Observed and projected climate change in the Philippines, Honduras, Kenya, Malawi and Ethiopia

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1. Introduction and Overview

1.1 Overview of this Report

This report provides a comprehensive review of climate change projections and impacts in each of Trocaire's Programme Countries (Ethiopia, Kenya, Malawi, Honduras and the Philippines). The report reviews over 150 publications on recent research, predominantly from peer reviewed international scientific journals to provide an up to date overview of our emerging knowledge on how climate change is likely to unfold in some of the most vulnerable countries in the world. This work therefore provides a solid scientific evidence base for understanding climate change and its impacts in each of the aforementioned countries. For each country an in-depth profile is provided with the following structure:

- An overview of vulnerability to climate change
- Collation of evidence on observed climate variability and change
- Collation of evidence on projected changes in climate from regional and national level studies in each country.
- Assessment of impacts in key sectors including; food production, water resources, human health, migration and economic impacts. Issues of gender are also integrated.

In some instances information on these aspects did not exist or were not yet developed enough for inclusion. Before presenting each country profile the remainder of this chapter provides a summary of findings at the global scale, as reported by the most recent assessment of the Intergovernmental Panel on Climate Change (IPCC) in their Fifth Assessment Report. This is done to provide context for each of the country profiles. In addition, a brief summary of how projected climate change impacts are derived is provided, together with a quick summary of key terms that arise.

1.2 State of Knowledge: Summary from IPCC AR5

The most recent assessment of the Intergovernmental Panel on Climate Change (IPCC) published in 2013/2014 provides the most comprehensive assessment of our understanding of climate change to date. The report concludes that warming of the climate system is unequivocal. The atmosphere and oceans have warmed and the volume of water held as snow and ice has decreased. Globally, the combined land and ocean surface temperature has increased by 0.85^{o}C over the period 1880 to 2012. Between 1901 and 2010 global mean sea level rose by 0.19 metres. Human influence on the climate system is clear and has been detected in the warming of the atmosphere and ocean, changes in the global water cycle, sea level rise and changes in some climate extremes. In a powerful conclusion the IPCC highlight that it is extremely likely that human influence, primarily through the impacts of greenhouse gasses (mainly carbon dioxide) have been the dominant cause of this warming since the mid-20th Century.

Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions in greenhouse gas emissions. Under business as usual and high emission scenarios the Global surface temperature by the end of this century is likely to exceed 2^{o}C relative to 1850 to 1900. Only the most ambitious scenario in terms of greenhouse gas reductions (RCP2.6) shows an increase in global temperature of less than 1.5^{o}C by the end of the coming century. It is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas.

While projections of precipitation are more uncertain high latitudes and the equatorial Pacific are likely to experience increases in precipitation while many mid-latitude and subtropical dry regions will likely see reductions in annual rainfall amounts under high emissions scenarios. With further heating sea level will continue to rise. For a business as usual scenario (RCP8.5) the best estimate of sea level rise by the year 2100 is 0.52 to 0.98 metres. Most aspects of climate change will persist for many centuries even if emissions are stopped.

In global terms projected changes in climate with continued greenhouse gas emissions are likely to have considerable impacts across a range of sectors important for development. There is wide agreement that the most damaging impacts are likely to be felt in the poorest areas of the world – in regions that have made least contribution to emissions of greenhouse gases. The following sections summarise the large scale findings of the IPCC Fifth Assessment Report for each of the impact sectors that are subsequently included in the country profiles.

1.2.1 Food Production and food security

The current century will see rapidly rising crop demands. In both tropical and temperate regions major crops of wheat, rice and maize are projected to be negatively impacted by climate change for local temperature increases of 2^{o}C or more above current levels. Projected impacts vary across crops and regions. After mid century the risk of more severe yield losses is linked to temperature increases and is greater with higher magnitudes of warming linked to higher greenhouse gas emissions. All aspects of food security are likely to be affected by climate change including food access, utilisation and price stability. Global temperature increases of 4^{o}C or more, coupled with increasing food demands would pose large risks to food security globally and regionally. These risks are greater in low latitude countries, including Trocaire programme countries given a heavy reliance on rain-fed agriculture, a lack of access to technology and pre-existing challenges of food security.

1.2.2 Water Resources

There is high agreement that climate change will increase water related risks over the coming century. Such risks include access to water for drinking supplies, as irrigation input to agriculture, as input to energy and hydro-electric schemes. Exposure to water related extremes of flooding and drought is also likely to increase. Associated risks increase with levels of greenhouse gas emissions. The fraction of the global population experiencing water scarcity and the fraction affected by major river floods increase with the level of warming over the coming century. Reductions in surface water and groundwater resources in sub-tropical regions are likely while increased competition between sectors for water is likely to increase. In dry regions of the world the frequency of droughts will likely increase under business as usual emissions levels. Climate change is also projected to reduce raw water quality.

1.2.3 Health

There is very high confidence that climate change will impact on human health directly and indirectly. Until mid-century climate change will exacerbate existing health problems. With higher levels of warming climate change is expected to lead to increases in ill-health in many regions, especially in low income developing countries. Health impacts will felt through greater likelihood of injury and death during extreme weather events, increases occurrence of diseases that are influenced by weather conditions and associated with risks from floods and water borne diseases. With increased food insecurity under nutrition is expected to increase susceptibility of many in developing countries to illness. While positive health impacts are associated with reductions in cold-related mortality and morbidity, globally over the coming century the magnitude and severity of negative health impacts are projected to increasingly outweigh any positive impacts.

1.2.4 Migration

Over the coming century there is high agreement that climate change is likely to increase displacement of people. Displacement increases when populations that lack resources necessary for planned migration experience higher exposure to extreme weather events. This is particularly the case in developing countries with low income. Migration can also occur in response to longer term, incremental changes in climate. There is low-confidence at present in quantitative impacts on displacement due to the complexities involved.

1.2.5 Economics

Global economic impacts from climate change are difficult to estimate. For most economic sectors the impacts of drivers such as population change, age structure, income, technology and governance are projected to be large relative to the impacts of climate change. With recognised limitations estimates of global annual economic losses for additional temperature increases of 2^{o}C are between 0.2 and 2.0 percent of income. Losses are more likely than not to be greater than this range. There are large differences in projected economic losses due to climate change within and between countries. There is high agreement however that losses will accelerate with greater levels of warming. Throughout the coming century climate change impacts are projected to slow down economic growth, make poverty reduction more difficult, prolong existing and create new poverty traps.

1.3 How future projections of climate impacts are derived

Future climate change impacts are derived using Global Climate Models (GCMs) to project future changes in climate. These are complex, physically based models that incorporate cutting-edge understanding of the climate system and key physical processes. Future scenarios of greenhouse gases are used as input to these models to explore how differing global concentrations of greenhouse gases are likely to affect important climatic variables such as temperature and precipitation. These models operate at large scales and are usually downscaled to higher resolution so that their outputs can be used as inputs to impacts models to explore how changes in climate might impact on specific sectors. For example downscaled output might be used as input to crop models to examine how changing temperatures may impact agricultural production, or used as input to a hydrology model to examine future changes in water availability or changes in floods.

Importantly, there are a number of uncertainties in this process. There are a large number of different climate models that have subtle differences in how they are formulated. Different models give different results. Given the importance of understanding future impacts to society studies usually employ a number of different models (ensembles) so that a good handle can be obtained on ranges of future change. Models agree that increases in greenhouse gases will result in increases in temperatures, i.e. there is agreement in the direction of change or positive forcing. However, the specific amount of warming expected for an equivalent increase in greenhouse gases varies between models. For precipitation however, there is greater disparity among models and therefore greater uncertainty in future projections for this variable. As will be seen in the country profiles sometimes there is even disagreement among models as to the direction of change. In order to give a best estimate averages across different models are usually taken to represent a ensemble average or central estimate across the ranges of change projected by different models.

How emissions of greenhouse gases will evolve over the coming decades is also important to understand. Therefore studies tend to use different scenarios of future concentrations of important gases such as carbon dioxide. These are formulated to represent different outcomes, for example where emissions continue to increase as they are now - a business as usual scenario; or scenarios that represent global agreements to reduce greenhouse gas concentrations; and different situations in between these. The Fourth Assessment Report of the IPCC used the SRES emissions scenarios to characterise global emissions based on different storylines of how key drivers of emissions such as population growth, energy consumption etc. might be expected to change over the coming decades. Storylines ranged from the high emissions, fossil fuel intensive storyline (A1F1) to the lower emissions scenarios such as the B2 storyline. In their Fifth Assessment Report the IPCC replaced the SRES scenarios with Representative Concentration Pathways (RCPs) which are subtly different in that they based specifically on greenhouse gas concentrations in the atmosphere rather than overall emissions and are not linked to specific drivers in recognition that multiple combinations of circumstances can lead to similar atmospheric concentrations of greenhouse gases. It is also the atmospheric concentration of greenhouse gases rather than total emissions that is most important in determining future climatic changes. Within the IPCC Fifth Assessment Report four RCPs were employed and these are described in table 1 below and linked to the SRES scenario that they most closely approximate.

RCP	**Description**	**Detail**	**Closest SRES**
RCP 8.5	High emissions	No policy changes to reduce emissions leading to high GHG concentrations	A1F1
RCP 6	Intermediate emissions	CO2 emissions peak in 2060, 75% above current levels and decline to 25% above to today by 2100	B2
RCP 4.5	Intermediate emissions	CO2 emissions increase only sightly from current levels and begin to decline around 2040	B1
RCP 2.6	Low emissions	CO2 emissions stay at current levels until 2020 and then decline and become negative by 2100. Ambitious GHG reductions required.	No equivalent SRES scenario

Table 1: Overview of Representative Concentration Pathways (RCPs) employed in IPCC Fifth Assessment Report and most similar SRES emissions scenario.

2. The Philippines

2.1 Summary of Findings

Observed Changes in Climate	Observations show increasing temperatures and precipitation extremes for the Philippines. Observed mean temperature shows an increase of 0.64 °C from 1951- 2010. Maximum (daytime) and minimum (night time) temperatures have increased by 0.36 °C and 0.1 °C, respectively. Increasing trends in the number of "no rain" days have been observed over western Philippines while significant decreasing trends are evident in the total southwest monsoon rainfall in the western half of the country.
Projected Changes in Climate	Models indicate significant warming for the regions of south east Asia. With unabated emissions an average warming of approximately 4^{o}C is simulated across all models by the end of the century. Rainfall, projections for the region show a large range of changes over the coming century, with the direction of change uncertain for the region. Country level studies indicate a reduction in rainfall in most parts of the country during the summer (March April May) season and an increase in rainfall during the southwest monsoon season in June, July and August. Increases in rainfall are also likely during the northeast monsoon months of December, January and February. These studies are based on a smaller sample of climate models.
Likelihood of Extreme Events	The country is expected to experience increases in both the frequency and intensity of extreme daily rainfall events. Lengthening of seasonal dry periods, and an increasing frequency of droughts are simulated for the region. there is a tendency in future simulations for longer wet and dry periods with implications for food production, coastal system services including fisheries, human settlement and health, livelihoods and socio-economic development.
Economic Impacts	Very little assessment of the economic impacts of climate change or the costs of adaptation have been conducted for the Philippines. Under the medium high A2 emissions scenario an estimated loss of up to 2.2 percent of gross domestic product (GDP) is projected annually by 2100 due to climate change impacts on agriculture. The cost of adaptation for agriculture and coastal zones is expected to be about $5 billion/year by 2020 on average.
Food Production	Climate change poses risks for food security in the Philippines, particularly for agriculture and fisheries. Under current conditions natural climate variability has a large impact on agricultural productivity with the effects of El Niño being felt in various sectors of the economy. The agricultural sector is most vulnerable to drought and changes in the southwest monsoon rainfall.
Access to Water	Projected changes in rainfall are expected to create severe water poverty and stress both in quantity and quality. Increases in rainfall variability and longer dry periods will affect the amount of water in dams which provide irrigation services to farmers, especially those in rain fed areas, thereby, limiting agricultural production.
Health	The effects of climate change on human health will be both direct and indirect, and are expected to exacerbate existing health risks, especially in the most vulnerable communities where the burden of disease is already high. Direct impacts of climate change on health in the Philippines relate to an increased incidence of floods and droughts. Increases in temperatures and changing rainfall regimes could trigger adverse health impacts; in particular, the outbreak and spread of water-based and vector-borne diseases leading to higher morbidity and mortality.
Gender	Research asserts that women are disproportionately impacted by disasters, severe weather events, and climate change because of cultural norms and the

	inequitable distribution of roles, resources, and power, especially in developing countries. In the Philippines there is gender bias in power and decision-making that limits engagement in community development and politics by women, and is exacerbated by many cultural restrictions on mobility and education.
Migration	Migration and relocation are important coping mechanisms for communities living in disaster vulnerable areas. The projected impacts of climate change on agriculture and coastal resources will influence migration. Following natural disasters and climate connected disasters many Filipinos have migrated to seek employment and support their families through remittances as a way of coping. With future climate change projections and intensifying disasters, migration as adaptation is likely to increase.

2.2 Vulnerability to Climate Change

The Philippines faces a pervasive threat from intense tropical cyclones, rainfall variability, sea level rise and increasing temperatures, flooding and landslides. Between 1998 and 2009 12.1 million were exposed to extreme weather events with damages accounting for a 23.9 percent loss in GDP[1]. In 2013 typhoon Haiyan impacted many thousands of people. Such extreme events seriously impact the country's natural ecosystems that are major sources of livelihoods and development of the country[2]. The river basins, coastal and marine systems are highly vulnerable, consequently impacting on food security, water resources, human health, public infrastructure and hydropower plants and human settlement [3]. For the Philippines climate change presents a systemic challenge to the country's efforts to address poverty and realise sustainable development [4]. Future projections of climate indicate that the Philippines is expected to experience a significant rise in temperature and increased rainfall variability, with the highest increases projected to occur in major agriculture regions [5].

