B scenarios (tons)

	SRES-B Scenario					
Country	B1-2020	B1-2050	B1-2080	B2-2020	B2-2050	B2-2080
Djibouti	0.00	0.00	0.00	0.00	0.00	0.00
Eritrea	-29.56	-44.47	-166.20	-76.90	-153.85	-402.94
Ethiopia	-7,521.94	-11,317.80	-42,297.07	-19,570.19	-39,154.69	-102,548.81
Kenya	5,735.90	-2,798.48	-15,362.54	2,691.80	-7,700.06	-17,920.39
Somalia	-3.95	-5.94	-22.21	-10.28	-20.56	-53.85
Sudan	-1,479.29	-2,225.80	-8,318.28	-3,848.74	-7,700.29	-20,167.58

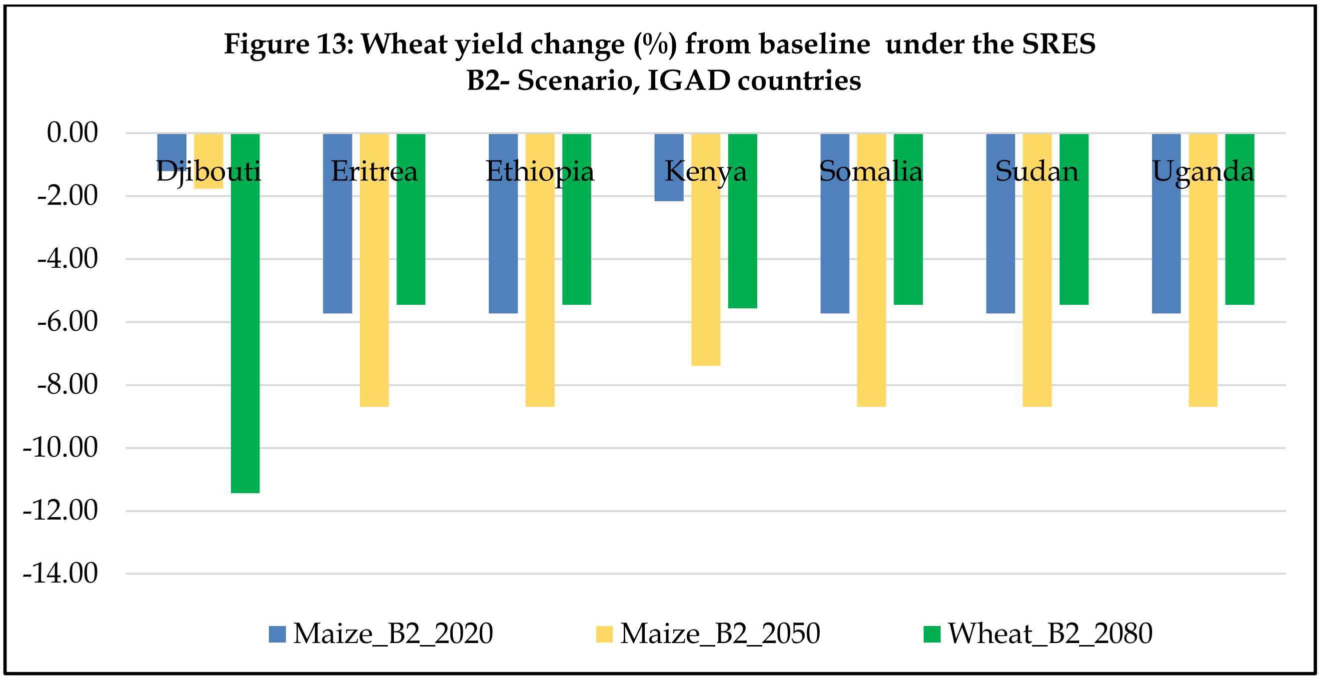
Uganda	-58.87	-88.58	-331.06	-153.18	-306.46	-802.65

Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/ with author's calculations

In a long run, across the SRES B models, the region will experience general major decline in wheat yields due to climate change impacts with Ethiopia affected most, followed by Sudan, then Kenya, Uganda, Eritrea and Somalia. For details of country specific performance in terms of percent point reduction under SRES B-models predicted for what yields reduction due to climate change impacts, please make reference to Figure 8 and 9.



Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/ with author's calculations.



Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/ with author's calculations.

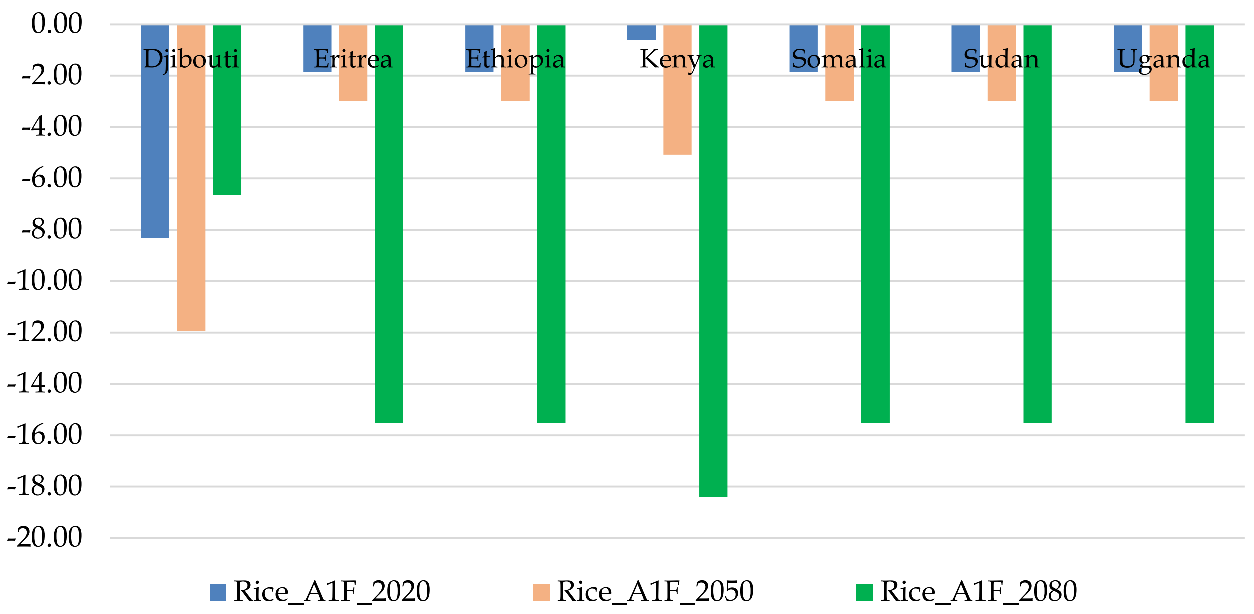
Table 10: Climate Change Impacts on rice yield change, SRES A scenarios (tons)

