SAVING
LIVES
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LIVES

Food security and livelihoods under a changing climate in Mozambique

PREPARING FOR THE FUTURE

WFP
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Met Office

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Executive summary

Food security and the climate are closely linked in Mozambique. The key economic sectors in Mozambique include agriculture, forestry, fisheries, and livestock. Altogether, these sectors constitute a quarter of Gross Domestic Product (GDP). Agriculture is the major contributor to incomes and the economy. 70 percent of the population lives in rural areas and practices agriculture as a main livelihood. Crops are grown in largely rain-fed systems, which makes the sector highly vulnerable to natural hazards, which are principally drought and floods.

Mozambique's climate is characterized by relatively uniform temperatures across the country and a north-south rainfall gradient which results in higher more reliable rainfall amounts in the North, and lower more variable rainfall amounts in the South.

Mozambique experiences hot, wet summers and cooler, dry winters. Annual average temperatures are relatively uniform across the country. Conversely, rainfall distribution varies. Rainfall is mainly driven by the Inter Tropical Convergence Zone (ITCZ). The ITCZ movement up and down along the equator results in higher and more reliable rainfall amounts in the northern regions (around 1000-1500 mm per year) and lower and more variable rainfall amounts in the southern regions (less than 500 mm per year in some parts). The position and intensity of the ITCZ varies year-to-year as it is influenced by large-scale dynamics in the climate system, such as the El Niño Southern Oscillation (ENSO).

Historical climate analysis for the country shows that temperatures are already increasing and rainfall trends are dominated by year-to-year variability.

Analysis of observed climate trends shows that temperatures are already increasing, mostly concentrated within the rainfall season and more marked in the southern and central regions. There is no clear long-term trend for all-country annual rainfall, as rainfall is dominated by year-to-year variability in amounts and timings. However, small increases in the south and small decreases in the north have been observed. Accordingly, observed trends of vegetation shows decreases matching the rainfall trends.

WFP helicopter providing live-saving assistance following cyclone.

Livelihoods and agricultural production systems are already being affected by the changing and more variable climate.

Analysis of rainfall trends on a monthly basis shows that increases in seasonal rainfall occur within the wettest periods of the year. Decreases in rainfall are tied to decreases in the number of rainfall events rather than to decreases in rainfall amount (per rain day). Heavy rainfall events are becoming more frequent and concentrated in already wet periods. On the other hand, dry spells are longer and more variable. As a result, the growing season is becoming more unpredictable (in terms of start and end dates) and concentrated on fewer days (considering incidence of dry spells and heavy rainfall days). This makes it hard to plan and undertake agricultural practices, especially under rainfed conditions, as a principal livelihood.

One of the most direct humanitarian impacts of climate change is more frequent and intense extreme weather events exposing both governments and communities in Mozambique to increasing losses and damages.

Climate projections for the 2050s show strong agreement for an increase in temperature, but no strong trend for changes in rainfall.

Climate change projections for the 2050s for Mozambique indicate a substantial warming trend across the country. In contrast, rainfall projections are mixed, with most models projecting decreases in average annual rainfall and some models projecting small increases. Increased evaporation will negatively impact water availability. Extreme events, such as floods and droughts, will increase in frequency and intensity.

All scenarios of projected climate change will result in increased heat stress, reductions in water availability, and more frequent and intense extreme weather events, which could exacerbate food insecurity in the absence of adaptation.

Two scenarios of climate change that span the range of plausible future climates for Mozambique were studied. Both scenarios showed increases in heat stress, reductions in water availability, and continued variability, resulting in more frequent and intense extreme weather events, which are already drivers of food insecurity across the country. In the absence of adaptation, food insecurity will increase under all climate change scenarios considered, with the scale of increase dependent on the scenario.

Identified actions are multi-sectoral, working across different locations and time-scales, requiring the strengthening of adaptation plans and processes, including design, implementation, and monitoring. Building on this, some adaptation barriers identified include the lack of information on suited practices for the future, limited investments in new techniques and technologies, poor coordination and collaboration across stakeholders, and limited capacity to plan with long term horizons.

1. Introduction

Villagers come and greet a WFP Helicopter loaded with Supplementary Plumpy (Ready to Use Supplementary Food, RUSF) to be delivered to the village of Barada (Sofala province). The village is not accessible by land due to the severely damaged infrastructure.

This report presents the outcomes of a collaborative project between the UN World Food Programme (WFP) and the United Kingdom's (UK) Met Office (MO) to assess the impact of projected climate change on livelihoods and food security in Mozambique and to orient the next steps for adaptation planning.

The approach is based on a similar study undertaken in Sudan in 2016 (WFP and MO, 2016), under the Climate Adaptation Management and Innovation Initiative (C-ADAPT), which used an adaptation of the Consolidated Livelihood Exercise for Analysing Resilience (CLEAR) methodology (WFP, 2014); a framework for assessing climate risk and food security. This study for Mozambique incorporated a higher level of stakeholder consultation compared to previous studies; to draw on the expertise of stakeholders across multiple sectors, engage them in the study and facilitate discussion on future adaptation planning. Notably, this report builds on a study on the impacts of climate change in Mozambique by INGC (INGC, 2009) by providing analysis of more recently available global climate model simulations.

The key elements of the approach taken in this study were:

- **Questionnaire:** A questionnaire was shared with key experts and stakeholder groups. The purpose of this questionnaire was to assess understanding and use of information about long-term climate change in decision-making across Mozambique.
- **Assessment of current climate, food security and livelihoods:** The baseline relationship between climate, food security and livelihoods was made by drawing on a number of key reports. These include:
    - > an analysis of the recent climate and observed trends in Mozambique (WFP, 2018),
    - > the Mozambique Integrated Context Analysis (WFP, 2017),
    - > the Zero Hunger Strategic Review for Mozambique (OMR-WFP, 2016), and
    - > the livelihood zoning analysis for Mozambique (FEWS-NET & SETSAN, 2014).
- **Climate analysis:** Two plausible scenarios of projected climate change were analysed, and the impact on livelihoods and food security were assessed in the context of the potential change from the present day.
- **Focus group discussions:** Sectoral specific focus group discussions with key stakeholders were held in country to draw on their expertise for use in the study and initiate discussion on adaptation options.
- **Multi-stakeholder workshop:** Key stakeholders were brought together to discuss the key vulnerabilities of the different livelihoods under the future climate scenarios and to identify adaptation options across different timescales for decision-making.
- **Co-produced summary report:** The findings from the study are presented in this co-produced summary report.