The IPCC Fifth Assessment Report affirms with high confidence that the vulnerability to multiple stressors, both climatic and non-climatic are expected to increase[1]. In the Philippines sea level rise is projected to result in agricultural land loss [5]. Studies show that for Filipinos, especially coastal communities, sea level rise will negatively impact their livelihoods because of their dependence on coral reef ecosystems for a range of services including coastal protection, subsistence fisheries and tourism[6,7].

The Philippines is classified as one of the least developed countries in the world. The National Human Development Report of 2014 ranks the country as 117 out of 187 countries in the world in terms of the Human Development Index (HDI). About 51.9 percent of its population live under multidimensional poverty as of 2010[8]. Vulnerability is exacerbated by increasing population rates with a high proportion of the population residing in areas that are not suitable for settlement and agriculture such as on riverbanks and mountain slopes[3]. In addition to local extreme climate events, the country is vulnerable to increases in precipitation, sea levels, and the emergence and re-emergence of tropical diseases[3].

2.3 Observed Climate Variability and Change

Trends in current observations show increasing temperatures and precipitation extremes for the Philippines. Observed mean temperature shows an increase of 0.64 °C (an average of 0.01°C per year-increase) from 1951- 2010[9]. In the last 59 years, maximum (daytime) and minimum (night time) temperatures have increased by 0.36 °C and 0.1 °C, respectively[9]. Observations in the Philippines are consistent with the Asia-Pacific region trends[1]. Increases in temperatures have been greatest throughout the latter half of the observed period of 1951-2010[10]. The years 1998 and 2010 were the warmest years since 1951 in the Philippines[10]. Largest increases are found in the minimum temperatures over the observed period suggesting that overall nights (often the minimum daily temperature) are becoming warmer in the Philippines. This demonstrates reduced variability and increased convergence between diurnal and nocturnal temperatures [10]. The country is experiencing an increased number of hot days and decreasing number of cold nights.

In terms of rainfall, increasing trends in the number of "no rain" days have been observed over western Philippines[5]. Time series analysis indicates significant decreasing trends from 0.026 percent to 0.075 percent per decade in the total southwest monsoon (SWM) rainfall in the western half of the country [5]. Rainfall across the Philippines shows inter-annual variations and large variability in extreme precipitation given the role of the El Niño Southern Oscillation in the region[11]. El Niño events are associated with significantly drier conditions, especially during the months of October to March. During July August September wetter conditions in the north-central Philippines are associated with El Nino conditions[11]. The opposite is associated with La Nina conditions. These findings from analysis of available datasets are consistent with Combest-Friedman et al. [7]who indicate that households have perceived changes in climate including an increase in rainfall variability and increase the intensity and frequency of storm events and sea level rise.

2.4 Projections of Future Climate –changes in averages and extremes

Under a business as usual evolution of greenhouse gases (RCP 8.5) models indicate significant warming for the regions of south east Asia. From figure 1 temperature increases are projected for all future greenhouse gas emissions, with scenarios diverging after mid century. With unabated emissions an average warming of approximately 4^{o}C is simulated across all models by the end of the century, with some models indicating temperature increases above 5^{o}C. The best case scenario (RCP2.6), which would require ambitious global agreements in reducing emissions shows an average warming of approximately 1^{o}C by the end of the century. Even within this scenario, some models show temperature increases approaching 2^{o}C. In terms of rainfall, projections for the region show a large range of changes over the coming century, with the direction of change uncertain for the region. However, the averages across all models indicate an increase in annual rainfall, with greatest increases associated with higher emissions scenarios.

In terms of extremes, under RCP8.5 lengthening of seasonal dry periods, and an increasing frequency of droughts are simulated for the region. Increases in precipitation extremes are associated with La Niña years and El Niño events in this region [5]. Literature shows that significant drying trends are observed in climatologically dry regions which may pose droughty conditions while a wetting tendency is observed during the wet season which may increase risk of flooding potential [11]. In addition, there is a tendency in future simulations for longer wet and dry periods with implications for food production, coastal system services including fisheries[12], human settlement and health, livelihoods and socio-economic development.

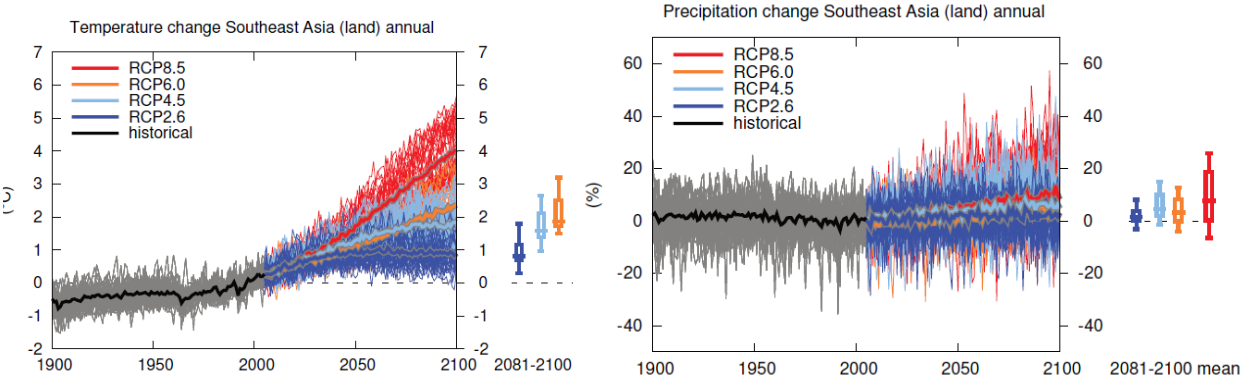

Figure 1 Projected changes in annual temperature relative to 1986-2005 (left) and annual precipitation (right) under different greenhouse gas emissions pathways for southern Africa. Red is business as usual emissions (RCP8.5), dark blue represents ambitious reductions in global emissions (RCP2.6) Thin lines denote a single model projection; thick lines show the mean simulation for multiple climate models. Bars to the right indicate the ranges of change projected by the end of the century (2081-2100) with colours representing different emissions pathways[1].

Country level studies have used a smaller number of climate models but at a higher spatial scale. From such studies mean annual temperature is projected to increase by 0.9 to 1.1°C by the 2020s and 1.8 to 2.5°C by 2050 under the SRES A2 (medium high) emissions scenario[9]. These climate projections further indicate that, generally, a reduction in rainfall in most parts of the country during the summer (March April May) season is expected. However, they also indicate that an increase in rainfall is likely during the southwest monsoon season in June, July and August until the transition months of September, October and November [5]. The country is expected to experience increases in both the frequency and intensity of extreme daily rainfall events[2]. Increases in rainfall are also likely during the northeast monsoon months of December, January and February [5].

2.5 Food Production and Climate Change

Climate change poses risks for food security in the Philippines, particularly for agriculture and fisheries. Under current conditions natural climate variability has a large impact on agricultural productivity with the effects of El Niño being felt in various sectors of the economy: agriculture, environment, water resources, energy and health. However, the agricultural sector is most vulnerable to drought and changes in the southwest monsoon rainfall[5]. About thirteen million hectares of agricultural area produce a wide variety of fruits, grains and vegetables. More than half of this area is devoted to rice and corn, the Filipino staple foods. Corn and rice producing areas are vulnerable to El Niño[13].

In the Philippines under the medium high A2 emissions scenario an estimated loss of up to 2.2 percent of gross domestic product (GDP) is projected annually by 2100 due to climate change impacts on agriculture [1]. Furthermore the Fifth Assessment Report of IPCC indicates that projected losses are well above the world's projected mean GDP loss of 0.6 percent each year by 2100 due to market impact alone. In addition, losses connected to agriculture could reach 5.7 percent of GDP and 6.7 percent of the GDP if catastrophic risks are also taken into account. The cost of adaptation for agriculture and coastal zones is expected to be about $5 billion/year by 2020 on average.

The majority of people living in coastal sea areas depend on agriculture and fisheries for food and livelihoods[14].There is high confidence that coastal resources will be severely impacted by global warming, particularly coral reefs which underpin fisheries in the country. The country's coastal resources are highly vulnerable due to its extensive coastlines. Sea level rise is highly likely in a changing climate, and low-lying islands are project to face permanent inundation in the future[15]. Under current conditions climate variability impacts heavily on fisheries. During El Niño years, fish move to areas where nutrients/food are bountiful (colder waters). It is projected that fish catch will tend to be lower during dry (summer) months than during rainy months[15]. Coastal flooding, coastal erosion, saltwater intrusion and drought will exacerbate food insecurity and habitat degradation in coastal regions, for example in Manila Bay. Among the various socioeconomic groups in the Philippines, poor coastal families, specifically small scale fishermen and shellfish gatherers are the most vulnerable to these impacts, followed by the enterprising poor and the self-employed. Women within these socioeconomic groups are likewise vulnerable to food insecurity impacts.[15]

The combined effects of continued temperature increases, changes in rainfall and accelerated sea level rise, and tropical cyclone occurrences including the associated storm surges would expose coastal communities to higher food insecurity. The livelihood of these communities would also be threatened in terms of further stress to their fishing opportunities, loss of productive agricultural lands and saltwater intrusion, among others[3]. Furthermore the rise in temperature is expected to negatively impact on coral reefs, an important resource in small tropical islands and an important source of wellbeing for many island communities. Reefs play a significant role in supplying sediment to island shores and in dissipating wave energy thus reducing the potential foreshore erosion[1]. They also provide habitat for a host of marine species upon which many island communities are dependent for subsistence foods as well as underpinning beach and reef-based tourism and economic activity. There is high evidence that climate change will reduce the extent of living coral and consequently fishing production[14]. The impact of global warming on food security in the Philippines could further lead to more malnutrition, higher poverty levels, and possibly, heightened social unrest and conflict in certain areas in the country due to loss of land.

2.6 Access to Water

Freshwater supply in small Island environments continue to present challenges[1] and in all previous IPCC reports fresh water supply in small islands has remained highly vulnerable[16, 17, 18]. Watersheds and river catchments are highly sensitive to rainfall variations. In the Philippines it is indicated that rivers on volcanic and granitic islands have limited storage for water. In addition rivers on porous limestone and low atoll islands have minimal surface runoff and water rapidly percolates into the groundwater. Therefore, the projected changes in rainfall are expected to create severe water poverty and stress both in quantity and quality. Increases in rainfall variability and longer dry periods will affect the amount of water in dams which provide irrigation services to farmers, especially those in rain fed areas, thereby, limiting agricultural production. The Fifth Assessment Report of the IPCC[1] indicates that stress on water due to heavy rain and increases in temperature will increase the risk of diarrheal diseases among the resource poor.

Domestic water supply will further be impacted by poor infrastructure and poor governance in the Philippines. The interaction of climate change, governance and infrastructure challenges will most likely cascade into more adverse impacts regarding access to safe water, especially in the rural areas. Although the joint Monitoring Programme for Water Supply and Sanitation[19] indicates that access to improved water sources is being achieved and access to sanitation is on track, the country's water quality is greatly compromised. Surface water and groundwater quality is deteriorating rapidly. Major pollution sources for surface and coastal waters in terms of Biological Oxygen Demand (BOD) load are point sources. Among non-pollution sources, agricultural runoff is the major source of pollution[20]. More intense rainfall will increase nutrient washout from agricultural land.

2.7 Gender

Increases in extreme weather conditions, such as droughts, storms, and floods, are already altering economies, economic development, and patterns of human migration[1]. These extreme events are projected to be among the most severe global threats in the 21st century to affect everyone, but not equally[21]. Research asserts that women are disproportionately impacted by disasters, severe weather events, and climate change because of cultural norms and the inequitable distribution of roles, resources, and power, especially in developing countries[22, 1].

In the Philippines over recent decades, climate change has rapidly become a serious threat to human society and wellbeing[3]. The country often experiences climate-related disasters, men and women have developed adaptation strategies that make them resilient to extreme weather events[21]. Available evidence shows that men and women adapt to flooding according to their traditional roles but women have extra new roles and burdens in addition to farming roles and managing daily household welfare[21]. Contemporary studies indicates that often men occupy freer spaces in society that enable them cope with and recover from disaster much easier than women because they occupy enclosed private spaces without windows of opportunities to adapt[22]. Even in their productive roles women fail to cope with disasters and recover after disaster because they are marginalised in governance structures and access entitlements as compared to male counterparts[21].

In the Philippines women lack resources, power and take up roles that make them less mobile[21]. Although in the Philippines there is transformation that may help women cope with climate related extreme events, literature shows that they continue to have less power over family finances and other assets because of culture[22]. There is gender bias in power and decision-making that limits engagement in community development and politics by women, and is exacerbated by many cultural restrictions on mobility and education[21]. Women in the country have lower incomes and are more likely to be economically dependent which compromises their adaptive capacity[1].

2.8 Migration

Literature indicates that the Filipinos have always migrated seeking employment globally. However, we only consider migration related to global warming and extreme events in this section. Migration and relocation are important coping mechanisms for communities living in disaster vulnerable areas[31]. The projected impacts of climate change on agriculture and coastal resources will influence migration[1]. Following natural disasters and climate connected disasters many Filipinos have migrated to seek employment and support their families through remittances as a way of coping[19]. With future climate change projections and intensifying disasters, migration as adaptation is likely to increase. Internal migration in the Philippines is driven by socio-economic factors. The general trends of migration show that poor people move from danger zones to safe zones, especially into cities. Rural-urban migration is also common. Poor people move into cities where services and infrastructure are developed[17]. This pattern is likely to be exacerbated by the underdevelopment of rural areas in the Philippines. Furthermore the impact of climate variability on the agricultural sector is leading to rural-urban migration. Crop and livestock producers abandon agriculture because of decreasing yields and migrate to urban areas to seek new job opportunities[1]. These shifts in population result in additional pressures in already depressed urban areas, particularly in mega cities.

2.9 Health

Globally, the effects of climate change on human health will be both direct and indirect, and are expected to exacerbate existing health risks, especially in the most vulnerable communities where the burden of disease is already high[1]. Direct impacts of climate change on health in the Philippines relate to an increased incidence of floods and droughts, and also typhoons. In addition to the direct loss of life associated with Typhoon Haiyan in the Philippines the storm was also associated with waterborne illnesses[6]. Incremental increases in temperatures and changing rainfall regimes could trigger adverse health impacts; in particular, the outbreak and spread of water-based and vector-borne diseases leading to higher morbidity and mortality.