Country	2000	SRES A-Scenarios					
		A1FI-Scenario			A2 (between SSP2 and SSP3)-Scenario		
		A1FI-2020	AIF-2050	AIF-2080	A2_2020	A2_2050	A2_2080
Djibouti		0.00	0.00	0.00	0.00	0.00	0.00
Eritrea		0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	13,665.14	-254.00	-407.71	-2120.88	-206.88	-156.59	-785.50
Kenya	51,380.43	-307.65	-2606.27	-9458.64	148.08	-1031.05	-4196.77
Somalia	12,000.00	-223.05	-358.03	-1862.44	-181.67	-137.51	-689.78
Sudan	19,106.86	-355.15	-570.07	-2965.45	-289.26	-218.95	-1098.30
Uganda	129,000.00	-2397.79	-3848.84	-20021.27	-1952.95	-1478.21	-7415.17

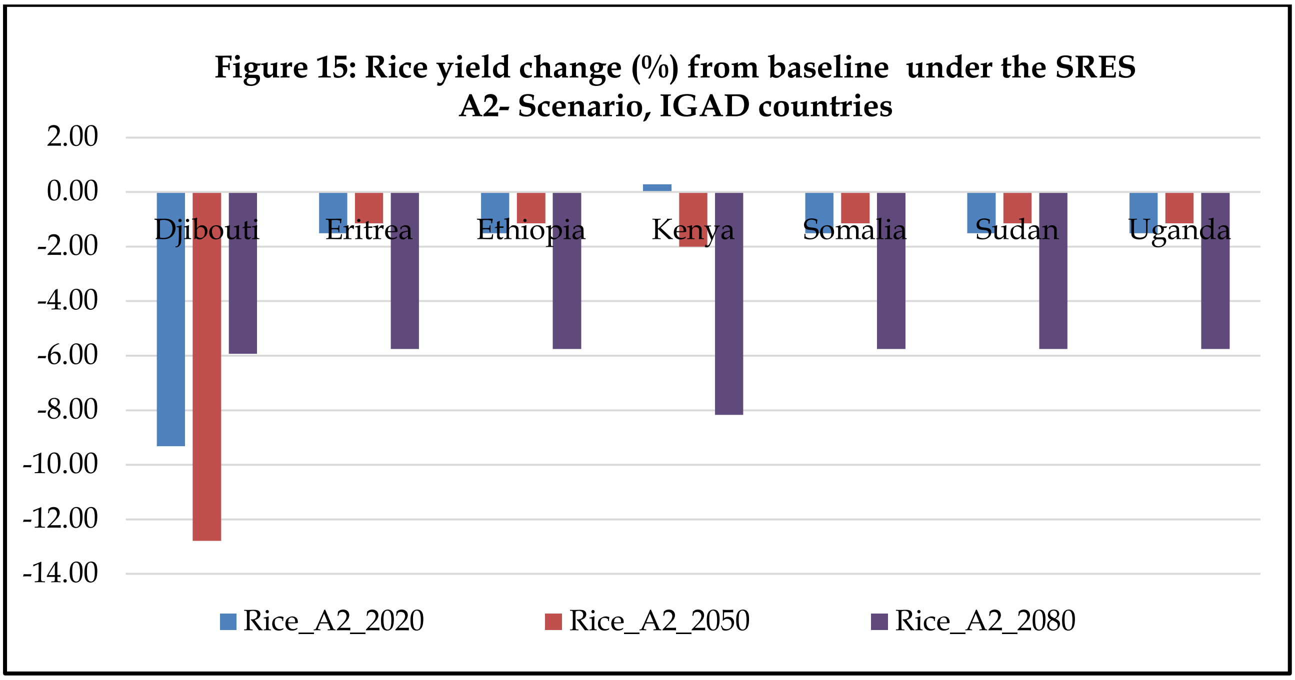
Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/ with author's calculations.

Across, the SRES A, models, the region will experience major decline in rice yields due to climate change impacts with Uganda recording the greatest reduction. For details of country specific performance in terms of percent point reduction under SRES A-models on rice yields due to climate change impacts, please make reference to Figure 10 and 11

Figure 14: Rice yield change (%) from baseline under the SRES A1F- Scenario, IGAD countries



Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/ with author's calculations.



Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/ with author's calculations.

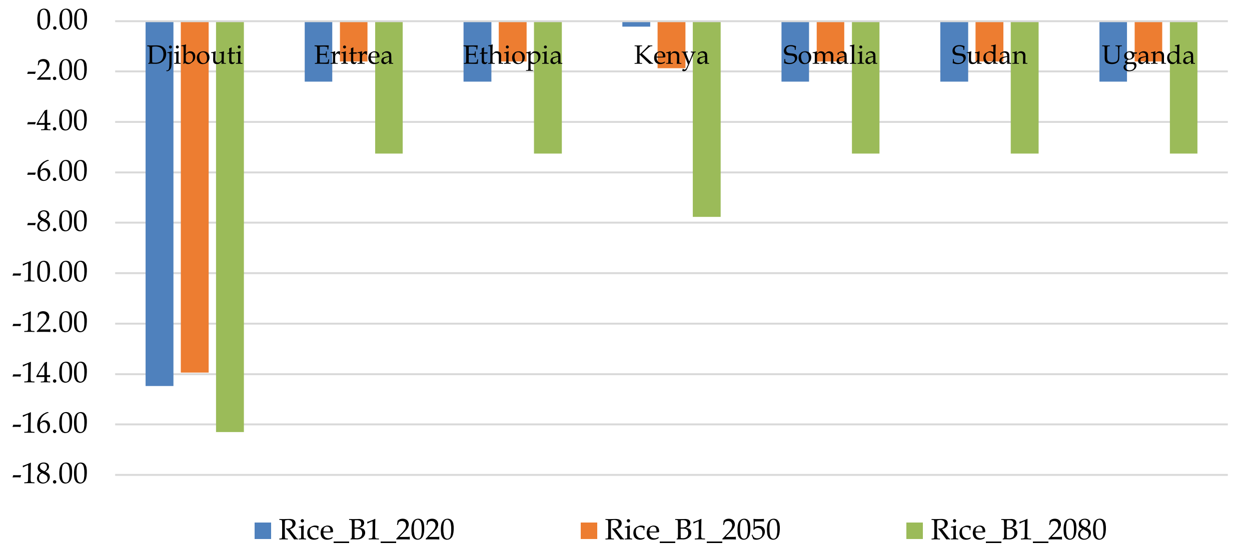
Table 11: Climate Change Impacts on rice yield change, SRES B scenarios (tons)

	SRES, B-Scenarios					
	SRES B1 (RCP4.5/SSP1)			SRES B2 (RCP6 or between SSP2 and SSP4)		
Country	B1_2020	B1_2050	B1_2080	B2_2020	B2_2050	B2_2080
Djibouti	0.00	0.00	0.00	0.00	0.00	0.00
Eritrea	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	-327.98	-218.92	-717.41	-415.56	-421.26	-882.07
Kenya	-112.14	-960.45	-3,993.33	-597.99	-1,742.76	-3,373.97
Somalia	-288.01	-192.24	-629.99	-364.92	-369.93	-774.59
Sudan	-458.59	-306.10	-1,003.09	-581.04	-589.02	-1,233.33
Uganda	-3,096.15	-2,066.62	-6,772.40	-3,922.89	-3,976.77	-8,326.83

Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/ with author's calculations.