More detail about the methods and data used in this study can be found in Appendices A and B.

Communities are motivated to shift to drought tolerant crops as a climate adaptation measure in the province of Gaza, including the production of cassava.

2. Climate, food security and livelihoods in Mozambique

Post-harvest losses may increase for smallholder farmers, since a more variable climate makes it harder to store seeds and grains effectively.

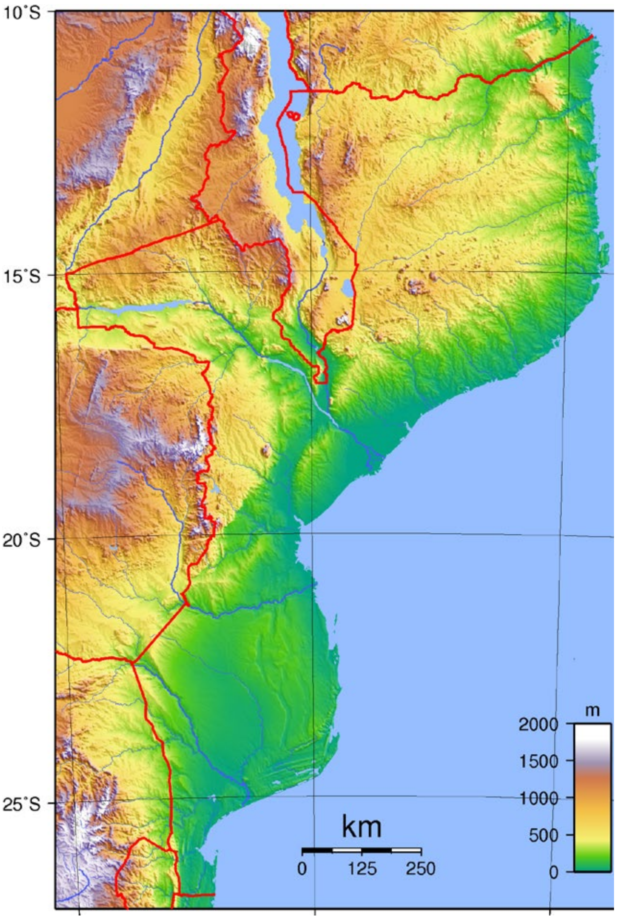
2.1.
Mozambique climate overview

Mozambique is located in the Southern Africa region and is bordered by Tanzania, Malawi and Zambia to the north, Zimbabwe to the west, South Africa and Eswatini to the south, and the Mozambique Channel of the Indian Ocean to the east. The topography of Mozambique is predominantly rugged highlands in the north-west and lowlands in the south and along the east coast (Figure 1). These topological regions are divided by the Zambezi River which enters the country from Zambia and flows out to the Indian Ocean. Other key rivers include the Limpopo River in the south and the Ruvuma River in the north. Lakes are also a key feature of northern Mozambique.

Mozambique spans a large latitudinal range from 10°S to 27°S, with climate types that range from warm desert and semi-arid climate types in the south to tropical savannah and humid subtropical climate types in the north (Peel et al. 2007). Mozambique experiences hot, wet summers and cooler, dry winters. Annual average temperatures are relatively uniform across the country (Figure 2), ranging from daily maximum values of around 25°C during winter (June to August) to around 32°C during October to December (over the 1981-2017 period; WFP, 2018). The warmest months coincide with the rainy season, which typically lasts from October to April.