2.10 Barriers to Adaptation

Climate change will worsen the adaptive capacity of Filipinos to natural disasters. Lesco[16] argues that major development plans and policies have not mainstreamed climate change adaptation. The main reason preventing mainstreaming are that national priorities are biased towards concerns deemed more pressing, specifically natural disasters. The NCCAP[9] indicates that adaptation programmes in the Philippines often face financing barriers. Recent lessons from Typhoon Haiyan reflect weak coordination mechanisms for population and climate change programs[6]. Although local community efforts play a significant role during and post-disaster, technocrats and relief agencies do not draw enough upon local knowledge and skills. Literature also shows that there are compartmentalized approaches which fail to address complexities of the at risk population. For instance a lack of privacy when providing temporary and shanty accommodation leave women more exposed to gender based violence in the country[20]. The erosion and degradation of coastal regions is projected to increase[4]. This has adversely affected important socio-economic activities such as tourism, settlements, utilities and infrastructure. Soil erosion and coastal degradation remain major challenges facing adaptation[21].

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3. Honduras

3.1 Summary of Findings

Observed Changes in Climate	The occurrence of extreme warm maximum and minimum temperatures has increased while extremely cold temperature events have decreased. Despite the large spatial variability in precipitation change, observations indicate that although no significant increases in the total amount are found, rainfall events are intensifying and the contribution of wet and very wet days are enlarging
Projected Changes in Climate	Simulations of future climate over the coming century indicate temperature increases under all greenhouse gas concentration pathways. Decreases in rainfall are expected throughout Central America under unabated emissions scenarios. There is high confidence that droughts will intensify and become more prolonged. Increases in sea surface temperatures in the region are likely to affect monsoonal rainfall upon which agriculture, water and energy depends. Projected sea level rise will compound the impacts of tropical cyclones where storm surges have been associated with great loss during past events.
Likelihood of Extreme Events	Under climate change, an increasing frequency and intensity of climate extremes, together with greater climatic variability will increase the social, economic and environmental risks posed by disasters in Honduras.
Economic Impacts	Economic losses associated with extreme events are likely to be high in Honduras. Financial losses for the country due to disasters over the past 30 years are estimated at 4.7 billion USD, representing approximately 50 percent of losses throughout Central America. Over the 20th century hurricanes caused direct and indirect damages to Honduras of over $5 billion USD, equivalent to 95 percent of Honduras' GDP in 1998.
Food Production	Maize is highly sensitive to water shortages with decreases in rainfall and more intense and prolonged drought likely to be problematic for agriculture. All parts of the country are expected to experience maize yield losses in excess of 10 percent by 2020. Beans, the other staple crop is also likely to be negatively impacted. Increasing instability of rainfall patterns will render agricultural planning more difficult and crop losses more probable.
Access to Water	Honduras faces considerable water scarcity challenges in the near future. Current water supply is affected by high levels of land degradation and deforestation with current pressures likely to be exacerbated with climate change. Reductions in annual rainfall, particularly in the northwest and southeast of the country pose significant challenges for water supply. Reductions in rainfall will likely imply a reduction in inflows to major reservoirs with a potential reduction in hydropower capacity.
Health	Very little research has been conducted on the health implications of climate change in Honduras. Increases in the intensity or frequency of extreme events would be associated direct and indirect impacts on health. Research has also shown linkages between climate variability and outbreaks of Dengue fever in Honduras.
Migration	In Honduras, issues of land tenure and access to resources influence adaptive migration patterns. Increases in land scarcity, coupled with displacement following extreme events is currently changing migration patterns in parts of Honduras. While this is not directly associated with climate change per se, increases in extreme events will add complexity to migration patterns.

3.2 Vulnerability to Climate Change

Honduras is the second-poorest country in Central America, after Nicaragua. Currently, about one million households live below the poverty line[1]. Poverty is greatest in rural areas and closely related to a land scarcity and governance of land distribution. Less than 2 percent of farmers own more than 40 percent of farmland and there is an estimated 300,000 landless families. The economy is based on international trade of agricultural commodities and manufactured goods.

The Honduran environment shows clear signs of rapid degradation. The land area covered by forests decreased from 66 percent in 1990 to 41.5 percent in 2006, the highest deforestation rate of any Central American country[1]. Water resources are threatened by overexploitation, as well as by contamination from diverse sources that include waste, agricultural drainage, surface runoff and mining leachates[2]. Taking into account casualties and GDP losses, Honduras was the third-most-affected country in the world by the impacts of extreme weather events in the period from 1990 to 2009 [1]. Over these 20 years, at least 53 events occurred in Honduras. They killed over 300 people per year on average and led to annual economic losses of over 3 percent of GDP[3]. In global terms Central America and Honduras are hotspots for adverse climate change impacts, consistently ranking highly on global assessments of climate change vulnerability.

3.3 Observed Climate Variability and Change

Honduras has seen increases in the number of warm days and decreases in the number of cold days[4]. Similarly the number of cold nights has decreased while the number of warm nights has increased[4]. The occurrence of extreme warm maximum and minimum temperatures has increased while extremely cold temperature events have decreased[4]. Observations indicate that although no significant increases in the total amount are found, rainfall events are intensifying and the contribution of wet and very wet days are enlarging [4]. Despite high spatial variation in trends throughout the region increasing trends are observed in more areas than decreasing trends. In global terms evidence for increases in heavy rainfall is most compelling for Central America[5].

3.4 Projections of Future Climate - changes in averages and extremes

Simulations of future climate over the coming century indicate temperature increases under all greenhouse gas concentration pathways (Figure 1). With unabated emissions the central estimate of warming for the region of Central America is approximately 4°C by the end of the century. Some individual models show increases of up to 6°C above current temperatures. With ambitious reductions in global emissions the central estimate of warming is approximately 1°C with projections from individual models ranging from slight increases to increases of up to 2°C by the end of the century. Projections of future changes in climate with continued greenhouse gas emissions indicate that is very likely that the number of warm days/nights will continue to increase and cold days/nights will continue to decrease.

Decreases in rainfall are expected throughout Central America under unabated emissions scenarios (Fig. 1). Under RCP 8.5 decreases are expected to be larger than natural variations by the end of the century. Under extreme projections decreases in annual rainfall of close to 40 percent are simulated. From the IPCC Fourth Assessment Report the full range of projections for the region range from -48 to 9% change in mean precipitation with half the models indicating reductions in rainfall of between -16 to -5%[6]. Modelling results with high resolution region climate models show large reductions in rainfall for the wet season under high emissions scenarios with negative impacts for the regions high value ecosystems[7].

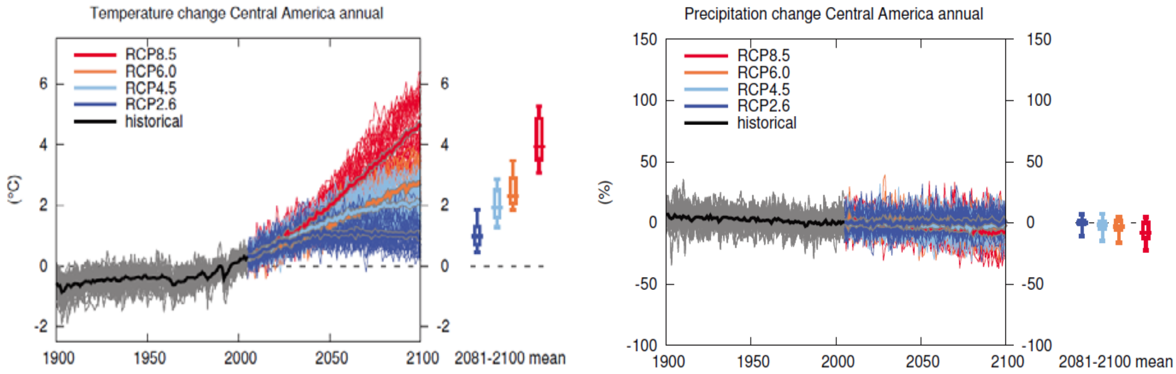

Figure 1 Projected changes in annual temperature relative to 1986-2005 (left) and annual precipitation (right) under different greenhouse gas emissions pathways for Central America. Red is business as usual emissions (RCP8.5), dark blue represents ambitious reductions in global emissions (RCP2.6) Thin lines denote a single model projection; thick lines show the mean simulation for multiple climate models. Bars to the right indicate the ranges of change projected by the end of the century (2081-2100) with colours representing different emissions pathways. (Source; IPCC, 2014)

There is confidence that droughts will intensify and become more prolonged in the 21st century in Central America, due to reduced rainfall and/or increased evapotranspiration[5]. Such changes in dryness will have implications for crop production on which the economy of Honduras is heavily dependent. Increases in sea surface temperatures in the region are likely to affect monsoonal rainfall upon which agriculture, water and energy depends. Projected sea level rise will compound the impacts of tropical cyclones where storm surges have been associated with great loss during past events. Increases in intense rainfall events will also increase the likelihood of mudslides, debris flows and slope failures to which there is high exposure and vulnerability in many parts of Honduras[8].

Under climate change, an increasing frequency and intensity of hydrometeorological extremes, together with greater climatic variability will increase the social, economic and environmental risks posed by disasters in Honduras. Risks from hurricanes are particularly high in Honduras. During the last century six of the twelve strongest hurricanes impacted Honduras, Hurricane Mitch with the most devastating consequences (see section on economic impacts). Vulnerability to extremes has consistently increased over recent years as a result of pervasive and structural poverty, extremely high levels of inequality in terms of income distribution, the impacts of persistent extreme events and limited access to critical infrastructure and basic services such as water supply. Climate change is predicted to increase the frequency of high-intensity storms in selected ocean basins depending on the climate model[9].

Drought conditions also affect Honduras with high frequency with negative social and economic impacts. Rural populations in central and southern Honduras are frequently subjected to food insecurity to drought conditions linked to the El Nino Southern Oscillation. Considering impacts of present day extremes in the region future warming and changes in the magnitude and variability of precipitation may pose a serious threat to biodiversity, water resources and related socio-economic sectors for Honduras and throughout Central America[7].

In a study of coping with climate variability and change in the city of La Ceiba in Honduras, literature highlights the high risks associated with flooding due to lack of city drainage infrastructure, river flooding from the Rio Cangrejal and flooding from heavy rainfall and storm surges associated with hurricanes[10]. For the city, the study suggests that impacts of climate change will be more adverse with higher temperature increases. An increase of 13 percent in the volume of heavy rainfall is associated high emissions for the 2050s which would result in increasing common flood flows by about 60 percent. With more intense hurricanes the flow of the Rio Cangrejal could increase by one-third during storms. Projected rapid development in coastal zones is also likely to increase the risks of sea level rise and storm surges. While no national-level projections are available for sea level rise, an increase of 0.18 m to 0.43 m by the 2090s using the B1 (low emission) scenario, and 0.23 m to 0.56 m for the A2 (high emission) scenario, relative to sea levels from 1980 to 1999 is projected[11].

3.5 Food Production and Climate Change

Maize and beans are the core components of diets and culture in Honduras with most smallholder farmers engaged in production of these crops. Overall yields are low. Land degradation coupled with climate change and limited access to credit and basic services are likely to adversely impact agriculture in Honduras. Across El Salvador, Guatemala, Honduras and Nicaragua losses in the gross production value of maize of $120 million USD is expected by 2025[12]. As impacts of climate change are relatively independent of emissions until after 2050 these losses are expected under all global emission scenarios. Maize is highly sensitive to water shortages with decreases in rainfall and more intense and prolonged drought likely to be problematic for agriculture. Without adaptation and mitigation further losses in production will pose challenges to the food security of many of the rural poor. All parts of the country are expected to experience yield losses in excess of at least 10 percent by 2020[12].

Beans are very sensitive to drought conditions and temperature extremes, especially night time temperatures which reduce flowering and overall production. With projected changes in climate, bean production in Honduras could be reduced by more than 20 percent[13]. With such changes in agriculture projected for early in this century rural households will have an especially hard time coping with climate change where infrastructure (equipment and roads) is inadequate, access to natural resources (water and land) is limited, financial resources are scarce, and social capital is very weak[13]. Losses from Maize production in Honduras could amount to 120,000 tonnes annually, valued at $40 million USD by 2025[13].

On a national level Medeiros and McCandless (2011) estimated the sensitivity of maize and beans, and small-scale cultivation of these staple crops, to projected increases in temperatures and reductions in rainfall[14]. Their results indicate significant reductions in yields with climate change. Maize yields are expected to decrease by 4 percent in 2025, and by 12 percent in 2050, compared with 2000. Average bean yields are expected to decrease by 11 percent in 2025 and 32 percent in 2050. Yields in lowland areas were more affected by increasing temperatures. Increasing instability of rainfall patterns will render agricultural planning more difficult and crop losses more probable[1].

3.6 Access to water

The main future climate impacts related to water concern its increasing scarcity. Severe water stress will affect human consumption and thereby health and productivity; limit agricultural production and thus threaten food security; reduce the potential for hydro-energy; and damage ecosystems[1]. Access to treated drinking water is limited in many rural parts of Honduras. In urban areas, particularly in the capital Tegucigalpa population growth as a result of rural-urban migration is increasing pressures on water supply where water rationing is in effect throughout the year. The country faces considerable water scarcity challenges in the near future. Current water supply is affected by high levels of land degradation and deforestation with current pressures likely to be exacerbated with climate change. Reductions in annual rainfall, particularly in the northwest and southeast of the country pose significant challenges for water supply with national assessments indicating reductions on rainfall by as much as 40 percent under pessimistic scenarios by the end of the century. Recent research over the region of Central America indicates that the prevalence of severe drought may increase significantly under a medium high emissions scenario. For the second half of this century, runoff which critical for replenishing rivers may reduce by as much as 30 percent in dry seasons with significant knock on effects for water supply, particularly in urban areas[15]. For the Lempa River basin, one of the largest basins in Central America, covering portions of Guatemala, Honduras and El Salvador research has shown that future climate projections (increase in evaporation and reduction in precipitation) imply a reduction of 20% in inflows to major reservoirs in this system with a potential reduction in hydropower capacity of up to 53 percent by 2070-2099[16].