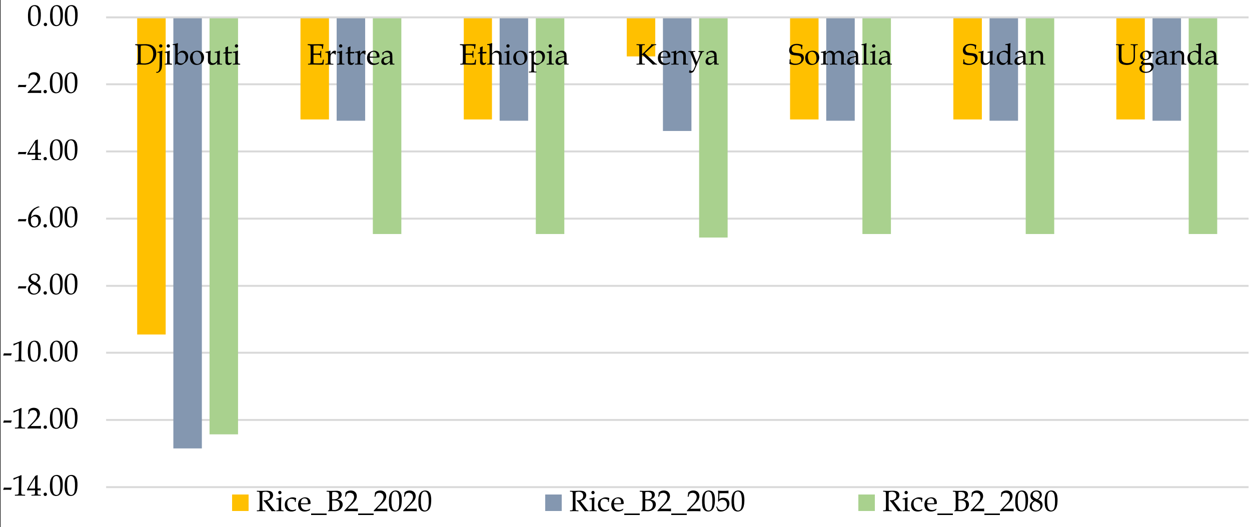
Across, the SRES B, models, the region will experience major decline in rice yields due to climate change impacts with Uganda recording the greatest reduction. For details of country specific performance in terms of percent point reduction, please make reference to Figure 12 and 13.

Figure 16: Rice yield change (%) from baseline under the SRES B1- Scenario, IGAD countries



Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/ with author's calculations.

Figure 17: Rice yield change (%) from baseline under the SRES B2- Scenario, IGAD countries



Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/ with author's calculations.

Table 12: Climate Change Impacts on maize yield change, SRES A-scenarios (tons)

		SRES, A-Scenarios					
		SRES, A1FI (RCP 8.5 or lies between SSP3 and SSP5)			SRES, A2 (between SSP2 and SSP3)		
Country	Maize_2000	A1F-2020	A1F-2050	A1F-2080	A2_2020	A2_2050	A2_2080
Djibouti	10.29	0.09	-0.24	-0.58	0.01	-0.09	-0.39
Eritrea	4,243.57	-177.46	-427.33	-880.60	-170.81	-330.42	-626.40

Ethiopia	3,199,788.29	-133,810.83	-322,223.16	-663,998.82	-128,793.53	-249,145.62	-472,324.41
Kenya	2,689,906.00	-43,005.21	-297839.54	-737,277.28	-19,146.76	-188,473.40	-488,702.74
Somalia	229,894.29	-9,613.87	-23,150.68	-47,706.14	-9,253.39	-17,900.30	-33,934.96
Sudan	52,714.29	-2,204.44	-5,308.40	-10,938.92	-2,121.78	-4,104.50	-7,781.22
Uganda	1,185,000.00	-49,555.10	-11,9331.16	-245,903.33	-47,697.01	-92,267.84	-174,919.21

Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/ with author's calculations.

Projections from SRES, A Scenarios indicates that major yield decline will be greatest in Kenya (-488,702.74) followed by Ethiopia (-472,324.41), then Uganda (-174,919.21), Somalia (-33,934.96), Sudan (-7,781.22), Eritrea (-626.40) and lastly Djibouti (-0.39) by year 2080 under SRES, A2 (lies between SSP2 and SSP3) scenario due to climate related stress. This trend is similar under SRES A1FI **(RCP8.5 or lies between SSP3 and SSP5)** scenario, with Kenya experiencing (-737,277.28), Ethiopia (-663,998.82); Uganda (-245,903.33); Somalia (--47,706.14); Sudan (-10,938.92); Eritrea (-880.60); and Djibouti (-0.58) tons lost to climate related stress.