FIGURE 1

Topography of Mozambique

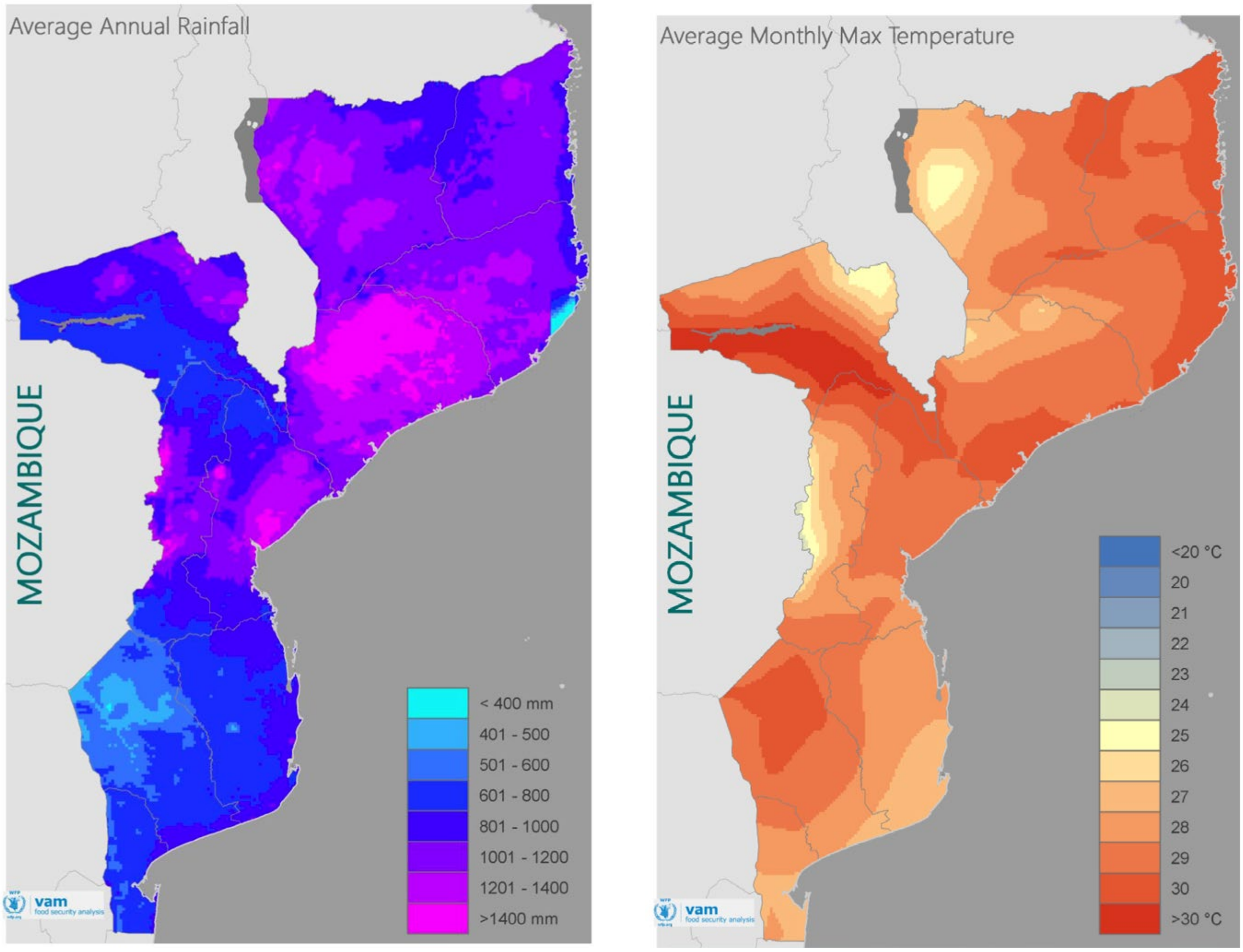


Source: https://commons.wikimedia.org/wiki/File:Mozambique_Topography.png

WFP speeding up food distributions, WFP's food is part of a multi sectoral support package which will be dropped at each location side.

FIGURE 2

Average annual rainfall (left panel) and temperature (right panel) from 1981 – 2017, taken from the recent climate analysis for Mozambique (WFP, 2018)



Rainfall is mainly driven by the Inter Tropical Convergence Zone (ITCZ); a band of convective rainfall which migrates either side of the equator throughout the year and reaches its southernmost extent in Mozambique during the summer. This results in higher and more reliable rainfall amounts in the northern regions (around 1000-1500mm per year), and lower and more variable rainfall amounts in the southern regions (less than 500mm per year in some parts; Figure 2; WFP, 2018). The position and intensity of the ITCZ varies year-to-year as it is influenced by large-scale dynamics in the climate system, such as the El Niño Southern Oscillation (ENSO). The El Niño phase is often associated with drier conditions in the south and wetter conditions in the north during the winter, whereas the La Niña phase brings wetter conditions in the south. Other regional climate processes influence year-to-year variability in rainfall over Mozambique, such as the Angola Low and the Sub-tropical Indian Ocean Dipole (SIOD); a positive SIOD event is often associated with increased rainfall over Mozambique.

OBSERVED CLIMATE TRENDS

Past trends in climate are difficult to assess due to the lack of reliable and consistent meteorological data. Trend analysis using both observed and reanalysis products (which blend observations and satellite data) from the latest Intergovernmental Panel on Climate Change Fifth Assessment report (IPCC AR5; IPCC, 2013; Niang et al., 2014) shows evidence of a continental warming trend over the 20th century, with increases of around 1°C over this period in Mozambique. Further detailed analysis for Mozambique for 1981-2017 indicates a warming of 0.1-0.25°C per decade in the southern part of the country (WFP, 2018).

Assessing trends in rainfall is more difficult due to the lack of available data, and the spatial variability in both the total amount and timing of rainfall. However, the available data does indicate that rainfall amounts are dominated by year-to-year variability with very little long-term trend observed at the national level (WFP, 2018). At the sub-national level there is an indication of a slight decrease in rainfall in the northern provinces of Niassa, Cabo Delgado and Nampula of around 2-5% per decade over 1981-2017, and a slight increase in the southern provinces of Inhambane and Manica of around 2-10% per decade (WFP, 2018). In addition, reductions in vegetation in the north and a shortening of the growing season in some localised areas have been observed (WFP, 2018).

PROJECTED CLIMATE TRENDS

Projections from the latest iteration of the Coupled Model Inter-comparison Project (CMIP5; Taylor et al., 2012) used to inform the IPCC AR5 report indicate a substantial warming trend across Mozambique with projected temperature increases of between 1°C and 3°C in daily maximum temperature by the middle of the 21st century (Niang et al., 2014). In contrast, there is less agreement on projected changes in average annual rainfall amounts for Mozambique. The majority of models project a slight drying over Mozambique. However, some models indicate a slight increase in annual rainfall by the middle of the 21st century. The dominant feature of the future climate for Mozambique is the continued year-to-year variability in rainfall amounts (see Appendix B).

Beyond the middle of the 21st century the future climate projections diverge depending on the scenario of greenhouse gas concentrations. A scenario of on-going and substantial increases in future global emissions of greenhouse gases (this scenario is known as RCP8.5; van Vuuren et al., 2011) is consistent with projections where temperatures continue to increase to the end of the 21st century, from mid-century level. In contrast, a scenario of rapid and sustained reduction in future global emissions of greenhouse gases (this scenario is known as RCP2.6; van Vuuren et al., 2011) is consistent with a stabilisation of climate conditions from the middle of the 21st century. Under both of these future greenhouse gas concentration scenarios the majority of climate models project a drying trend over Mozambique (see Appendix B).

These long-term trends in daily temperatures and annual rainfall amounts will also impact the frequency and intensity of extreme weather events, such as droughts and flooding, which Mozambique is already exposed to (WFP, 2017). These extremes are likely to increase in frequency and intensity, with more frequent and intense hot periods and more extreme rainfall events (IPCC, 2013). In addition, the intensity of tropical cyclones is projected to increase, though the overall number of cyclones is projected to remain about the same (IPCC, 2013).