3.7 Migration

The availability of land and water are key resources in rural livelihoods. In recent years extreme events, particularly hurricanes have resulted in the displacement of individuals and entire communities in Honduras[17]. In Honduras, issues of land tenure and access to resources influence adaptive migration patterns. Increases in land scarcity, coupled with displacement following extremes events is currently changing migration patterns in parts of Honduras. Where temporary migration was the norm, in building resource bases before returning to rural villages, contemporary trends are showing more permanent migration driven by changing power structures around land tenure, economic decline and extreme weather events[17].

3.8 Health

Very little research has been conducted on the health implications of climate change in Honduras. Increases in the intensity or frequency of extreme events would be associated direct and indirect impacts of flooding. As a past analogue, the aftermath of Hurricane Mitch, in addition to a high death toll saw outbreaks of malaria, dengue fever and cholera. Research has also shown linkages between climate variability and outbreaks of Dengue fever in Honduras[9].

3.9 Economic Impacts

It is estimated that the impact on economic, social and environmental losses as a result of climate change will amount to more than 100 billion USD by the end of the century. The poorest and most vulnerable will be the most heavily impacted. Honduras consistently ranks highly on international assessments of exposure and vulnerability to extreme events. The World Bank estimates that 62 percent of the territory of Honduras and 92 percent of the total population are at risk of two or more natural hazards, placing it in the world's top ten countries at risk from natural disasters[19].

In Honduras, financial losses due to disasters over the past 30 years are estimated at 4.7 billion USD, representing approximately 50 percent of losses throughout Central America[8]. Six of the twelve strongest hurricanes of the 20th Century impacted on Honduras, the most notable being Hurricane Mitch in 1998 resulting in more than 10,000 deaths, devastation of the country's infrastructure and drinking water network and extensive crop losses[8]. Over the 20th century hurricanes caused direct and indirect damages to Honduras of over $5 billion USD, equivalent to 95 percent of Honduras' GDP in 1998[20]. Impacts of such extreme events are felt most strongly by the poor. Studies in the aftermath of Mitch indicate that among rural households greatest losses were experienced through loss of crops, household assets and loss of wages or income. Relief amounted to less than one-tenth if the losses incurred by households[21]. Such extreme events can push households into poverty traps from which recovery can be difficult[22].

3.10 Barriers to Adaptation

In adapting to climate change in Honduras studies have highlighted a number of barriers and opportunities. A key barrier is a lack of institutional leadership on environmental issues leading to a lack of platform and common vision in adapting to climate change[12]. Local authorities have been slow to integrate national action plans into their remits with many efforts carried out in isolation. Additionally, some stakeholders claim that the development of adaptation plans were far from participatory and lacked engagement with on-the-ground experts[12]. In terms of knowledge, a lack of access to information on the impacts of climate change on agriculture and food security among the public and institutional personnel has been highlighted as a barrier to adaptation, as has a lack of training of climate change issues. Local specialists tend to be associated with international agencies or project and when they move of reach completion, the local knowledge base that is built up can also disappear, negatively impacting local scale adaptive capacity[12]. One of the main barriers to adaptation in Honduras is the lack of financial resources for the generation of projects and in developing adaptive capacity and education and training. Cultural barriers are also apparent in the uptake of new technologies and practices both by local scale farmers and institutional personnel[12].

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4. KENYA

4.1 Summary of Findings

Observed Changes in Climate	There has been an increase in seasonal mean temperature in many areas of Kenya over the last 50 years. An increase in the frequency of extreme warm events has been observed for the region between 1961 and 2008. Observational evidence shows that the frequency of dry years is increasing while rainfall has declined significantly since the mid-1970s.
Projected Changes in Climate	With continued emissions of greenhouse gases, Global Climate Models show warming projected for all seasons in all regions of Kenya, except for coastal regions. Under RCP 8.5 (business as usual with no policy changes to reduce global emissions) the average warming across all models shows temperature increases of approximately 4.5^{o}C by the end of the century. Future simulations for rainfall are uncertain with both increases and decreases simulated depending on the model used. Sea level rise presents a significant risk to Kenya's second largest city Mombasa which is also the region's largest sea port.
Likelihood of Extreme Events	Kenya is projected to experience increases in heavy precipitation with high certainty alongside an increase in the number of extreme wet days by the mid-20th Century. Increases in rainfall extremes are likely to translate into rising flood and drought risks for Kenya with implications for disaster management, development planning and local livelihoods.
Economic Impacts	Net economic costs of climate change could be equivalent to a loss of almost 3% of GDP each year by 2030 in Kenya. Costs include potential threats to coastal zones (sea-level rise), health burdens, energy demand, infrastructure, water resources, agriculture and loss of ecosystem services. While the costs of adaptation are only emerging, an initial estimate of immediate needs for addressing current climate as well as preparing for future climate change for Kenya is $500 million / year.
Food Production	Recent evidence indicates that climate change will have variable impacts on agriculture, with both production losses and gains possible. Climate change is expected to increase agricultural pests and diseases, particularly ticks and tick-borne diseases in East Africa.
Access to Water	In eastern Africa there is high confidence that rising temperatures, associated increases in evaporation losses and changes in rainfall, together with increases in the frequency and magnitude of extremes events will impact negatively on water resources. In Kenya projected water supplies are affected by increases in temperature and local variability of precipitation.
Health	Malaria is major cause of death in Kenya and has a large negative impact on farm labour. Women and children are particularly vulnerable. Consensus is growing in Kenya that the malaria epidemic is connected to changing climate conditions. Highland areas, especially in East Africa, will likely experience increased malaria epidemics as temperatures increase and areas above 2,000m, with temperatures currently too low to support malaria transmission are affected
Gender	Women are more reliant on agriculture than men and are therefore likely to be more adversely affected by climate change. In addition water access also has important gender dimensions with young girls in particular being more vulnerable to changes in water availability and competition.
Migration	Rural-urban migration in Kenya is accelerated during periods of drought such as in 2008-2011. Conflicts that are sparked by dwindling pasture and water resources contribute to migration. An increased incidence of droughts under climate change is likely to increase rural-urban migration and confound urban vulnerability.

4.2 Vulnerability to Climate Change

Kenya's socio-economic development is already highly susceptible to climate change and climate-related extreme events[1]. Climate sensitive-agriculture is fundamental to the Kenyan economy with the agricultural accounting for 67 percent of employment. Thirty percent of the total population are pastoralists in semi-arid areas. Agriculture directly contributes 24 percent of Kenya's GDP, valued at KSh342 billion in 2009 and another 27 percent indirectly, valued at KSsh.385 billion[1]. The IPCC Fifth Assessment Report indicates that in the horn of Africa climate change is expected to negatively impact food security[2]. Kenya is regarded as one of the most vulnerable countries in the Horn of Africa facing major food security challenges due to a high dependence on natural resources for food production. In Kenya approximately 85 percent of the land area is classified as arid or semi-arid[1].

Climate change projections indicate that yields of staple crops of maize and beans will decline over the coming decades and that Kenyans will face increasingly serious food security issues in the next 40 years due to water stress and droughts in semi-arid regions. Although some parts of country will experience increased precipitation, the country will likely suffer more floods that are likely to impact on crop and livestock production[3]. These extreme climate events are expected to increase in frequency and result in the displacement of communities and migration of pastoralists resulting in conflicts over natural resources. These numbers are likely to increase in future because of an already eroded adaptive capacity and community resilience in these areas. The vulnerability of poor Kenyans will be exacerbated by projected climate change impacts that will reduce household food security over the coming decades. In particular, areas in which agriculture is currently marginal and dominated by pastoralism are the most vulnerable to changing climatic conditions.

4.3 Observed Climate Variability and Change

The Government of Kenya in 2010 indicated that "the evidence of climate change in Kenya is unmistakeable" because rainfall has become irregular and unpredictable, extreme and harsh weather is now the norm and some regions experience frequent droughts during the long rainy season while others experience severe floods during the short rains[4]. Observations in Kenya are consistent with trends in Eastern Africa identified by the Fifth Assessment Report of Intergovernmental Panel on Climate Change[5]. Kenya's National Climate Change Response Strategy[4] highlights that observed temeprature trends between 1960-2006 show general warming over land locations except for the coastal zone that shows cooling trends. The minimum temperature has risen by 0.7 – 2.0 ^{o}C and the maximum by 0.2 – 1.3 ^{o}C, depending on the season and the region. In areas near the Indian Ocean, maximum temperatures have risen much like in other areas but minimum temperatures have either not changed or become slightly lower.

Region	Minimum (night) Temperature		Maximum (day) Temperature	
	Trend	Magnitude/°C	Trend	Magnitude/°C
Western	Increase	2.9 – 0.8	Increase	2.1 – 0.5
Northern & N Eastern	Increase	1.8 – 0.7	Increase	1.3 – 0.1
Central	Increase	2.0 – 0.8	Increase	0.7 – 0.1
South Eastern	Increase	1.0 – 0.7	Increase	0.6 – 0.2
Coast	Decrease	1.0 – 0.3	Increase	2.0 – 0.2

Figure 1: Observed temperature between 1960 and 2006 in Kenya (Source: NCCRS –Government of Kenya, 2010)

The Fourth and the Fifth Assessment Report of the Intergovernmental Panel on Climate Change affirm with high confidence the occurrence of extreme precipitation changes over Eastern Africa such as droughts and heavy rainfall[6,2].Kenya has been vulnerable to precipitation extremes events: 2003 was the wettest in 70 years in some parts of Kenya. The years 2003-2006 were marked by drought with the country receiving only 50 percent of expected rainfall. Early 2010 saw seroius flooding after weeks of heavy rainfall and was identified as the worst flood in more than a decade. Drought conditions between 2008-2011 badly affected pastoralist communities in the north east of Kenya, where some 70 percent of livestock died[7,8]. During these drought conditions many pastoralsits migrated to peri-urban areas increasing significantly their vulnerability and dependency on food aid [7,9] .

Research has indicated that there has been an increase in seasonal mean temperature in many areas of Kenya over the last 50 years[10]. In addition, warming of the near surface temperature and an increase in the frequency of extreme warm events has been observed for countries bordering the western Indian Ocean between 1961 and 2008[11]. Observational evidence shows that the frequency of dry years is increasing while rainfall has declined significantly since the mid-1970s. In particular, reductions in rainfall and increases in the frequency of dry years threaten critical surplus crop growing areas in central Kenya. If such trends continue the amount of prime arable land could diminish substantially[10].

4.4 Projections of Future Climate –changes in averages and extremes

With continued emissions of greenhouse gases, Global Climate Models show warming projected for all seasons in all regions of Kenya, except for coastal regions [12,13].Regardless of the SRES scenario, decade, season or model, all simulations show warmer future [14].Results for Kenya show that, compared to the 1961-1990 average, the mean annual temperature will increase by between 0.8 - 0.9°C across the country by the year 2030 and from 1.5 to 1.6°C by the year 2050 for the IPCC mid-range emission scenario (A1B) [5,6].The A2 medium high emissions scenario produces warming of around 4°C by the end of the century in both seasons. The projections from the most recent IPCC report using Representative Concentration Pathways indicate considerable warming for the region of east Africa, consistent with previous work, with the degree of warming greatest for higher greenhouse gas emissions pathways (Figure 1). Under RCP 8.5 (business as usual with no policy changes to reduce global emissions) the average warming across all models shows temperature increases of approximately 4.5°C by the end of the century. When the range of projections from individual models is examined, some show temperature increases approaching and exceeding 6°C by the same period. Under ambitious global greenhouse gas emission reductions (represented by RCP2.6) temperatures are expected to increase by approximately 1°C by the end of the century, however, even under this ambitious scenario increases in mean annual temperature above current conditions still approach 2°C.

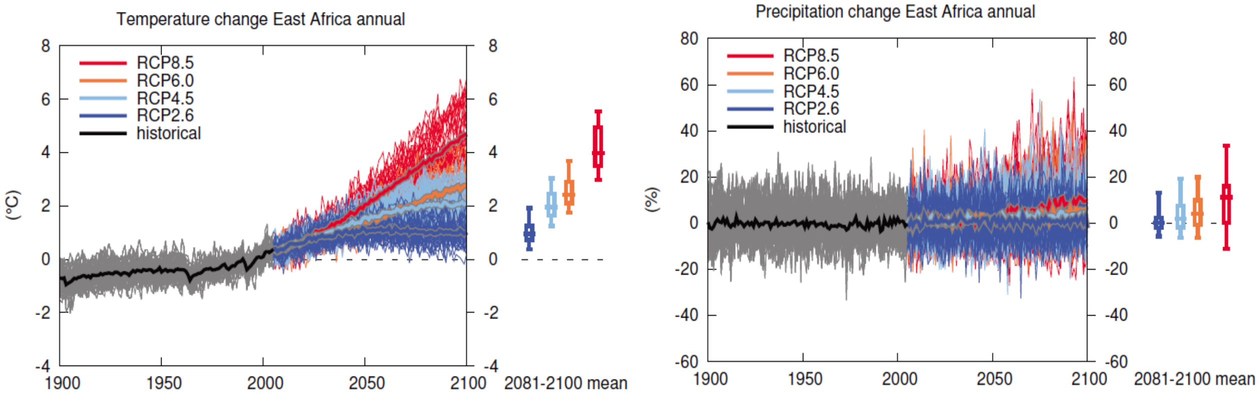

Figure 1 Projected changes in annual temperature relative to 1986-2005 (left) and annual precipitation (right) under different greenhouse gas emissions pathways for East Africa. Red is business as usual emissions (RCP8.5), dark blue represents ambitious reductions in global emissions (RCP2.6) Thin lines denote a single model projection; thick lines show the mean simulation for multiple climate models. Bars to the right indicate the ranges of change projected by the end of the century (2081-2100) with colours representing different emissions pathways. (Source; IPCC, 2014)

Future simulations for rainfall are uncertain with both increases and decreases simulated depending on the model used. For RCP8.5 projected changes in annual rainfall range from an increase of approximately 35 percent to a decrease of 15 percent. DFID indicates that Kenya is likely to experience rainfall increases of up to 40 percent by the end of the century and an increase in seasonal total rainfall in the short rainfall season occurs due to increasing rainfall extremes, specifically in northern Kenya[3]. At the same time droughts remain as extreme as present, even increasing in intensity through the 21st Century[1]. These projected changes are the opposite to observed changes to date with most weather stations depicting decreasing trends in rainfall both for annual and seasonal totals (particularly long season rainfall), except for the coastal stations in Kenya - Mombasa, Mtwata and also Mandera[3]. Funk et al. (2008) warn that the link between observed declines in growing season rainfall and anthropogenic warming in the Indian Ocean are likely to intensify over the coming decades as warming continues, with the risk of droughts being under estimated in current projections[15].