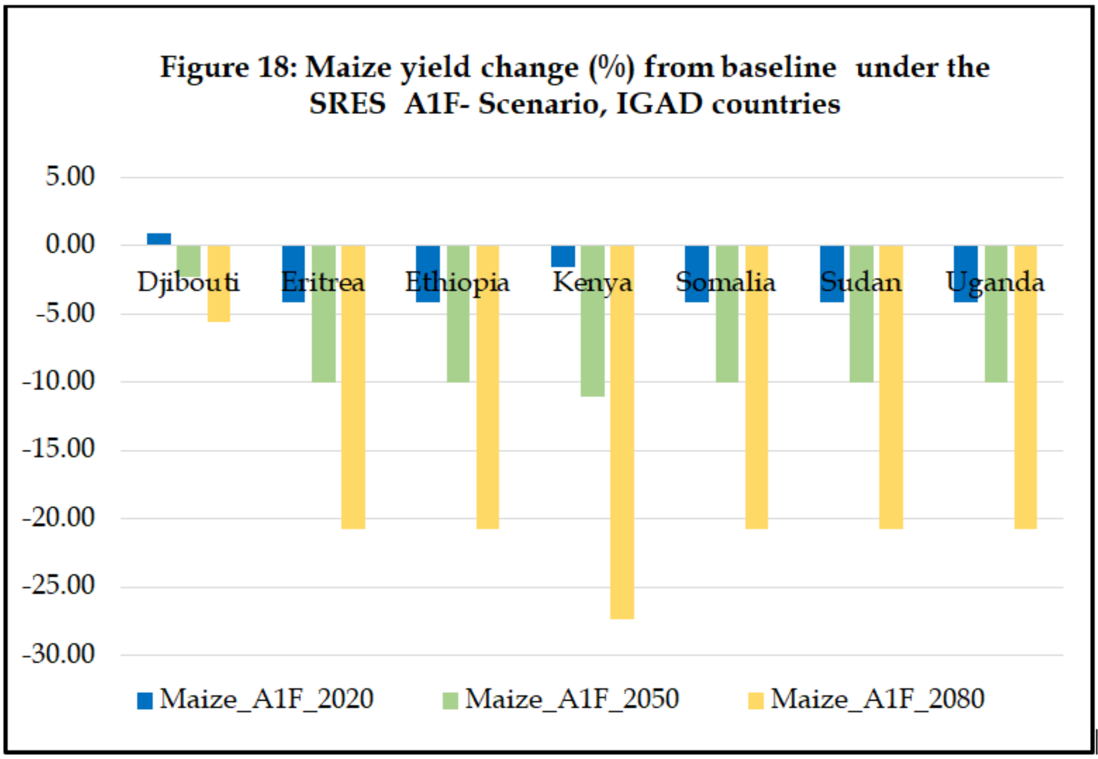
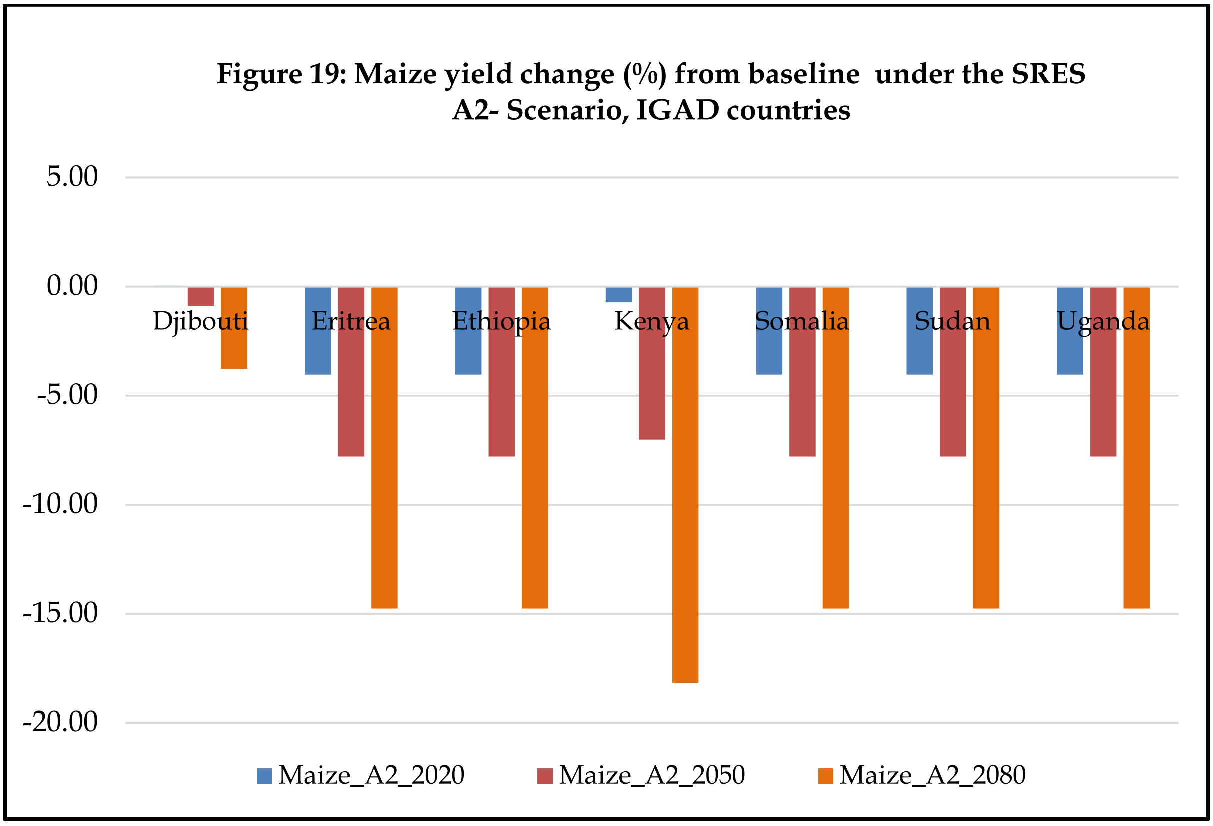


Figure 18: Maize yield change (%) from baseline under the SRES A1F- Scenario, IGAD countries

Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/ with author's calculations.



Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/ with author's calculations.

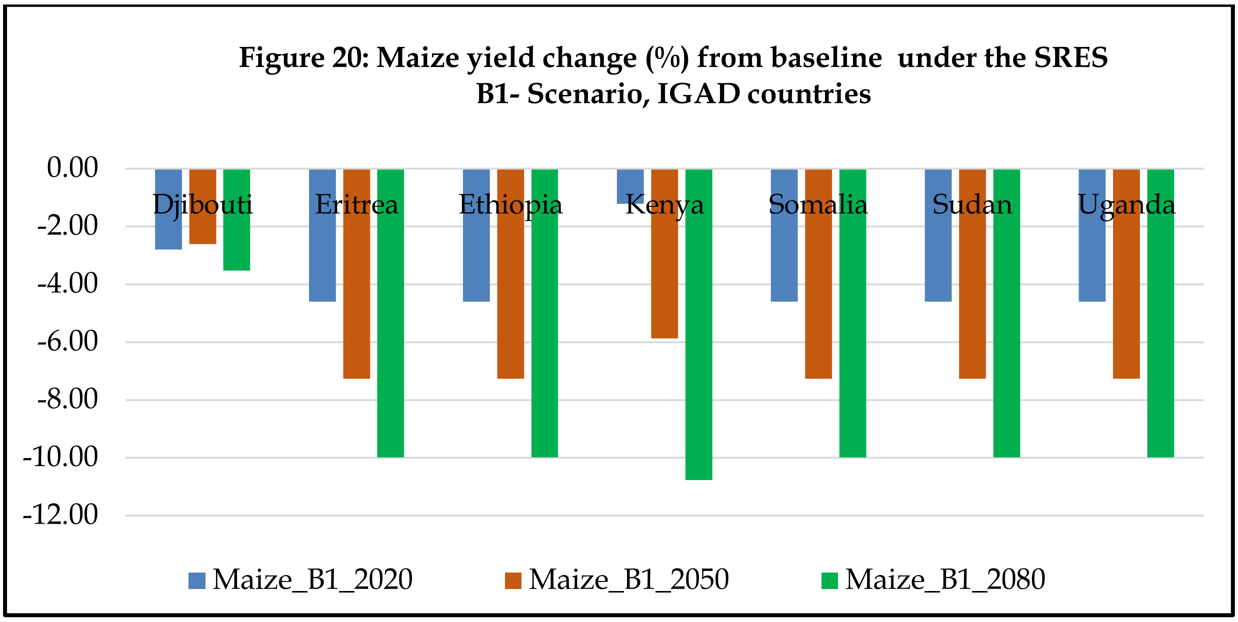
Note Sudan in this cases covers also South Sudan