These general trends are consistent with previous studies, such as the INGC study on climate impacts in Mozambique (INGC, 2009), which used the previous iteration of climate model projections and different future scenarios from the IPCC Fourth Assessment Report (IPCC AR4; IPCC, 2007). However, this report provides an update to these previous studies by summarising the trends from the more recent CMIP5 archive of climate models, which are at a higher spatial resolution, include more physical processes and use the latest approach to simulating future greenhouse gas concentration scenarios (Representative Concentration Pathways; van Vuuren et al., 2011), compared to the IPCC AR4. This report also specifically analyses these models for Mozambique, at appropriately defined spatial zones, for interpretation with respect to livelihoods and food security (see Sections 3 and

4).

2.2.
Food security and livelihoods in Mozambique

KEY SECTORS AND LIVELIHOODS IN MOZAMBIQUE

Mozambique is ranked 181 among 189 countries in terms of the Human Development Index (HDI) and is categorized as a low human development country (UNDP, 2020). Poverty affects close to half of the population, or 48.4 percent of the population, mainly in rural areas, who live below the poverty line set at 1.9 USD (adjusted for purchasing power parity) per day (World Bank, 2018). While progress has been made in terms of poverty reduction in recent years,[1] due to growth in emerging sectors of the economy (like the service and extractive sectors), evidence shows that the distribution of income is not equal, undermining the overall poverty reduction potential of the economic growth experienced.

As the economy diversifies, agriculture is still a key economic sector. In Mozambique, the agriculture sector includes cropping, forestry, fisheries, and livestock-keeping activities. Altogether, these constitute to a quarter of Gross Domestic Product (GDP) (with some fluctuation across the years[2]) and to the income of over 70 percent of the population. Due to the climate sensitivity of the agricultural sector, without effective climate action, the incomes and wellbeing of the population maybe negatively affected in the long-run, undermining efforts to eradicate poverty and hunger.

The key sectors that constitute agriculture in Mozambique are discussed in more detail below.

Cropping

Cropping is the major contributor to incomes and the economy. 70 percent of the population lives in rural areas and practices agriculture as a main livelihood. The sector is mainly composed of smallholder farmers, growing roots, tubers (cassava), cereals (maize, millet, sorghum, and rice), groundnuts, and pulses. Maize and cassava are the main food crops grown, followed by pulses, roots, and tubers (FAO, 2005). These crops are mainly produced for local consumption, with the exception of maize in the northern region, which can be exported to the neighbouring countries. Crops are grown in largely rain-fed systems, making the sector highly vulnerable to climate-related shocks.

Fisheries

Mozambique is rich in fisheries resources, including inland and marine species. However, the sector contributes only 3 to 5 percent of the country's GDP (Benkenstein, 2013a; Oceanic Développement, 2014). In the period between 2008 and 2014, the small-scale sector constituted 90 percent of the overall fisheries sector and about one-third of the labour force (UNCTAD, 2017). Industrial and semi-industrialized sectors make up the second largest contribution to the sector, with aquaculture being the smallest sector. In 2012, production reached 189 thousand tonnes (ibid). This compared to the national potential, shows an underutilization of the sector, especially the aquaculture sub-sector. 80 percent of the overall production, composed mainly of crustaceans, marine/lake fish, and molluscs, is consumed in-country, with the destined to the export market (ibid). Productivity and market potential of the sector is being affected by a variety of factors. More pressure on fish stocks is exerted as more people engage in the sector without an overarching, coherent sustainable management plan. Coal and gas exploration along the coast also undermines fishing potential by negatively affecting the marine ecosystem. The changing climate is also a threat, as warmer temperatures compromise the health of marine/inland aquatic ecosystems, and thus, the quantity, quality, and diversity of fish stocks.

Livestock

The livestock sector is crucial to the country, because it is used by households as a means of wealth accumulation, not just food security. Livestock production is practiced widely across the country. In 2008, the National Agricultural Survey showed that 88 percent of households across the country engage in the sector. The highest production levels are realized in the southern region. The numbers of livestock units show a

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1. Reduction in poverty rate between 2008/9 and 2014/15 period of over 10 percent, from 58.7 percent to 48.4, respectively.
2. In 2017, agriculture was responsible for 21 percent of GDP.

steady upward trend, with significant decreases experienced during times of conflict (1981-1994). The sector comprises of cattle, goats, pigs, sheep, and chicken. Cattle is mainly concentrated in the southern and central regions, and goats in the central region. Chicken are the most predominant throughout. Livestock production is generally practiced by those who are also in crop production. Therefore, it is mainly a sedentary sector, not marked by pastoral trends, which limits options for grazing, especially as hotter and drier conditions are making vegetation and water scarce in key production areas like in the southern region.

Forestry

Forestry is increasingly making larger contributions to the economy and local incomes. There are 32 million hectares of forest in the country, covering 40 percent of its area (World Bank, 2018). The forest sector contributed approximately US$330 million to Mozambique's GDP in 2011 and directly employed 22,000 people (ibid). Forests provide local households with key resources and services, such as food, medicine, energy, and construction materials. The miombo woodlands, the predominant forest ecosystem, is estimated to contribute to 20 percent of household cash income and 40 percent of household subsistence (non-cash) income (ibid).

Challenges experienced in smallholder farming production have resulted in the greater exploitation of forest resources. For example, to increase production of key crops, forest land is being converted to farming purposes. Similarly, forests are being increasingly explored to expand grazing potential for livestock production. Besides this, charcoal production is also adding pressure on the sector. Charcoal offers a viable source of income for rural, farming households, who are in need of additional income to meet their basic needs. The large demand for charcoal originates from the lack of access to other sources of energy for the majority of the rural population.