Increases in rainfall extremes are likely to translate into greater flood and drought risks nationally affecting disaster management and local livelihoods. Kenya is projected to experience increases in heavy precipitation with high certainty alongside an increase in the number of extreme wet days by the mid-20th Century[12].

Sea level rise presents a significant risk to Kenya's second largest city Mombasa which is also the region's largest sea port. The city has very high levels of poverty. Sea level rise of only 0.3 metres would submerge an estimated 17 percent of Mombasa[16], with large areas becoming uninhabitable due to flooding, or will become agriculturally unsustainable due to salt water flooding. Impacts of sea level rise on Mombasa are likely to be felt nationally and across the region due to its strategic economic importance. The most recent IPCC report indicates that over the period 1901-2010 global mean sea level rose by approximately 0.19 metres[17]. Under all greenhouse gas emissions scenarios seal level will continue to rise over the coming century. For the most ambitious scenario (RCP2.6) sea level rise by the end of the century relative to the period 1981-2005 will likely be 0.26-0.55 metres. For the unabated scenario (RCP8.5) estimated sea level rise for 2100 is 0.52 – 0.98 metres[17].

4.5 Food Production and Climate Change

The IPCC indicate with high confidence that in southern Africa agricultural production, including access to food, is projected to suffer negative impacts for several important crops[2]. In Kenya climate change is having far reaching negative effects on the already precarious food security situation for both crop cultivators and pastoralists[18]. In recent years droughts have become frequent reducing production of maize, the staple food crop, sugarcane and coffee, worsening Kenya's food security[19]. Sherwood (2013) argues that extreme precipitation events including drought have the ability to create poverty traps, for instance, crop failures in 2009 placed an estimated 10 million Kenyans at risk of hunger, malnutrition and starvation[4]. The FAO has reported that in 2011 maize production in Eastern Province of Kenya dropped by 8% due to a poor harvest caused by early cessation of the 2011 short rains, attributed to changing climatic conditions[20].

Recent evidence indicates that climate change will have variable impacts on agriculture, with both production losses and gains possible. The IPCC Fifth Assessment Report indicates that in eastern Africa production of cassava is estimated to moderately increase up to the 2030s assuming CO_2 fertilization[5]. Bean yields in Eastern Africa are estimated to experience yield reductions by the 2030s under an intermediate emissions scenario (A1B)[21] and by the 2050s under low (B1) and high (A1FI) emissions scenarios[22]. Banana and plantain production could decline in lowland areas of East Africa, whereas in highland areas of East Africa it could increase with temperature rise[23].

Climate change is expected to increase agricultural pests and diseases, particularly ticks and tick-borne diseases in East Africa[5]. Changing weather patterns could expand the distribution of ticks causing animal disease in particular *Theileriosis* (East Coast Fever) disease, which causes anaemia and skin damage that expose cattle to secondary infections[24]. Ticks and tick-borne diseases will specifically exacerbate the growing food insecurity among the pastoral community in Kenya[25]. Food production is confounded by habitat destruction, land use and cover change and land and water degradation in semi-arid regions of Kenya[26]. Increases in floods are expected to exert considerable impacts on food security, for example, heavy rains in 2002 caused floods on farms and mudslides, which forced tens of thousands to leave their homes in Kenya. In addition food security is confounded by frequent and prolonged droughts in Kenya[14]. Such extremes are likely to increase over the coming century.

4.6 Access to water

In eastern Africa there is high confidence that rising temperatures, associated increases in evaporation losses and changes in rainfall, together with increases in the frequency and magnitude of extremes events will impact negatively on water resources[27]. In Kenya projected water supplies are affected by increases in temperature and local variability of precipitation[12]. Most water for domestic use and other uses is derived from rivers whose recharge depends on rainfall[13]. Extreme climate change events are already changing the hydrological cycle that in turn affect water availability and runoff and thus may affect the discharge regime of rivers across Kenya[28,29,30].

The availability of water for domestic and other uses is highly dependent on rivers whose recharge depends on rainfall[31]. Kenya's per capita water availability is very low and likely to decrease with climate change in combination with population growth and environmental degradation[13]. It is predicted that aggregate water demand will rise by 2020[27]. At the present time, 35 percent of people are reliant on drinking from unimproved water sources such as ponds, streams and rivers that are often contaminated[32].

Apart from anthropogenic climate change, access to water is hardest in semi-arid region of Kenya where livelihoods are derived from livestock keeping. Any reductions in surface run-off are likely to impact negatively on pastoral livelihoods through drying of water sources[33]. Kenya's GDP is greatly impacted by its livestock sector; during 2008-2011 the Kenyan Government had to spend Ksh 643.2 billion towards providing services including water and feed for animals in addition to a Ksh 56.1 billion loss following the drought[14]. These losses are likely to be exacerbated by climate variability and change over the coming decades and, consequently, increase pressure on water resources[34]. Changes in water availability under climate change are likely to exacerbate existing burdens on women in relation to water collection. Women are more affected when the quantity of water and/or its accessibility changes. Okayo et al. (2013) argue that the extra burden carried by women in the aftermath of disasters deteriorate women's adaptive capacity in Kenya[35].

4.7 Migration

Rural-urban migration in Kenya is accelerated during periods of drought such as in 2008-2011[36]. For pastoralists migration is influenced by livestock deaths and acute food shortage due to depletion of pasture and water for livestock. Also conflicts that are sparked by dwindling pasture and water resources contribute to migration. For example, during the severe droughts in 2000, the Maasai pastoralists moved as far as the slopes of Mount Kenya (approximate distance of 29 km) and the Aberdare ranges (approximate distance of 38 km) in search of pasture and returned to their base afterwards[37]. In the event that a pastoralist loses the herd, they often migrate to peri-urban and urban areas to seek alternative livelihoods. Research shows that migration has increased school drop-outs significantly with school going children migrating with families in search of food, water and pasture for their livestock[36]. An increased incidence of droughts under climate change is likely to increase rural-urban migration and confound urban vulnerability.

4.8 Economic Impacts

Climate change impacts in Kenya could threaten past development gains and constrain future economic progress. SEI (2009) have produced an in-depth assessment of the economic impacts of climate change for Kenya and highlight that existing climate variability has significant economic costs in Kenya[38]. Periodic floods and droughts cause major macro-economic costs and reductions in economic growth. Future climate change will lead to additional and potentially very large economic costs. These are uncertain. However, aggregate models indicate that additional net economic costs (on top of existing climate variability) could be equivalent to a loss of almost 3% of GDP each year by 2030 in Kenya[38]. Costs include potential threats to coastal zones (sea-level rise), health burdens, energy demand, infrastructure, water resources, agriculture and loss of ecosystem services. While the costs of adaptation are only emerging, an initial estimate of immediate needs for addressing current climate as well as preparing for future climate change for Kenya is $500 million / year (for 2012)[38]. The cost of adaptation by 2030 will increase: an upper estimate likely to be in the range of $1 to 2 billion / year[38].

4.9 Health

Malaria is major cause of death in Kenya and has a large negative impact on farm labour. Women and children are particularly vulnerable. Consensus is growing in Kenya that the malaria epidemic is connected to changing climate conditions[39]. Highland areas, especially in East Africa, will likely experience increased malaria epidemics as temperatures increase and areas above 2,000m, with temperatures currently too low to support malaria transmission are affected[39]. Maes et al. (2014) showed that in Kenya in 1997/1998 and 2006/2007 for Wajir County in the north-east, extreme climate events were associated with a large malaria epidemic resulting in high admissions to Wajir Hospital and a weekly malaria incidence of 40–55 cases per 1000 population per week in all persons and children.

Research also argues that climate change is expected to increase stunting among children in the country[40]. The poorest people that depend on locally grown crops will disproportionately suffer with increased health risks likely to compromise labour needed for crop and livestock production. Rift Vally fever (RVF) epidemics in Kenya are associated with precipitation and temperature[39]. Therefore projected climate change could further exacerbate its incidence and spread. In 2006–2007 uninterrupted rainfall and the worst flooding in the county for over 50 years, was linked to an outbreak of RVF in the county[39].

4.10 Barriers to Adaptation

Government of Kenya has comprehensive policies and strategies that aim to create an enabling environment for adaptation[1,4]. There are opportunities in East Africa, in particular in Kenya to build capacity by addressing other developmental problems such as infrastructure, energy, public health education and other poverty reduction initiatives as well as forging partnerships with local communities in the spirit of facilitative collaboration[42]. Although Kenya has is moving in the right direction in creating an enabling environment to respond to climate change, there are barriers that need to be overcome including chronic budget deficits that impede delivery of basic services, in particular to the utra-poor living in slums and rural areas.

Kenya's National Climate Change Action Plan 2013-2017 identifies gaps in policy and legislation, weak institutional capacity, poor management of natural resources, limited private sector involvement, lack of capital and financing, and inadequate access to adaptation and mitigation technology as key challenges in advancing climate change adaptation. These barriers inhibit transition to a low carbon and resilient development pathway and successful adaptation to climate change[42].

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5. MALAWI

5.1 Summary of Findings

Observed Changes in Climate	Increase in temperatures of 0.9°C between 1960 and 2006 have been observed with increases most rapid in December-February (mid-summer). The number of hot days and hot nights have also increased. Decreases in rainfall have been observed but these are not significant. Reductions in annual runoff and increases in evaporation losses have been found over the period 1971-2000 indicating that decreasing rainfall has practical significance in Malawi becoming more water limited.
Projected Changes in Climate	Increased rates of warming are associated with all greenhouse gas emissions scenarios. By the end of the century temperature increases under business as usual indicate an average warming of over 5°C, with some models indicating a temperature increase of over 6°C. Even with ambitious reductions in greenhouse gases some models show temperature increases reaching and exceeding 2°C by the end of the century. While rainfall projections are uncertain the average of change across the latest models indicates decreases in rainfall, particularly by the end of the century with simulated decreases in annual rainfall of between 0 percent and 25 percent.
Likelihood of Extreme Events	Substantial increases in drought and heat extremes are expected under business as usual emissions. All projections indicate substantial increases in the frequency of hot days and nights along with increases in the proportion of rainfall falling as heavy events. The latter will likely result in increased incidence of flooding. Increases in extreme climate events can influence poverty by affecting agricultural productivity and raising food prices that are critical to poor households
Economic Impacts	Climate change will reduce agricultural production and output in sectors linked to agriculture. At an individual level climate change is likely to raise income inequality, reduce household wealth and fuel poverty. Following extreme events the number of people entering poverty as a result of impacts on agriculture is likely to increase. Climate sensitive rain-fed agriculture is a major contributor to the national gross domestic and foreign exchange earnings and is likely to be adversely affected by increasing temperatures and increased occurrence of drought.
Food Production	Maize is by far the dominant crop produced in Malawi, occupying more than 70 percent of available agricultural land and is critically important to the livelihoods. Recent climate variability has seen erratic productivity and future increases in temperature and water limitations are likely to see decreases in output, especially under business as usual scenarios. The impacts of climate change on food production are expected to be confounded and complex because of underlying poverty.
Access to Water	There is high confidence that rising temperatures, evaporation losses and changes in rainfall, together with increases in the frequency and magnitude of extremes events will impact negatively on water resources. Increases in flooding and drought are likely to increase the vulnerability of exposed communities and river-based infrastructure such as hydro-electric power and drinking water plants. Droughts are expected to impact on water levels in Lake Malawi and the Shire River that are highly vulnerable to changes in hydrology.
Health	Direct impacts of climate change on health relate to an increased incidence of extremes which are associated with higher rates of infant mortality due to malnutrition and chronic illness associated with malaria, cholera and diarrhoea. The high incidence of HIV/AIDS increases individual and community

	vulnerability and decreases agricultural productivity due to frequent and prolonged illness.
Gender	In Malawi women represent the larger proportion of the poorest people and are highly dependent on local natural resources. Therefore they are more likely to be vulnerable to climate change than men because of social and cultural contexts that determine access to resources and the division of labour.
Migration	Internal migration in Malawi is primarily linked to growing land pressure due to rapid population growth with little evidence to date of migration due to increased frequency and intensity of extreme events connected to climate variability.

5.2 Vulnerability to Climate Change

In Malawi climate change is a threat to economic growth, long-term prosperity, as well as the livelihoods of an already vulnerable population[1]. Climate sensitive rain-fed agriculture is a major contributor to the national gross domestic and foreign exchange earnings and supports the livelihoods of over 80 percent of Malawians who are involved in primary and secondary agricultural activitie[2]. Furthermore, agriculture is the principal producer of raw material for agro-based industries. The IPCC Fifth Assessment Report indicates that in parts of Africa, yields from rain-fed agriculture could reduce by up to 50 percent towards the end of the 21st century[3], which would further adversely affect food security and exacerbate the poverty and vulnerability of Malawians. Malawi is classified as one of the least developed countries in the world. The National Human Development Report of 2014 ranks Malawi as one of the lowest in terms of the Human Development Index (HDI), placing it at number 174 out of 187 countries in the world[4]. About 66 percent of its population live under multidimensional poverty as of 2010[4] and 90 percent of the population are dependent on rain-fed agriculture, 60 percent of whom are food insecure on a year-round-basis[1].