Table 13: Climate Change Impacts on wheat yield change, SRES B-scenarios (tons)

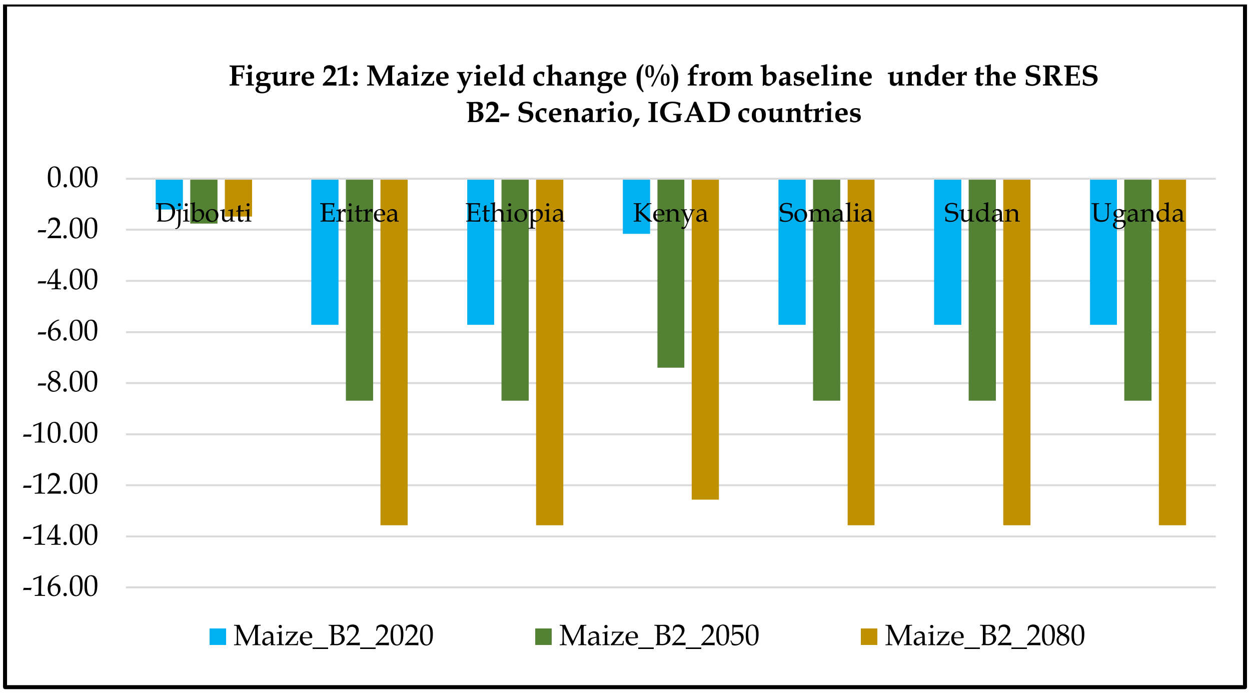
	SRES, B-Scenarios					
	SRES B1 (RCP 4.5 / SSP1)			SRES B2 (RCP6.0 and lies between SSP2 and SSP4)		
Country	B1_2020	B1_2050	B1_2080	B2_2020	B2_2050	B2_2080
Djibouti	-0.29	-0.27	-0.36	-0.12	-0.18	-0.15
Eritrea	-195.32	-308.17	-423.77	-242.79	-368.86	-575.89
Ethiopia	-147,278.56	-232,370.49	-319,539.07	-183,068.25	-278,132.69	-434,241.24
Kenya	-32,769.78	-157,878.52	-289,759.07	-58,205.30	-198,834.66	-338,030.72
Somalia	-10,581.48	-16,695.06	-22,957.83	-13,152.85	-19,982.92	-31,198.81
Sudan	-2,426.31	-3,828.14	-5,264.18	-3,015.92	-4,582.04	-7,153.82
Uganda	-54,542.70	-86,055.39	-118,337.14	-67,796.95	-103,002.83	-160,815.60

Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/ with author's calculations.

Under SRES, B1 (RCP4.5/ SSP1) scenario, by 2080s, the major yield losses to maize will be in Ethiopia (-319,539.07), Kenya (-289,759.07), Uganda (-118,337.14), Somalia (-22,957.83), Sudan (-5,264.18), Eritrea (-423.77), and Djibouti (-0.36). By SRES, B2 (RCP6.0 and lies between SSP2 and SSP4) scenario, the trend will remain the same with Ethiopia (-434,241.24), Kenya (-338,030.72), Uganda (-160,815.60), Somalia (-31,198.81), Sudan (-7,153.82), Eritrea (-575.89), and Djibouti (-0.15).



Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/ with author's calculations.



Source: http://sedac.ciesin.columbia.edu/mva/cropclimate/ with author's calculations.

Uganda in particular, under the scenarios considered overall losses for food crops by 2050 are not likely to be more than US$1.5 billion under the assumed growth in the economy this would be close to 0.2 percent of GDP in that year (MAAIF, 2015). The largest impacts in the East and North for all crops) in the country. For some crops the impacts on production of climate change in 2050 are quite significant in percentage terms (e.g. cassava, potato and sweet potato show around 40 percent reductions). Estimated impacts on livestock production range between 1-2 percent. In coffee sub-sector alone, the loss estimates could accrue to 50% for Arabica and Robusta coffee combined, which could be about US$1,235 million in 2050 (MAAIF, 2015).

Climate change impacts on water sector

Renewable freshwater resources per capita in IGAD region

Renewable internal freshwater resources flows refer to internal renewable resources (internal river flows and groundwater from rainfall) in the country. In order o maintain sustainable

levels of water resources, rates of water withdrawals must be below rates of freshwater replenishment. 'Renewable internal freshwater flows' refer to internal renewable resources (internal river flows and groundwater from rainfall) in the country.