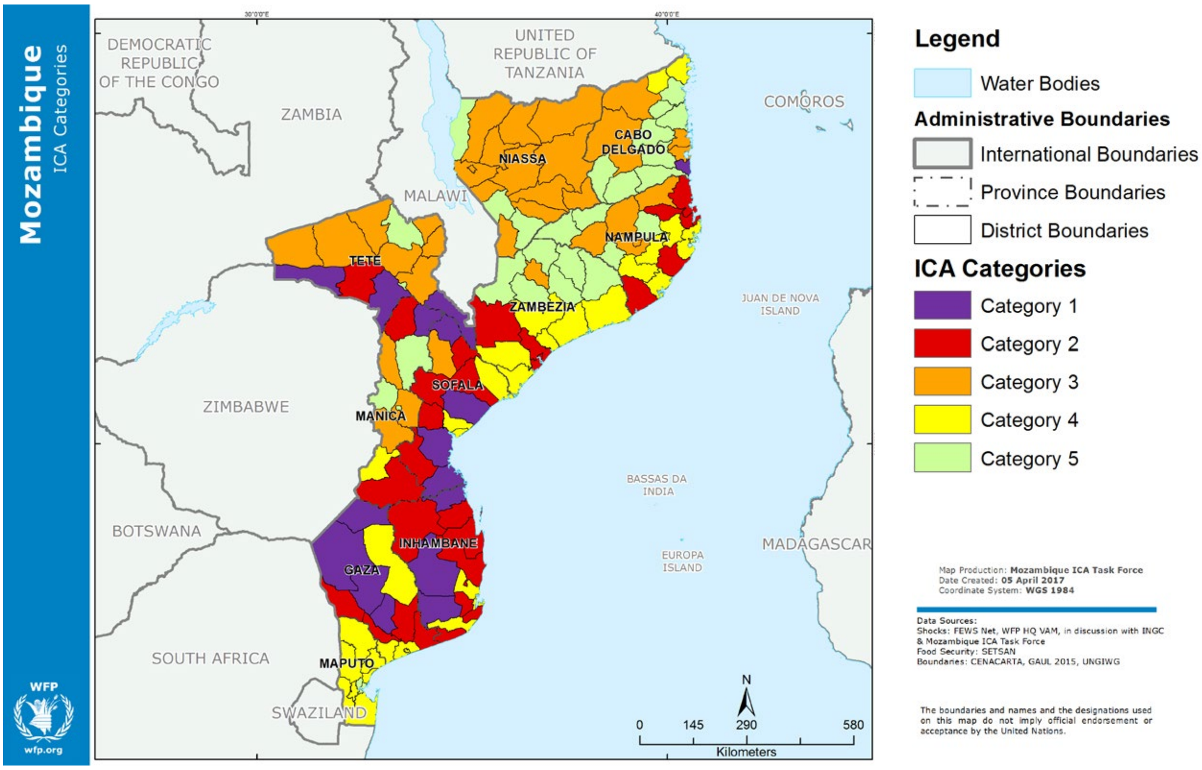
The bulk of activities across these sectors, fisheries, forestry, cropping, and livestock, are based in rural areas. These are also the sectors that employ the bulk of the population, especially those that are food and income insecure. Therefore, they hold great potential for the achievement of national development commitments, as represented in the Sustainable Development Goals. As such, it is important to look into the adaptation and transformation of these sectors for the future of the country, especially in the context of a changing climate, noting that Mozambique is one of the most vulnerable countries in terms of exposure to natural hazards, namely drought, floods, and cyclones.

CURRENT FOOD SECURITY AND NUTRITION STATUS

Food insecurity in Mozambique remains a key concern, despite of recent improvements. Food insecurity prevalence dropped from 56 percent of the population in 2003 to 24 percent of the population in 2015. This is a significant reduction of 32 percent in 12 years. Generally, food insecurity is chronic in nature. Food insecurity rises during the lean season (December to March generally, with some regional variations between North and South), when food stores from the previous harvest have been exhausted. With the high occurrence of climatic shocks, food production and stores are minimized and the duration of lean season has been increasing. With shocks of this nature occurring with little time in between to allow households to recover, there has been a negative trend in terms of food security. This creates a complex relationship between chronic and acute food insecurity in the country.

WFP, working with partners. developed the Integrated Context Analysis (ICA) for Mozambique to explore the trends of food insecurity across the country (WFP, 2017). The ICA used the Food Security and Nutrition Baseline data from SETSAN for the years 2006, 2009, and 2013. In addition, the ICA used data from the Vulnerability Assessment from 2012 to 2016. The food security threshold was set at 20 percent of the population indicating that within the area of study (the district) at least one in five households was food insecure. By putting together this data, the ICA was able to capture both chronic and acute cases of food insecurity. The ICA output indicated that the most food insecure provinces in the country include Tete, Sofala, Manica, Inhambane, and Gaza (Figure 3). Notably, the ICA also indicates that these are also locations with great exposure to natural hazards, considering drought, floods, and cyclones. With this additional lens, the provinces of Tete, Sofala, Manica,

FIGURE 3
Map of ICA priority areas (WFP, 2017)



Exposure to Natural Shocks	Recurrence of Food Insecrity above Threshold		
	LOW	MEDIUM	HIGH
LOW	Area S	Area 3 B	Area 3 A
MEDIUM	Area 4 B	Area 2 B	Area 1 B
HIGH	Area 4 A	Area 2 A	Area 1 A

Gaza, and Inhambane are shown to be the most vulnerable and prone to food insecurity. Malnutrition is more pervasive in nature, when compared to food insecurity. The national stunting prevalence of 43 percent of children aged below five years in 2011 was relatively unchanged from 1997 (45 percent). Six of eleven provinces have high levels of stunting, most of which are in the northern region, including Nampula (55 percent), Cabo Delgado (53 percent), Niassa (47 percent), Zambézia (45 percent), Tete (44 percent), and Manica (42 percent). It is also worth noting that stunting is higher in rural areas compared to urban areas and also higher among females over males. Key drivers of malnutrition are poor diet quality and poor absorption due to infectious disease and parasitic disease,[3] resulting in micronutrient deficiencies. The Fill the Nutrient Gap Study for Mozambique concluded that most households in the country can afford to meet their energy needs, but it would cost them four times as much to afford a nutritious diet (WFP, 2018). Nutrition security in this context is currently out of reach for many in the country. Non-affordability and stunting prevalence is influenced by seasonal gaps and climate shocks, as evidenced by prevalence rate increases during the lean season and following climate shocks, like the recent El Niño event (WFP, 2018).