Climate extremes and weather events severely erode the resilience and adaptive capacity of individuals and communities via declining yields and food security. UNICEF (2013) indicates that flood conditions, especially in the south of the country can result in food insecurity with significant impact on the livelihoods of poor people in rural areas[5]. More than 15 percent of the population (2.31 million people) were affected by floods in the 2012/13 rainy season. In addition to floods, in the last few decades Malawi has experienced droughts during the 1978/79, 1981/82, 1991/92 and 1993/94 crop growing seasons. Therefore Malawi's is highly vulnerable to climate change under even modest temperature increases. Over the coming decades increased climate variability and extreme events will increase the vulnerability of chronically and transiently poor households, heavily dependent on rain fed agriculture.

5.3 Observed Climate Variability and Change

Recent climate trends observed from temperature data across Malawi indicate an increase in temperatures of 0.9°C between 1960 and 2006 at an average rate of 0.21°C per decade[6]. The increase in temperature has been most rapid in December-February (mid-summer) and slowest during September-November (early summer)[6]. Observations in Malawi are consistent with Sub-Saharan Africa and global trends[3]. In terms of temperature related extremes the frequency of hot days and hot nights has increased in all seasons. The average number of hot days increased by 30.5 days per year between 1960-2003, particularly in summer. The average number of hot nights increased by an additional 41 days per year over the same period[7].

In terms of rainfall, longer term trends in precipitation over Malawi do not show statistically significant trends either in total rainfall amount, the date of rainfall onset, or the length of the wet season[6]. Additionally, there are no statistically significant trends in extreme rainfall events calculated using daily rainfall data. Analysis of trends in monthly rainfall across Malawi indicates that most regions have experienced decreasing but non-significant rainfall trends over the period 1960-2006. Decreases are evident for annual and seasonal rainfall and for the months of March to December. The highest rainfall months of January and February show increasing trends in rainfall amounts but again are not statistically significant[8]. Decreases in annual runoff and increases in evaporation losses have also been found over the period 1971-2000[9] indicating that decreasing rainfall has practical significance in that Malawi has become more water limited in recent decades.

5.4 Projections of Future Climate –changes in averages and extremes

Increases in temperature are projected under all greenhouse gas emissions pathways for the southern African region where mean land surface warming is likely to exceed the global mean increase in all seasons[10,11]. The greater the level of future greenhouse gas emissions, the greater the warming projected. By the end of the century temperature increases under RCP8.5 (business as usual) indicate an average warming of over 5°C across all models, with some models indicating a temperature increase of over 6°C. Such changes would be very difficult to adapt to. Under RCP2.6 (ambitious global agreements to reduce greenhouse gas emissions) a mean temperature increase of just over 1°C is simulated. However, even under this ambitious target, simulations of temperature rise from some individual models approach and exceed 2°C.

Again at the regional scale the pattern of change in rainfall is noisy with both increases and decreases simulated by individual models. When the average of change across all models used in the IPCC Fifth Assessment Report is considered, decreases in rainfall are likely, particularly by the end of the century where decreases in annual rainfall of between 0 percent and 25 percent are likely with greater decreases associated with higher greenhouse gas emissions. Substantial increases in drought are expected under RCP8.5. Soil moisture drying is expected consistent with changes in atmospheric circulation and increased surface temperatures so that surface drying is likely, with high confidence, by the end of the century. Decreases in runoff projected for the region are also consistent with changes in Hadley Circulation which is likely to drive precipitation decreases in the region with increased evaporative losses associated with increased temperature. In addition, there is a tendency in future simulations for longer dry periods with implications for food production. In the southern Africa region Mariotti et al. (2011) indicate that countries with a single rainy season will experience a delay in onset of precipitation with possible implications for agriculture, which will impact negatively on maize production[10].

At the country level mean annual temperature is projected to increase by 1.1 to 3°C by the 2060s and 1.5-5°C by the end of the century under the A2 (medium high) emissions scenario. All projections indicate substantial increases in the frequency of hot days and nights. No substantial changes in rainfall are predicted for the current dry period of June to October, while changes in the wet season are inconsistent with some models projecting increases and others decreases. Largest project decreases are found for the months of September to May. All models consistently project increases in the proportion of rainfall falling as heavy events.

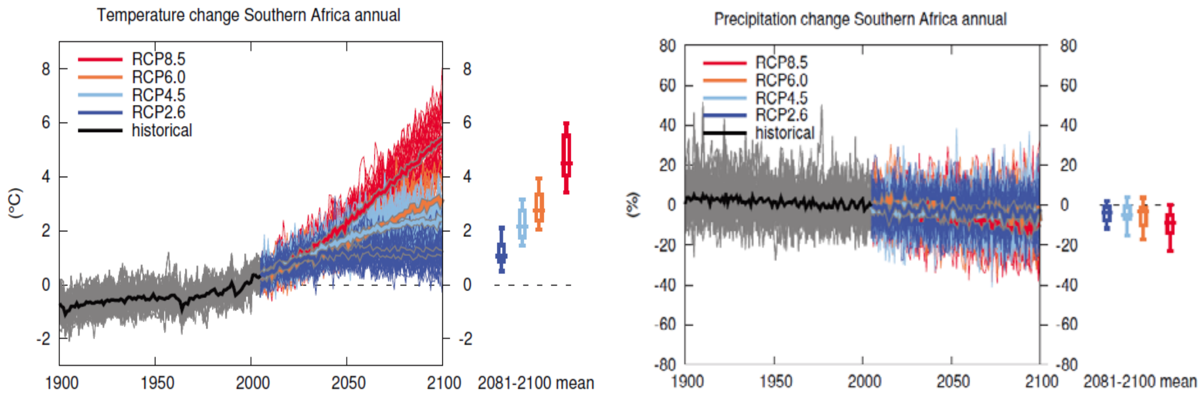

Figure 1 Projected changes in annual temperature relative to 1986-2005 (left) and annual precipitation (right) under different greenhouse gas emissions pathways for southern Africa. Red is business as usual emissions (RCP8.5), dark blue represents ambitious reductions in global emissions (RCP2.6) Thin lines denote a single model projection; thick lines show the mean simulation for multiple climate models. Bars to the right indicate the ranges of change projected by the end of the century (2081-2100) with colours representing different emissions pathways. (Source; IPCC, 2014)

5.5 Food Production and Climate Change

The effects of climate change on crop and food production are evident in several regions of the world[3]. The IPCC indicate with high confidence that in southern Africa agricultural production, including access to food, is projected to suffer negative impacts for several important crops[3,12]. Because of underdeveloped agriculture systems, yields in sub-Saharan Africa are projected to decrease by as much as 50 percent over the century while crop net revenues could fall by as much as 90 percent by 2100, with small-scale farmers being the most affected. This would adversely affect food security and exacerbate poverty and malnutrition.

In Malawi smallholder farmers account for 78 percent of the cultivated land and generate about 75 percent of Malawi's total agricultural output. Average farm size is approximately 1.12 hectares, however, more than 72 percent of smallholders farm less than 1 hectare. The vast majority of farmers rely on rain fed production with little capacity to invest in irrigation. Small farm size is driven by a high density population with Malawi being the third most densely populated country in sub-Saharan Africa (2.3 rural people per hectare of agricultural land)[13]. Maize is by far the dominant crop produced in Malawi, occupying more than 70 percent of available agricultural land and is critically important to the livelihoods of the majority of Malawians. Over the last two decades maize productivity has been erratic due to weather variability, declining soil fertility, limited use and uptake of technologies and market failures[13].

Analysis of the sensitivity of maize production in Africa to climate change has identified nonlinear heat effects based on analysis of historical yield trials and found that roughly 65 percent of present maize-growing areas in Africa would experience yield losses for 1 °C of warming under optimal rain-fed management, with 100 percent of areas harmed by warming under drought conditions[14]. While maize yields may gain from warming at relatively cool sites, they are significantly reduced in areas where temperatures commonly exceed 30°C[14]. This roughly corresponds to areas with average temperatures of 23°C or greater during the growing season Sensitivity of maize yields to heat was found to be further exacerbated in drought conditions, with even the coolest sites hurt by warming in the absence of adequate soil moisture[14].

In addition to direct impacts of climate change on specific crops, the impacts of climate change on food production are expected to be confounded and complex because of underlying poverty. In terms of agricultural production, the most serious weather events have been dry spells, seasonal droughts, intense rainfall, riverine floods and flash floods. Each cropping season Malawian famers experience localised dry spells which can significantly impact on food production[15]. With climate change, shifting planting dates will exacerbate challenges in growing maize and other crops. Seasonal dry spells and drought can occur at critical stages of crop development often during flowering[3]. Flooding has also severely disrupted food production in several districts of the country. The most vulnerable groups are rural communities, especially women, children, female-headed households and the elderly[5], for example in 2012/2013 rainy season 12 districts experienced floods which flooded smallholder farmers across the country. In addition, the 2012/13 agricultural season was characterized by a two to three week delayed start of season in the southern and central regions, erratic rainfall, and an early cessation of rainfall in the surplus central and northern areas. During such conditions the ultra-poor can spend 75 percent of their income on market purchases for food at exorbitant prices of MWK 218/kg ($0.55/kg)[15].

In particular increases in extreme climate events can influence poverty by affecting agricultural productivity and raising food prices that are critical to poor households. Under changed climate conditions extreme events are likely to become more intense for Malawi (see Figure 2). In particular, by the end of the century the number of consecutive dry days is projected to increase, as is the percent of total rainfall falling as extreme bursts. The duration of hot events (maximum period greater than 5 days with temperatures greater than 1961-90 average) is likely to increase substantially under the higher emissions scenario. For each extreme indicator the magnitude of change is greater with higher levels of greenhouse gas emissions.

Ahmed et al. (2009) assessed the consequences of extreme weather events under a medium high greenhouse gas emissions scenario, on the number of people entering poverty as a result of impacts on agriculture and found that for the coming century Malawi has among the highest proportion of population entering poverty in the wake of extreme events[16]. This study finds that following extreme climatic events under a changed climate large productivity declines of approximately 75 percent may be expected. Such reductions in grain for Malawi with extreme events are not unrealistic as during the severe drought of 1991-92 productivity decreased by between 50 and 65 percent[16].

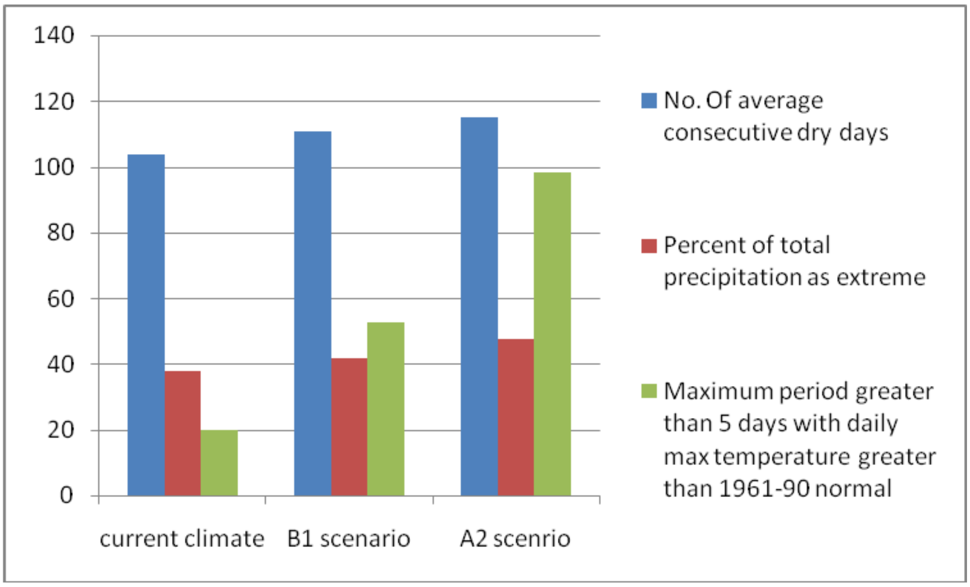

Figure 2 Simulated changes in extreme climatic indicators for Malawi. Results are based on the average of model simulations from the Coupled Model Intercomparison Project (CMIP3). Current climate represents the mean of GCM simulations for the period 1971-2000. Future simulations are made for the period 2071-2100 under the B1 and A2 greenhouse gas emissions scenarios. The B1 scenario is broadly consistent with RCP4.5 and represents a future with relatively ambitious emissions reductions. The A2 scenarios represents is characterised as a medium to high level of greenhouse gas emissions globally. Source: Ahmed et al. (2009).

5.6 Access to water

In southern Africa there is high confidence climate change through rising temperatures, associated increases in evaporation losses and changes in rainfall, together with increases in the frequency and magnitude of extremes events will impact negatively on water resources[12, 11, 3]. In Malawi projected water supplies are affected by increases in temperature and local variability of precipitation[6]. River flows could drop by 10 percent in the Zambezi basin by the end of 21st century which covers major rivers in Malawi[17]. For the Shire catchment increases in extremes of flooding and drought are likely to increase the vulnerability of river basin communities and river-based infrastructure such as hydro-electric power and drinking water plants. Droughts are expected to have greater impacts on the changing water levels on Lake Malawi and the Shire River that are highly vulnerable to changes in hydrology. For Lake Malawi Kumambala and Ervine (2010) estimate that water levels will drop in tandem with decreases in rainfall and increases in evaporation. Consequently water supply and hydro-electric power generation in southern Malawi, especially Blantyre city and surrounding districts are likely to be negatively impacted[18].