Renewable internal flows are therefore an important indicator of water security or scarcity. If rates of freshwater withdrawal begin to exceed the renewable flows, resources begin to decline. The Figure 19, shows the level of renewable internal freshwater resources per capita across the region will continues to decline.

The per capita renewable resources depend on two factors: the total quantity of renewable flows, and the size of the population. If renewable resources decline — as can happen frequently in countries with large annual variability in rainfall, such as monsoon seasons — then per capita renewable withdrawals will also fall. Similarly, if total renewable sources remain constant, per capita levels can fall if a country's population is growing. As we see, per capita renewable resources are declining in many countries across the region explained by combine effects of population increases and large annual variations in rainfall patterns resulting to droughts.

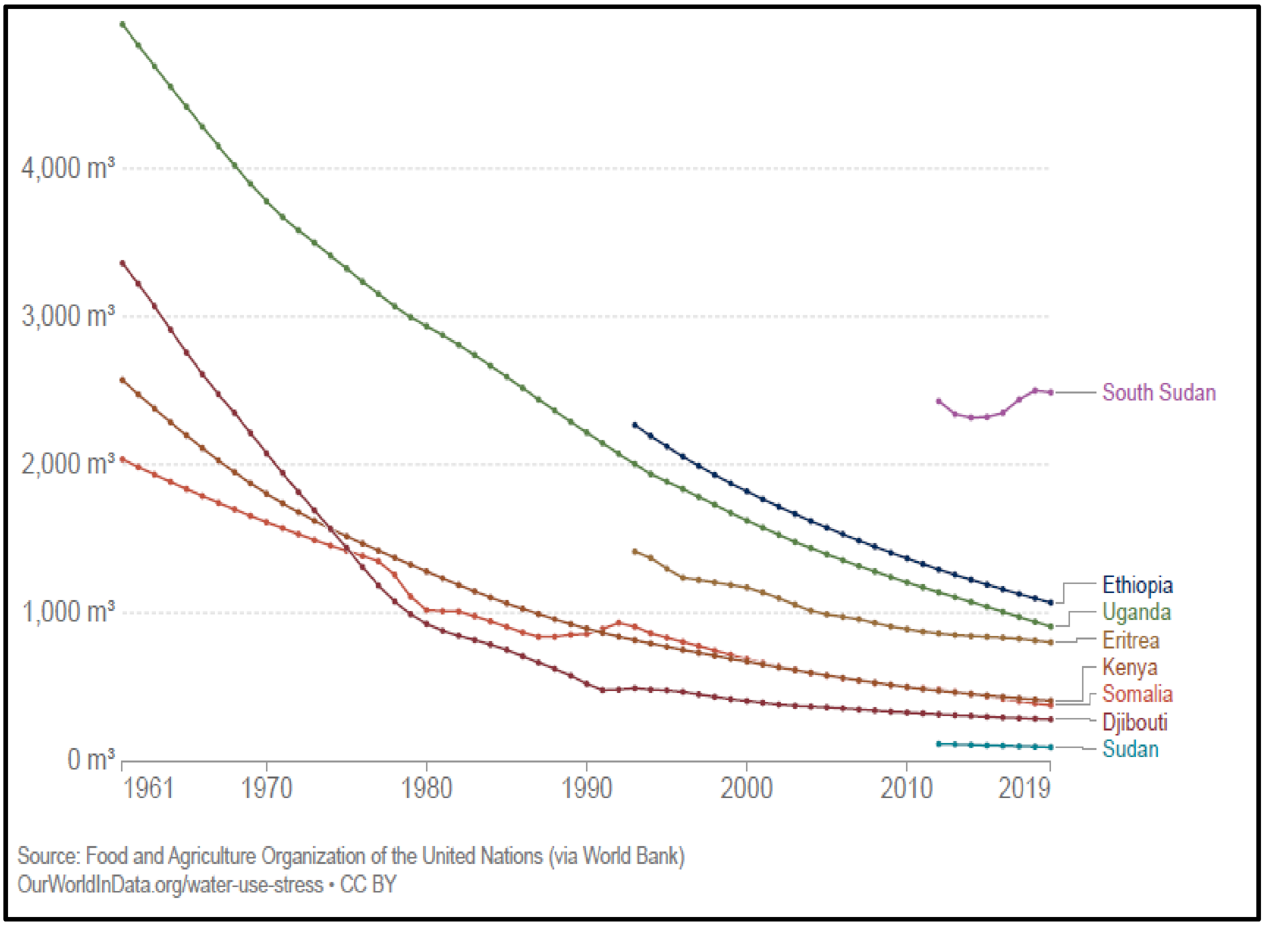


Figure 22: Renewable freshwater resources per capita, IGAD countries11

Recommendations and Conclusions

Recommendations

In view of the findings, the study identified the following regional and national needs and priorities and ways forward in reducing the impacts of climate change; and

A. Adaptation priority in water sector

1) Promote and participate in water resource regulation between users so as to ensure the availability of water for hydropower production;
2) Diversify energy sources by promoting the use of alternative renewable energy sources (such as solar, biomass, mini-hydro, geothermal and wind) that are less sensitive to climate change; and

[11]https://ourworldindata.org/water-use-stress

3) Promote and participate in water catchment protection as part of hydroelectric power infrastructure development, through soil conservation practices such as agroforestry
4) A need for strong political will and sufficient funding for employing Community Development Officers to enforce existing laws. Enabling factors also include better weather forecasting and early warning systems for water supply shortage
5) There is a clear need for effective integrated river basin management in the transboundary water sources e.g. Lake Victoria Basin, and Mpanga River Basin to ensure that costs are minimised and that effective adaptation strategies are implemented. Further work is needed to improve the data on river flows to ensure appropriate policy action is taken.

Actions to reduce biomass demand, for instance, will improve the quality of water in the river due to reduced soil erosion and measures to reduce energy consumption would reduce demand, and hence the losses due to climate change in the energy sector.

B. Adaptation for food security and agricultural sector in climate change context

Mobilizing social protection to increase resilience of livelihoods in the face of climate change. A major and urgent area for intervention is increasing the resilience (and thus reducing the vulnerability) of livelihoods, particularly among the poor who are highly dependent on natural resources and exposed to climate risks. Social protection programmes are essential in this effort, with proven effectiveness in breaking the vicious cycle of poverty and hunger. Social protection covers a wide array of instruments and objectives, encompassing both safety nets and "safety ropes", i.e., mechanisms that enhance income-generating abilities and opportunities for the poor and vulnerable. Adequate, well-designed social protection would tackle some of the main vulnerabilities of households to climate risks. Income provided to the poor and hungry through social protection can enable them to access sufficient food to meet their basic nourishment needs, without compromising the future productivity of their livelihoods. Such actions will be particularly efficient if targeted to the needs of women.