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[3] The key diseases of concern are malaria, HIV, and diarrheal disease.

When considering food and nutrition security, it is also important to note that access to improved water sources is limited across the country, affecting food production, processing, and consumption. Just over half of the population, 51 percent, have access to improved water sources (Water Aid 2016; UNICEF 2014). The disparity between urban and rural settings is great. In urban areas, 84 percent of the population have access to improved water sources, compared to just 37 percent in rural settings. It is also worth noting that the main water sources in rural areas are unprotected wells, accounting for 42 percent, and surface water. A key challenge in rural settings is the lack of management of surface water. Mozambique has 104 major river basins which also channels water resources from other countries, however, this is not greatly used or stored.

DRIVERS OF FOOD INSECURITY

In Mozambique, agricultural value chains are underdeveloped, characterized by challenges across the different components, namely: production, harvesting and transport, processing, distribution and sales. This has undermined the potential of the sector and also the country's progress in terms of food security and nutrition. Table 1 shows some of the key challenges across the value chain that negatively affect food security and nutrition.

The bulk of the agricultural sector in Mozambique is rainfed and done by smallholder farmers, which is highly vulnerable to changes in climate and weather.

TABLE 1

Table summarising the key challenges to food and nutrition insecurity in Mozambique

Production	• The country has 36 million hectares of arable land of which less than 10 percent is in use (FAO, 2007, 2015). • Food production is predominantly low-input and low-output, as it is mainly done by smallholder farmers in rainfed systems. • Poor access to extension support, irrigation, seeds, fertilizers, pesticides, fodder, veterinary services, grazing areas, and financing options for investment in production. • Production of food staples has increased since the end of the 20th century, but national per capita production has declined in recent years (except for cassava). For maize, productivity is approximately 800 kilograms per hectare which is less than half the average for the southern Africa region (IIAM, 2006). • Aquaculture potential remains unexplored, with the bulk of the fishery sector done by smallholder actors (UNCTAD, 2017). • Livestock are concentrated in few areas (Southern and central regions) where there is natural pasture for grazing. However, this concentration and dependence on natural pasture limit the growth of the sector. Limited access to veterinary services, also keep production low, and not readily suited for sale (FAO, 2005).

(Continued...)

(…Continued)

Harvesting and transport	• Overall, post-harvest loss rate is unknown for the country. Estimates approximate the loss rate at 25 percent. • For maize specifically, loss rates in the northern and central regions is estimated at 12 percent and 18 percent for the southern region. The regional difference comes from the greater availability of storage facilities in the northern and central regions, when compared to the southern region. • For sorghum and millet, the loss rates are approximately 6 percent throughout the country, reflecting the lower susceptibility of sorghum to storage pests and the lower volumes stored (FAO, 2011). • For cassava, loss rates have been assumed to be 40%, 25% and 15% in the northern, central and southern regions, respectively. The losses (for cassava) are assumed to be mainly due to lack of effective harvesting, and therefore, higher figures are associated with high production areas where surpluses can most reasonably be expected (ibid). • A 10 % loss has been assumed for wheat and rice (ibid). • For both livestock and fishery sectors, the bulk of the production is for domestic consumption, since there are limited options for storing and transporting the produce under suited conditions for long distances. • Population density is low with 26 inhabitants per kilometer squared, which results in a need to travel long distances to reach markets for the sale of produce. • Nationally, 42 percent of the population live more than 30 minutes walking distance from a market and 76 percent live more than 2km from any road (WFP, 2017). As a result, large sections of the population are unable to sell produce, earn an income or purchase the goods needed.
Processing	• The limited production and high loss rates mean that little produce makes it to the processing stages (FAO, 2011). • Even the commodity that makes it to the processing stage, the quality may not be suited to allow for processing. Missing established food quality standards are also aggravating the situation. • The financial capacity of processing entities, especially those in remote rural areas, is often limited, restricting their capacity to process high volumes of raw materials. • Processing of commodities is limited in range, focusing on a few select crops, and within basic levels of processing. Value addition activities, are therefore, few. • Limited processing opportunities act as a bottleneck for market outlets, especially for the export of meat and fish which require refrigeration or drying of the produce before being exported. • Inadequate market information can also act as a bottleneck for processing, as farmers have little knowledge of the possible market opportunities. • Less constraints are faced in the cash crop sector (e.g. cotton, sugar, cashews), but it is still largely limited to primary processing.
Distribution and sale	• Consumption outstrips national production for rice, wheat, vegetable oil, and meat. As a result, these products are imported (UNDP, 2019). • Imported goods are subject to different terms (e.g. duties) which affect the price. Price volatility among imported, food commodities has been a key characteristic in recent years (ibid). • In some cases, prices of imported goods are far below the prices of local goods, which hinders the growth of the national sector. • In other cases, the prices are high (and variable) without a national substitute, restricting access to these goods. • The country is self-sufficient in terms of maize, cassava, beans, and pulses, but the fragmented markets make it hard to access these widely. • Market fragmentation is characterized by limited traders, low prices, big distances, lack of market information, among other factors.

3. Defining the baseline climate and food security in Mozambique

WFP provides school assistance to Mozambique children through the provision of daily school lunches and take-home rations for girls and orphans. WFP is supporting the government with the design of a nationally-owned school meals programme.