Apart from anthropogenic climate change, access to water in Malawi is expected to be impacted by socio-technical factors in future decades. Presently 92 percent of Malawians have access to water sources, largely surface water sources[19], that are dependent on rainfall recharge and are highly impacted by projected droughts and floods[17]. For example, the 2012/2013 floods in Karonga and other districts were reported to have damaged water reticulation and boreholes. Water sources such as unprotected boreholes, springs, ponds, streams and rivers were contaminated[5]. In addition to droughts, soil erosion due to surface run-off is a serious environmental problem causing sedimentation[20]. Increases in rainfall intensity following longer dry spells are likely to increase erosion and sedimentation rates. With reductions in rainfall, reductions in surface run-off are likely to impact negatively on groundwater recharge and consequently contribute to drying of boreholes across the country. Currently Malawi is losing about MKW8.8 billion due to water connected economic losses[21] and these losses are likely to be exacerbated by climate variability and change over the coming decades.

5.7 Gender

Exposure and sensitivity to climate risks vary between men and women with men having more opportunities than women to adapt to climate change through diversifying livelihoods away from subsistence agriculture. In Malawi women represent the larger proportion of the poorest people and are highly dependent on local natural resources[22]. Therefore they are more likely to be vulnerable to climate variability and change than men because of social and cultural contexts that determine access to resources and the division of labour. Within agriculture women tend to hold responsibility for growing food crops while men are more likely to grow cash crops such as cotton or tobacco. Men are also more likely to be involved in small businesses such as production and selling of charcoal. In Malawi men and women are differently affected by climate change and climate variability related disasters because women are already considered as marginalized in socioeconomic, institutional, cultural engagements and political participation[4]. In addition, educational access is unequal between boys and girls with girls educated to master domestic chores while boys are encouraged to attend schools. For instance, UNICEF indicates that at secondary level, girls' enrolment remains lower than that of boys with dropout rate for girls being high because of the extra burden they take at household level[24].

5.8 Migration

Internal migration in Malawi is primarily linked to growing land pressure due to rapid population growth with little evidence to date of migration due to increased frequency and intensity of extreme events connected to climate variability. Malawi is facing social conflicts arising from the highly unequal access to land and high rural population density[23]. Inequality in land distribution, land degradation, rural tensions, and land market failures which the country is facing impact heaviest on the rural poor and on women in particular. Muller et al. (2012) report that in the southern region of Malawi the government is implementing the Malawi Land Reform Program to address land redistribution issues arising from inequality[23]. Although there is no direct study to link migration (rural-urban) to climate change, some studies are showing that economically active populations are migrating into urban areas in pursuit of education and developing alternative livelihoods[25].

5.9 Health

Direct impacts of climate change on health in Malawi relate to an increased incidence of floods and droughts. Such extremes are associated with higher rates of infant mortality due to malnutrition and chronic illness associated with malaria, cholera and diarrhoea. The incidence of malaria is expected to increase and spread to previously cool zones as temperature increases[1]. Malawi also has a high incidence of HIV/AIDs which poses a serious threat to development. Estimates indicate that over 14 percent of Malawians between the ages of 15-49 are HIV positive. The high incidence of HIV/AIDS increases individual and community vulnerability to climate change and extreme events and decreases agricultural productivity due to frequent and prolonged illness.

5.10 Barriers to Adaptation

Efforts to increase food production are increasingly important as 60 percent more food will be needed by 2050 given current food consumption trends and assuming no significant reduction in food waste[26]. However, Malawi's agriculture is unlikely to meet this target because of an underdeveloped agricultural sector and confounding pressures such as HIV/AIDS, disasters (droughts and floods), soil erosion, land-tenure limitations, over dependency on traditional technology and high levels of poverty[2, 5]. The majority of smallholder farmers do not have the resources to facilitate adaptation of their cropping to climate variability, thus posing very significant risks and challenges to food production in future decades to feed an estimated future population of 26.1 million people in 2030[27]. Malawi faces a number of macro-level barriers in adequately delivering services that will enable the poor adapt to current and future climate variability and change[28]. The barriers include:

- Lack of comprehensive climate change policy and strategy that address future food and water needs
- Weak coordination mechanisms for population and climate change programs
- Weak analysis of issues and slow approval of policies
- Poor implementation of policies
- Insufficient government funding for population and climate change programs, leading to over-reliance on donors
- Weak technical capacity in program design, implementation, and evaluation
- Weak research capacity to generate evidence to guide policies and programs

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6. Ethiopia

6.1 Summary of Findings

Observed Changes in Climate	Increases in seasonal mean temperatures have been observed across Ethiopia over past 50 years. Rainfall shows decreased rainfall amounts in the main gowing season while the length of the main gowing season has reduced by ~15 percent in the region. Changes in rainfall have been associated with human induced warming of the Indian Ocean. Increases in extreme warm events has also been observed.
Projected Changes in Climate	Increased rates of warming are associated with all greenhouse gas emissions scenarios. Under a business as usual scenario median temperature increases of approximately 4°C are projected. With ambitious reductions in emissions warming may be contained within the 2°C threshold associated with dangerous climate change. Changes in rainfall are uncertain but most models show an increase in both average rainfall totals and intensities.
Likelihood of Extreme Events	Increased rainfall intensity is likely to result in greater likelihood of flood events. Greater extreme hot events are also expected. The impact of climate change on drought is unclear and depends on the balance between increased rainfall and increased evaporation losses.
Economic Impacts	Climate change will reduce agricultural production and output in sectors linked to agriculture and is likely to reduce GDP by ~10 percent. At an individual level climate change is likely to raise income inequality, reduce household wealth and fuel poverty.
Food Production	Food production is expected to be consistently and negatively impacted and confound challenges of food security. Changes in rainfall will make critical decisions at household level such as dates for preparing and planting more difficult. Large decreases in the productivity of major cereals have been simulated. Coupled with small and decreasing farm sizes adaptation to future impacts will be challenging.
Access to Water	Associated benefits of increases rainfall will be compromised by increased floods and soil erosion, which associated increased sediments and pollutants in fresh water bodies. A number of studies of the response of major rivers suggest decreasing river flows towards the end of the century due to increasing temperatures and associated evaporation losses.
Health	Rising temperatures and increases in rainfall intensity may shift or extend the areas affected by vector borne diseases. Increased occurrence of floods and heatwaves will also have implications for health, as will impacts on food production.
Gender	Women are more reliant on agriculture than men and are therefore likely to be more adversely affected by climate change. In addition water access also has important gender dimensions with young girls in particular being more vulnerable to changes in water availability and competition.
Migration	Migration results from a complex interplay of social, cultural, economic and environmental factors. Historically drought has been a major driver of population movements in Ethiopia. Research is also highlighting that issues with land tenure, coupled with increases in climatic extremes are acting as important drivers of rural-urban migration in the northern highland of Ethiopia under present conditions. Increases in the frequency of extreme events is likely to reducing coping capacities and increases rates of migration with social and cultural impacts in both sending and receiving areas.

6.2 Vulnerability to Climate Change

Ethiopia is arguably the most at risk African country from climate change impacts on agricultural productivity and food security[1] with agriculture accounting for more than 48 percent of Gross Domestic Product and up to 90 percent of exports and employment. Under current climatic conditions rainfall is highly variable and chronic food insecurity affects about 10 percent of the population during average years. Drought conditions can result in sharp reductions in agricultural output and with significant knock on effects on the wider economy, together with profound social impacts during extreme drought conditions. Over the period 1980-2010 ten major drought disasters were reported in Ethiopia. The major drought of 1984 resulted in over 300,000 deaths and affected over 7.5 million people, while drought in 2003 affected over 12.6 million people. Droughts in 2009 and 2011 also affected large proportions of the population.

Approximately 85 percent of Ethiopians live in rural areas and rely heavily on subsistence farming for survival. Family households usually cultivate areas less than 1 ha and collectively account for approximately 95 percent of the country's agricultural production. Nearly 40 percent of Ethiopia's ~90 million population is considered food insecure[2], while agriculture is highly dependent on the amount, timing and seasonal distribution of rainfall. Even under conservative greenhouse gas emission scenarios, future climate changes are expected to significantly reduce Ethiopia's cereal production.

6.3 Observed Climate Variability and Change

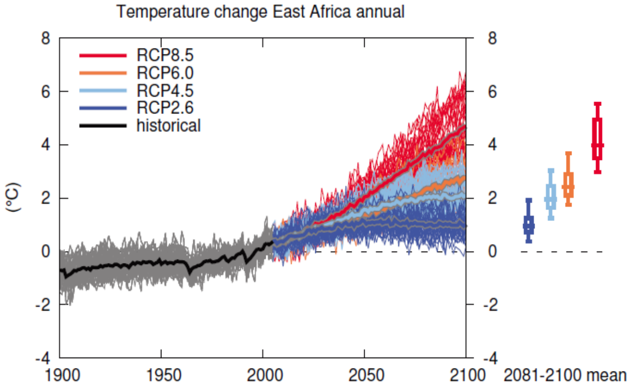
Analysis of observed temperature data indicates that there has been an increase in seasonal mean temperature in many areas of Ethiopia over the last 50 years[3], consistent with wider African and global trends[4]. Warming of near surface temperature and an increase in the frequency of extreme warm events has also been observed for countries bordering the western Indian Ocean between 1961 and 2008[5]. For the past four decades the average annual temperature in Ethiopia has been increasing by 0.37°C per decade, with the majority of warming occurring during the second half of the 1990s[6]. In terms of rainfall, Ethiopia experiences high inter-annual and inter-seasonal rainfall variability. A number of studies have pointed out that changes in rainfall are non-uniform and highly sensitive to the region and period of analysis. Seleshi and Camberlin (2005) examined trends in extremes of seasonal rainfall over the period 1965-2002 with decreasing trends found for Kiremt (main rainy season between June- September) and decreasing trends in extreme rainfalls in Belg (small rainy season from March - May)[7]. From the majority of studies, the most prominent trend has been towards reduced rainfall amounts with the main growing season length (March-May) across much of eastern Africa declining by approximately 15 percent since the 1980s[7]. Such changes have had multiple effects on agricultural production and water availability for irrigation, especially in the north, northeast and eastern lowlands of the country[7]. Occurring during the main growing seasons in poor countries dependent on rain-fed agriculture, these declines are societally dangerous[3]; impacting adversely on household livelihoods and food security and have been associated with human induced warming of the Indian Ocean[3]. In addition, recent years have seen significant socio-economic disruption due to flooding. Floods along many major rivers in 2006 resulted in the death of over 800 people and resulted in over $3 million USD losses, with more than 20,000 people being made homeless.

6.4 Projections of Future Climate - changes in averages and extremes

Under all scenarios of greenhouse gas emissions, Global Climate Models show warming projected for all seasons in all regions of Ethiopia. Conway and Schipper (2011) using the medium high SRES A2 emissions scenario show an annual warming across Ethiopia of 1.2°C by the 2020s with a range of 0.7-2.3°C, and warming of 2.2°C with a range of 1.4-2.9°C by the 2050s[8]. Regional differences in warming are modest, with warming associated with a greater frequency of heatwaves and increases in evaporation leading to moisture deficits. Projected maximum and minimum temperatures over equatorial eastern Africa show a significant increase in the number of days warmer than 2°C above the 1981–2000 average by the middle and end of the 21st century under the SRES A1B and A2 scenarios[9]. Elshamy et al. (2009) show a temperature increase over the upper Blue Nile of between 2°C and 5°C at the end of the 21st Century under the A1B scenario compared to the period 1961-1990[10].

Temperature projections from the most recent IPCC report using Representative Concentration Pathways indicate considerable warming for the region of east Africa, consistent with previous work, with the degree of warming greatest for higher greenhouse gas emissions pathways (Figure 1). Projections of future change from different climate models can result in large ranges of future change. Under RCP 8.5 (business as usual with no policy changes to reduce global emissions) the average warming across all models shows temperature increases of approximately 4°C by the end of the century. When the range of projections from individual models is examined, some show temperature increases approaching and exceeding 6°C by the same period. Under ambitious global greenhouse gas emission reductions (represented by RCP2.6) temperatures are expected to increase by approximately 1°C by the end of the century, however, even under this ambitious scenario increases in mean annual temperature above current conditions still approach 2°C.

When considering ranges of projected changes it is important to note that the average does not imply a greater likelihood of occurrence. It is important to account for the full range of projected changes when considering impacts and adaptation with the level of temperature increase having a large bearing on the extent of impacts in many sectors – the greater the temperature increases the more severe the impacts are likely to be. For Ethiopia, even the projected temperature change under the most ambitious emissions scenarios will have significant impacts for agriculture, extreme events and the livelihoods of many.



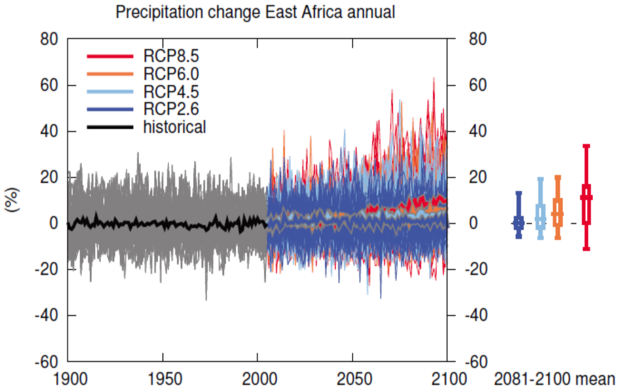


Figure 1 Projected changes in annual temperature relative to 1986-2005 (left) and annual precipitation (right) under different greenhouse gas emissions pathways for East Africa. Red is business as usual emissions (RCP8.5), dark blue represents ambitious reductions in global emissions (RCP2.6) Thin lines denote a single model projection; thick lines show the mean simulation for multiple climate models. Bars to the right indicate the ranges of change projected by the end of the century (2081-2100) with colours representing different emissions pathways. (Source; IPCC, 2014)

Future projections of precipitation are more complex to disentangle. Shongwe et al. (2010) indicate a future positive shift in rainfall for most models with increases in both average precipitation and intensity simulated for most of east Africa, including Ethiopia[11]. They also highlight that global warming will enhance the likelihood of anomalously intense, short rains. The main climate hazards in Ethiopia are associated with rainfall variability including amount, timing, intensity and associated floods and droughts. Upward precipitation trends are projected from early this century[12]. Funk et al. (2008) highlight that the link between observed declines in growing season rainfall and anthropogenic warming in the Indian Ocean are likely to intensify over the coming decades as warming continues, with the risk of droughts being under estimated in current projections[3].