1) Build resilience of agricultural systems

i) Increasing the efficiency of scarce resource use in productive systems, particularly water, is an important aspect of building resilient livelihoods. Climate change is altering rainfall and water availability patterns, making capacity to deal with water scarcity (or overabundance) essential to maintaining productivity levels. Adaptation measures can include water harvesting and storage, access to irrigation, improved irrigation technologies, as well as agronomic practices that enhance soil water retention such as minimum tillage, and increase in soil carbon and organic matter, among others.

ii) Adaptation measures for crops can include the use of adapted varieties or breeds, with different environmental optima and/or broader environmental tolerances, including currently neglected crops, also considering that increased diversification of varieties or crops is a way to hedge against risk of individual crop failure. Adaptive changes in crop management – especially planting dates, cultivar choice and sometimes increased irrigation – have been studied to varying extents and are generally estimated to have the potential to increase yields by about 7–15 percent on average, though these results depend strongly on the region and crop being considered. Changes in post-harvest practices, for example the extent to which grain may require drying and how products are stored after harvest.

iii) A range of adaptation options is available for livestock production at different scales: animals, feeding/housing system, production system and institutions. They differ between small-scale livestock production with low market integration and large-scale production with high market integration. In particular, breeding livestock but also feed crops and forages is a major component of building resilience to climate change. Many livestock breeds are already well adapted to high temperatures and harsh environments, but their wider diffusion is restricted by the limited extent to which they have been characterized and improved in structured breeding programmes and by trade constraints. Adaptation-related traits are more difficult to study and to record than production traits, have lower heritability, higher levels of non-additive genetic variation and phenotypic variance, and are more susceptible to genotype-by-environment interaction.

iv) *Healthy, diversified forest ecosystems are more resilient*: they are better able to cope with stress, recover from damage and adapt autonomously to change. Healthy ecosystems are more resilient to negative biotic and abiotic influences than are ecosystems under stress whose ecological processes are impaired. Best practices include integrated pest management, disease control, forest fire management, employment of reduced impact logging in production forests, limitation of gathering of non-wood forest products or livestock grazing in forests at sustainable levels, and forest law enforcement. Restoring degraded forests to healthy states, thereby re-establishing ecosystem functions, is a major strategy for increasing resilience.

v) *Fishing and fish-farming practices and management* will need to adapt to changing species composition and location and increased risks at sea. Changes in the distribution of fish, will require to adapt fishing effort, with flexible allocation and access schemes. Adaptation options to declining or variable yields in terms of fisheries technologies and management will need to be carefully assessed, to avoid exacerbating the overexploitation of fisheries or impacting habitats. For aquaculture, a set of adaptive practices has been identified, such as diversified and integrated aquaculture systems, water quality monitoring, species selection, selective breeding, genetic improvement, site selection, and improved cage and pond construction.

vi) *Adaptation action can be conducted at landscape level*, for instance watershed protection and management, fire management, erosion control, coastal zone management, and pest and disease control. Adopting a landscape approach to management includes taking into consideration the physical and biological features of an area as well as the institutions and people who influence it. Landscape-level adaptation will require appropriate institutions and policies to improve coping capacities of communities.

3) Invest in resilient agricultural development

i) *Resilient agricultural development, and related investment, can support adaptation*. Farmers, fisherfolk and forest dwellers need support from governments and from the private sector, and there is also an important role for civil society organizations.

ii) *Investments in agriculture, and especially in smallholder agriculture, are key to eradicating poverty.* As shown by the World Bank, growth in agricultural GDP from investments in agriculture is three times more effective than growth in any other sector for reducing poverty in countries highly dependent on agriculture. As shown by the High Level Panel of Experts on Food Security and Nutrition, agricultural development strategies should put smallholder and family farming at the centre. Such strategies, emphasizing access to markets and value addition shall also be part of broader rural development.

iii) *Rural and R&D investments* needed to eradicate hunger could, to take into account climate change effects, be reoriented or complemented by additional investments and appropriate measures. Climate change adaptation investment could be joined-up with regular agricultural investment programmes to scale-up effects. Public investment can help guide, enable and increase returns to private investments, such as for instance public investment in research, support to water management facilities and user associations, land restoration and extension services.

iv) *Investments of farmers, fishers and forest dwellers need to be supported* by increased capacity to take collective action, including for investments, and by strengthening the evidence base. For instance, mutualized systems to assess risks, vulnerabilities and adaptation options can help orient individual decisions and actions. Weather observations at stations and by satellites, weather forecasts, climate projections, yield response models, environmental monitoring tools and vulnerability assessments can help determine how local climate conditions will change in the future, and what will be their impact on production. Integrated packages of tools for facilitating an interdisciplinary assessment of impacts of climate change on agriculture are already available. They are key to ground the set-up of early warning systems and of adaptation option assessments.

v) *Managing genetic resources is another key means of adaptation.* This requires large collective investments to preserve, characterize and valorize genetic resources, and also to revise the goals of breeding programmes. Breeding programmes take time to attain their goals and therefore need to start many years in advance. In some places the introduction of new varieties and breeds is likely to be needed. Improvements to *in-situ* and *ex-situ* conservation programmes for domesticated species, their wild relatives and other wild genetic resources important for food and agriculture, along with policies that promote their sustainable use, are therefore urgently required.

4. Enable adaptation through policies, strategies and institutions in line with IGAD Regional Climate Change Strategy

i) *Appropriate policies and institutions at national and international levels are needed to enable, support and complement* the economic and technical options presented in 3, to enable adaptation of food producers, and especially to support small-scale food producers in their efforts to adapt to climate change.

ii) *Institutions that generate and manage public goods are key*, as well as those that generate and channel public investments. Dedicated policies and institutions are needed for the prevention and management of specific risks and vulnerabilities that can be modified by climate change, such as water scarcity, plant pests, animal diseases, invasive species and wild fires. Many of these policies and institutions are local and national. They can be effectively supported by international cooperation and tools, particularly to manage transboundary pests and diseases. Securing access of smallholder and family farmers, pastoralists and women to such public goods and services is essential.

iii) *Securing land tenure is paramount* to enable farmers to benefit from the value added on the land and to encourage them in adopting a long-term perspective. The Voluntary guidelines on the responsible governance of tenure of land, fisheries and forests in the context of national food security adopted in 2012 by the Committee on World Food Security promote secure tenure rights and equitable access to land, fisheries and forests as a means of eradicating hunger and poverty, supporting sustainable development and enhancing the environment. They can play an important role.