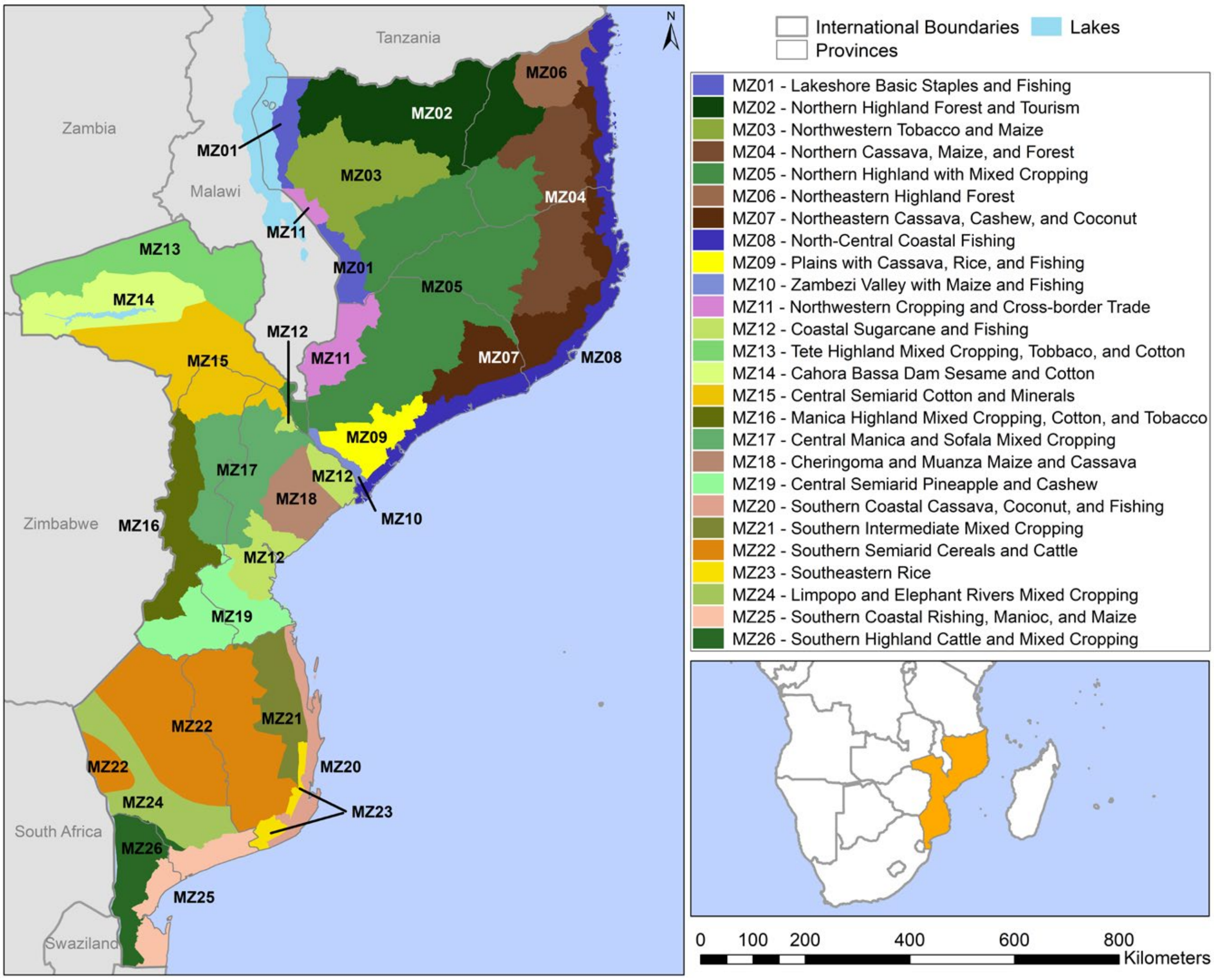
3.1.
Livelihood and climate zoning: defining climate zones A, B and C

Using participatory and consultative methods with key national stakeholders, a scheme was developed to enable discussions on the impacts of a changing climate on the prevailing livelihood systems. Leveraging this, analysis was conducted to estimate the likely impacts on food security. This section provides an overview of the scheme developed and the climate sensitivities explored for the different livelihood systems.

Mozambique is a large country with great diversity. The country is divided into 11 provinces, 154 districts, and 407 administrative posts. There are 10 different agro-ecological zones, based on the varied topography, climate, biodiversity, and soil profiles of the country. Finally, there are 26 livelihood zones (LHZ) defined by FEWSNET and SETSAN (2014). These are shown in Figure 4.

FIGURE 4

Livelihood zones of Mozambique, as defined by the FEWS-NET and SETSAN Livelihood zoning anaysis



Source: FEWS-NET & SETSAN, 2014.

With a focus on agriculture, livelihoods in Mozambique can be summarized into four main categories, with some overlap:

1. **Livestock**
   MZ22, MZ26[4]
2. **Cropping**
   MZ03, MZ04, MZ05, MZ07, MZ09, MZ10, MZ11, MZ12, MZ13, MZ14, MZ15, MZ16, MZ17, MZ18, MZ19, MZ20, MZ21, MZ22, MZ23, MZ24, MZ25, MZ26,
3. **Forestry**
   MZ02, MZ04, MZ05, MZ06
4. **Fishery**
   MZ01, MZ08, MZ09, MZ10, MZ12, MZ14, MZ20, MZ24, MZ25

These categories are supported by the stakeholder consultations.