Increases in rainfall extremes are likely to translate into rising flood risks for the region[11]. In addition, rising temperatures and the higher risk of excessive rainfall have implications for the health sector by shifting and/or extending the areas affected by vector borne diseases such as Malaria or Rift Valley fever - a viral disease spread to livestock and humans via mosquitoes[11]. In highland regions, warming may lead to an expansion of crop pests into previously cold-limited areas. In the arabica coffee producing Ethiopian highlands warming trends may result in the coffee berry borer (Hypothenemus hampei) becoming a more serious threat with serious implications for livelihoods based on coffee production[13]. Small-scale coffee producers are likely to be hardest hit because they rely more heavily on natural resources for survival and have little capital to invest in costly adaptation strategies and/or pest and disease management[13].

6.5 Food Production and Climate Change

With increasing temperatures and changes in rainfall, food production is expected to be consistently and negatively impacted in Africa in the coming decades due to higher average temperatures, greater extremes, longer periods of dangerously hot weather, and high temperatures at important and vulnerable times in the life cycle of plants[12, 14]. The IPCC Fifth Assessment Report shows high confidence in fluctuations and variability in precipitation and temperature over the coming century. In Ethiopia the variability of precipitation and temperature is critical to 84 per cent of rural Ethiopians dependent on rain-fed agricultural livelihoods[15] with changes likely to affect productivity of certain crops, timing of agricultural practices and losses imposed by pests and diseases, all of which impact on food security.

Additionally, the impacts of climate change on food production are expected to be widespread and complex to manage as food production systems are profoundly influenced by socio-economic conditions and ethnicity in Ethiopia[16]. Climate variability and change will differentially impact crop production and pastoralism in the country. The decline of main growing season (belg) rainfall will continue to provide difficulties in decision making for farmers - particularly deciding on planting dates and increasing the risk of crop failure. Similarly, critical decisions around the timing of land preparation and planting for long-cycle (meher) crops such as maize, sorghum and millet will become more problematic due to changes in variability. Keller (2009) also highlight how changes in rainfall can impact adversely on flowering and development of perennial crops, in particular coffee[16]. Such changes in climatic inputs highlight the challenges of food security in Ethiopia. Evangelista et al. (2013) exemplify the scale of the challenge for cereal production. Their study showed similar decreasing trends for the four main cereal crops (teff, maize, sorghum and barley) currently critical to food security[1]. Barley was predicted to have the greatest reductions, with net losses in land area ranging from 28 to 62 percent. Sorghum had the least change, ranging from a net loss of 21 percent to a net gain of 14 percent[1]. In addition the study shows dramatic geographic shifts in land suitability for cereal production over the coming century[1]. In terms of pastoralism climate change is likely to lead to increased conflicts over pasture and water for livestock[17, 18]. For pastoral communities in Ethiopia, droughts and high temperatures threaten cattle life, feed and water. Some pastoralists may shift from livestock to crop cultivation, from nomadism to sedentary livestock keeping, from pastoralism to agro-pastoralism[19].

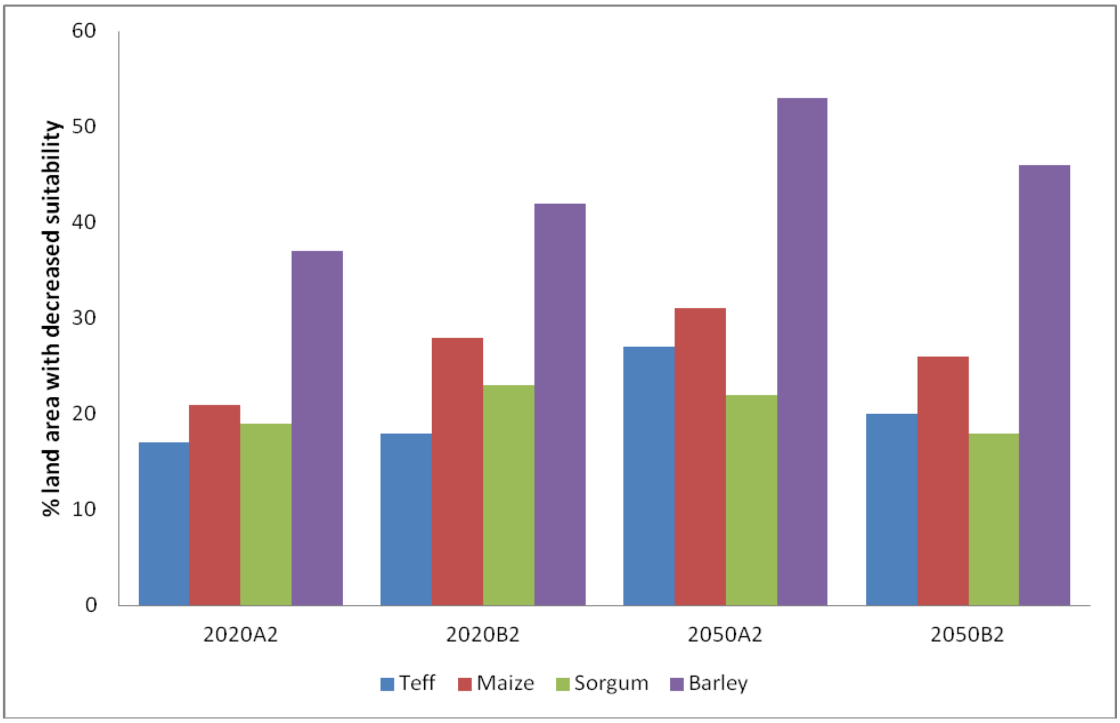


Figure 2: Percent change in land area with decreased suitability for production of certain crops. Projections are for the 2020s and 2050s for the A2 and B2 SRES emissions scenarios. The results are average across three Global Climate Models. Source: Evangelista et al. (2013).

Existing gender inequality is increased or heightened by climate-related hazards (IPCC, 2014). Men and women are differently affected by climate change and climate variability related disasters intertwined with socioeconomic, institutional, cultural and political drivers[12]. Women play a vital role in food security. In Ethiopia, as in most African countries, more women than men are engaged in the production, distribution and utilization of food. Agriculture is therefore central to women's livelihoods, with climate change impacts on agricultural production making women especially vulnerable. Evidence shows that during extreme weather conditions women experience more social disruption given a greater reliance on agriculture employment in rural areas as compared to men employed in service sectors across the country[17, 19].

6.6 Access to water

The IPCC Fifth Assessment Report (2014) affirms with high confidence that the impact of anthropogenic climate change on African fresh water resources will be significant by the end of the 21st century[12]. There is high confidence that increasing temperatures affect the water balance and thus water availability through changes in transpiration, vegetation structure and distribution. Increasing temperatures in arid and semi-arid areas will decrease water availability for human consumption and for agriculture. Climate change will constrain the technical performance of large reservoirs with knock-on effects for agriculture and electricity production[12].

In Ethiopia projected water supplies are affected by increases in temperature and local variability of precipitation[15]. While little work has been completed on assessing impacts of climate change on river flows, studies have shown that for the Gibe catchment in the south west of Ethiopia average annual streamflow (an important indicator of water availability) is predicted to decreased up to 2050[20]. In addition, research on the Geba river, a tributary of the Nile suggests annual reductions in river flows by up to 50 percent by the end of the century under a high emissions scenario, with significant decreases also expected under lower emissions scenarios. De Wit and Stankiewicz (2006) suggest that river flows in the Ganane and Nile Basins in Ethiopia will be reduced towards the end of 21st century[21] because of increasing temperatures and associated evaporation losses[22].

There is also high agreement that climate change will reduce raw water quality and even pose risks to treated drinking water because of anticipated increases in extremes [12]. Even though most recent model simulations for east Africa suggest rainfall increases[22], associated benefits will be compromised by negative impacts of high rainfall on water supply and access. Increased precipitation will be associated with increased floods and soil erosion, which associated increased sediments and pollutants in fresh water bodies[12, 14]. Soil erosion is already a serious problem in Ethiopia where every year, 1.5 billion metric tons of topsoil erodes from the highlands into streams and rivers, thus increasing sediments, pollutants and reducing stream flows[23].

Anthropogenic climate change is only one of the many pressures that will determine access to water in future decades. Presently 48 per cent of the population in Ethiopia is without access to safe water and relies on water sources such as unprotected springs, ponds, streams and rivers many of which are located far from households and are contaminated. Additionally, drought seriously impacts pastoral regions of Somali, Afar and Oromia which covers 50 to 61 percent of the surface area of Ethiopia[18]. In these semi-arid and arid regions droughts and temperature rise cause traditional water sources for people and livestock to rapidly disappear. Water access also has important gender dimensions throughout much of Africa, including Ethiopia. Tesfu (2011) argue that women and girls are mainly involved in water collection but young girls are particularly vulnerable to associated health and physical risks[19].

6.7 Migration

Historically, drought has been a major driver of population movements in Ethiopia. While such cases are not attributable to climate change an increased frequency and intensity of extreme events is expected under climate change and may lead to migration as changes exceed the coping capacity of individuals. Understanding migration as a response to environmental and climate change is complex, with decisions to migrate or not associated with a complex interaction of social, cultural, political and economic factors. Morrissey (2013) has examined migration in Ethiopia related to environmental shocks and degradation by exploring mobility dynamics in two rural areas of the northern highlands of Ethiopia[25]. Within the region, livelihoods revolve around small scale, rain-fed subsistence agriculture with ongoing environmental stresses associated with a worsening rainfall regime for agriculture over the past 20-25 years (less rainfall totals, shorter seasons, and more intense and variable rainfall), increased exposure to severe frosts at high altitudes and losses of topsoil and soil fertility[25].

Shrinking land holdings also play an important part in shaping livelihoods in Ethiopia. The government's decision to maintain ownership of all the country's land in transitioning from the feudal system of Selasie's regime, means that households cannot acquire land other than through centrally organised re-distributions. Coupled with rural population growth this system of redistribution serves to fracture landholdings so that individual household plots are very small. Reducing land holdings compromise livelihood security by reducing available harvests and limiting the size of herds that households can maintain[25]. Such land tenure arrangements decrease the coping and adaptive capacity of communities to extreme climatic events. This is particularly the case for women where land ownership is traditionally held by men[25].

Morrissey (2013) reports that in the northern highlands extreme weather events have seen production shortfalls with many households seeing their stores of wealth reduced and cattle stocks depleted due to lack of available grazing or through sale to purchase cereals and other necessities[25]. Such circumstances have resulted in high levels of migration to urban areas, particularly among the young who cannot obtain land by private purchase. In addition, access to credit is generally available only to those with land who can offer holdings as collateral. The pursuit of education in developing alternative livelihoods also forces movement to urban areas[25].

6.8 Economic Impacts

The economic cost of climate change to Ethiopia is high given the importance of the agricultural sector to livelihoods, production and employment. In addition, in poor countries large costs can be incurred due to small shifts in climate due to low levels of adaptive capacity, technology and resources. Ethiopian agriculture accounts for nearly 42 percent of the nations output, employs 85 percent of the popultation and contributes more than 90 percent to national exports and serves as the main input to the industrial sector. The main export commodity is coffee accounting for 35.7 percent of total exports. Given its large role in income and employment failure in agriculture has widespread impacts throughout the economy, as has been experienced by recent climate extremes.

Agricultural output is closely linked to fluctuations in rainfall in Ethiopia with micro-level analysis suggesting that climate change has already created costs through the drying of lakes, decreased water volumes leading to serious electircal power interruptions, increased drought length and frequency and flood events. Aragie (2013) estimates that Ethiopia has lost a cumulative level of over 13 percent of its current agricultural output between 1991-2008 with high costs in terms of increased poverty, while over the coming years the country could lose in the order of $2 billion USD due to rainfall variability[26].

Robinson et al. (2013) find that by 2050 climate change could reduce Ethiopian GDP by 8-10 percent and increase variability in agricultural production by a factor of two[27]. This research also indicate that adapting to climate change in the areas of agriculture, energy provision and road infrastructure, may cost an annual average of $0.8-2.8 billion[27]. Climate change impacts are also likely to be felt most by the rural poor and particularly women. The poor in urban areas are also likely to be negatively impacts due to increasing food prices. Mideksa (2010) highlights that climate change will make the prospect of economic development harder for Ethiopia in at least two ways: first, by reducing agricultural production and output in sectors linked to agriculture, which is likely to reduce Ethiopia's GDP by about 10% from its benchmark level; and second, by raising the degree of income inequality which is likely to further decrease economic growth and fuel poverty[28]. In addition, extreme climatic events have historically been shown to be costly to individuals, reducing consumption or forcing the sale or destruction of assets; thereby re-enforcing poverty[28].

6.9 Barriers to Adaptation

Efforts to increase food production are increasingly important as 60% more food will be needed by 2050 given current food consumption trends and assuming no significant reduction in food waste[29]. However, current crop and livestock production systems are to a high extent not adapted to current climate[12]. Adaptation in both crop and livestock production is negligible in Ethiopia because of the growing land pressure, soil erosion, market and land-tenure limitations, over dependency on traditional technology and high levels of poverty[15, 16]. The majority of smallholder farmers do not have the resources to facilitate adaptation of their cropping and livestock systems to climate variability, thus posing very significant risks and challenges to food production in future decades to feed more that 90 million people. Bryan et al. (2009) identified factors influencing farmers' decision to adapt to perceived climate changes with results indicating that factors including wealth, access to extension, credit, and climate information were important in influencing decisions by Ethiopian farmers[30]. Constraints on adaptation identified in Ethiopia have been related to a number of barriers including[12]:

Financial barriers - including poverty and a lack of access to credit.

Biophysical/infrastructural barriers - limited access to water and land, poor and deteriorating soil quality, land fragmentation and pests and diseases.

Institutional barriers - shortage of labour, insecure land tenure, poor market access, corruption, lack of quality controls by government.

Informational barriers - climate weather projections, adaptation strategies, new crop varieties.

6.10 Chapter References

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