iv) *Collective management of natural resources*, including land and water, is particularly important for adaptation, especially at landscape level. It requires specific institutions, often at local level. Policies and institutions need to account for the specificities and needs of pastoral systems and indigenous peoples in terms of management of natural resources, and their particular needs in terms of adaptation to climate change. Improving land use and management, or changing farming systems can bring long-term adaptation benefits but often imply significant up-front costs either in inputs or labour, and/or reduced income during the transition period. Specific policies and instruments will be needed to enable those investments and facilitate the transition**.**

v) *Gender-specific support services are needed*, recognizing the differentiated roles of household members in production, consumption and the reproduction of the family unit over time. Government intervention is important to bridge gaps in economic and political power that can exist between smallholders and family farmers, their organizations and other food chain actors in accessing adaptation support, institutions and finance.

vi) *Market development and better linkages of smallholder and family farmers to domestic, national and regional markets* are important to support adaptation actions, to enable food producers to get the inputs needed to adapt, and to sell new products from a diversification of activities. Developing these market linkages also requires investment in small- and medium- size food processors, and small-scale traders at the retail and wholesale levels.

vii) *Policies will be needed to reduce financial risks,* especially those related to price volatility, which is a major disincentive for smallholder and family farmers investment. Policies will also be needed to lower transaction costs, facilitate monetary transactions, enable access to financial services and facilitate long-term investments, such as safe savings deposits (with incentives to save), low-priced credit (such as through joint-liability group lending) and insurance (such as index-based weather insurance). Smallholder and family farmers' financial needs for both working capital expenditures (fertilizers, seeds) and medium- and long-term investments, have to be addressed and supported. The agriculture sectors are the most impacted by climate change of all economic sectors with, as this report shows, a range of food security implications. This calls for better recognizing, in climate policies and tools, the importance and the specificities of the agriculture sectors and of food security, and for integrating climate change concerns in food security and agricultural policies. Specific national climate-related instruments like adaptations plans, national adaptation plans of action (NAPA), prepared by least developed countries, and national adaptation plans (NAPs), aim to identify vulnerabilities to climate change and actions to be implemented. Most countries have also integrated agriculture and land use in their intended nationally determined contributions (INDCs). The countries that have included adaptation in their INDCs generally insisted on the importance of food security and of the agriculture sectors.

Enhance markets and trade's contribution to stability of food security

Global markets and trade can play a stabilizing role for prices and supplies and provide alternative food options for negatively affected regions. Climate impacts on future food supply suggest an enhanced role for trade given the modification of production patterns, and climate shocks. Attention has focused on three possible measures that could help reduce market volatility, namely limiting trade restrictions, widening and deepening markets, and improving the flow of information.

A lack of reliable and up-to-date information on crop supply, demand, *stocks and export availability* contributed to recent price volatility on food markets. An agricultural market information system (AMIS) has been set up to monitor global markets of wheat, maize, rice and soybeans (production, utilization, stocks and trade) in order to detect situations that could require international policy action and, if necessary, bring together the main exporting and importing countries to identify and implement appropriate solutions.

6. Strengthen regional and international cooperation

85. With climate change, we are likely to see a "migration" of some production systems, including from one country to another. Strengthened regional and international cooperation will be needed to facilitate exchanges of knowledge on production systems and on adaptation options, undertake vulnerability assessments, exchange and give value to genetic material and practices, manage fish stocks and other transboundary resources, as well as to prevent and manage transboundary risks, like plant pests and animal diseases.

86. It is likely that climate change will necessitate more international exchanges of genetic resources as countries seek to obtain well-adapted crops, livestock, trees and aquatic organisms. The prospect of greater interdependence in the use of genetic resources in the future underscores the importance of international cooperation in their management today and to facilitate exchanges of these resources internationally, through fair and equitable – and ecologically appropriate – mechanisms. For plant genetic resources, the International Treaty on Plant Genetic Resources for Food and Agriculture, provides useful dispositions for the conservation of genetic resources, exchange of information, transfer of technology, capacity building and benefit sharing. Also, global cooperation to prevent and manage transboundary pests and diseases will be increasingly important. The International Plant Protection Convention, provides an example of a useful instrument to be mobilized. It promotes action to protect plants and plant products from the spread of pests, and sets out measures to control plant pests while minimizing interference with the international movements of goods and people.

Conclusions

Hazards due to climate change are increasing in number and intensity; unaddressed climate change will increasingly affect yields and rural livelihoods (FAO, 2017). They reduce food availability, disrupt access to food and health care, and undermine social protection systems, pushing many affected people back into poverty and hunger, fueling distress migration and increasing the need for humanitarian aid. Violent conflict also frequently characterizes protracted crises. On average, the proportion of undernourished people living in low-income countries with a protracted crisis is between 2.5 and 3 times higher than in other low-income countries.

Conclusively, climate change brings a cascade of risks from physical impacts to ecosystems, agro-ecosystems, agricultural production, food chains, incomes and trade, with economic and social impacts on livelihoods and food security and nutrition.

The people who are projected to suffer the earlier and the worst impacts from climate change are the most vulnerable populations, with livelihoods depending on agriculture sectors in areas vulnerable to climate change. Understanding the cascade of risks, as well as the vulnerabilities to these risks, is essential to frame ways to adapt. Reducing vulnerabilities is key to reducing the net impacts on food security and nutrition and also to prevent long-term effects. Increasing resilience of food security in the face of climate change calls for multiple interventions, from social protection to agricultural practices and risk management.

The changes on the ground needed for adaptation to climate change in agriculture and food systems for food security and nutrition will need to be enabled by investments, policies and institutions in various areas. To be the most effective such interventions have to be part of integrated strategies and plans. Such strategies should be gender-sensitive, multi-scales, multi- sectors and multi-stakeholders. They should be elaborated in a transparent way and consider the different dimensions (social, economic, environmental) of the issues and different time scales by which the changes will need to be implemented and supported. They should be based on assessments of risks and vulnerabilities, learn from experience and progresses, and be regularly monitored, assessed and updated. Middle- and high-income countries are increasingly carrying out regular assessments but countries without this capacity will need specific support. The National Adaptation Plan process set up under the UNFCCC provides the opportunity to integrate food security and nutrition as a key objective. Such national strategies and plans need also to be supported by enhanced regional and international cooperation.

Actions by different stakeholders are needed in the short term to enable responses in the short, medium and long term. Some medium- and long-term responses will need immediate enabling action and planning, and immediate implementation of investments, especially those investments that require longer time frames to be developed and arrive in the field: forestry, livestock breeding, seed multiplication, R&D, innovation and knowledge transfer to enable adaptation.

- For the world's poor, adapting to climate change and ensuring food security go hand in hand.
- A paradigm shift towards agriculture and food systems that are more resilient, more productive, and more sustainable is required.

In that effort, agriculture has also a role to play, keeping in mind that food security is the priority.

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