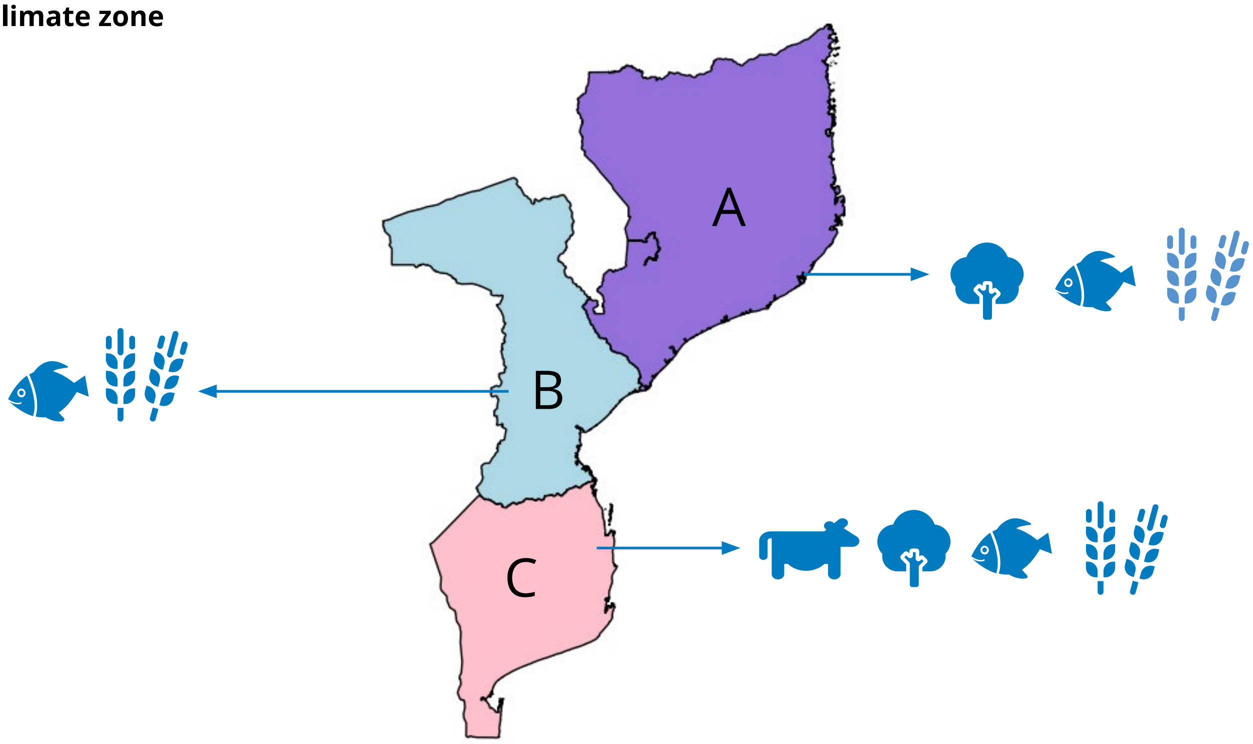
Figure 5 shows the distribution of the livelihood categories across climate zones A, B and C, which have been defined for use in this study. Climate zones A, B and C are defined by grouping the 26 livelihood zones into three climatologically similar zones that reflect the average rainfall in Mozambique (Figure 2). The specific livelihood zones included in each climate zone are:

- Climate zone A (MZ01 – MZ11)
- Climate zone B (MZ12 – MZ19)
- Climate zone C (MZ20 – MZ26)

This approach of grouping livelihood zones to define the climate zones enables analysis and interpretation of the key climate sensitivities of these livelihoods and the baseline climatology within each zone (see also WFP, 2016). The climate zones are also at an appropriate spatial scale for analysing data from climate model projections (see Section 4).

FIGURE 5

Climate zones A, B and C: Icons show the major livelihood categories in the respective climate zone



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[4] Livestock is not limited to the southern region. However, it is the most predominant region where livestock-based activities are practiced. Livestock keeping is increasing in importance in semi-arid areas in the north and central regions, like the province of Tete. This is a recent trend being driven by climate change, which is making it harder to depend solely on cropping as a livelihood.

3.2.

Climate sensitivities of main livelihoods in Mozambique

The consultations also helped identify the climate sensitivities of the livelihood systems and the likely impacts under a changing climate. These are summarised in Table 2. Vulnerability in this context is understood as the driver of climate risks. The impact focuses on the consequences when such a climate risk. Notably, Table 2 focuses on the vulnerabilities and impacts associated with the current climate and weather trends, it does not consider future climate projections.

Communities are motivated to shift to drought tolerant crops as a climate adaptation measure in the province of Gaza, including the production of cassava.

TABLE 2

Table summarising climate sensitivities, key vulnerability factors and the observed impact on each of the main livelihoods in Mozambique

Sector	Climate sensitivity	Current Vulnerability Factors	Observed Impact
Livestock	High temperatures and dry conditions impact the availability of grazing areas and water for livestock. Farmers need to travel farther away for food and water, as supplementary feeding is not a wide practice. The stress on livestock, as a result of these changes, compromises the quality and quantity of meat, dairy, and other animal products. This, in turn, affects the price and bankability of livestock activities. Higher temperatures are also associated with an increase in disease, especially vector borne disease, which poses a considerable danger as access to veterinary services is limited. Marketing of livestock and related produce is constrained, given cultural preferences, but also lack of information and opportunities.	• Dependence on open pasture and rain-fed model, without access to supplementary feeding or veterinarian services. • Livestock raised in drought-prone areas, where conditions are increasingly hotter and drier. • Low access to livestock support services and management practices are limited. • Large number of units by a small-scale farmer, which places great pressure on limited resources. • Limited market access and information to support the sale of livestock and related products.	• Hotter and drier conditions making it harder to access food and water for livestock, in addition, competition across sectors is increased (crop farming or household consumption) • Increase in disease and mortality, affecting the quality and availability of livestock and related products, reduction in marketing opportunities. • Livestock is a way for households to save and invest, while also a means for liquidity, as needed, which is being jeopardized given reductions in quality and availability of stocks. • Livelihoods constrained, with poverty increasing as well as food insecurity, including diet diversity reductions.

(Continued...)

(...Continued)

Sector	Climate sensitivity	Current Vulnerability Factors	Observed Impact
Cropping	The main food crops are maize and cassava, followed by pulses, roots, and tubers. These, as previously noted, are mainly grown in subsistence and rainfed systems by smallholder farmers. This makes them highly sensitive to weather patterns. For Maize, the optimum temperature is 20°C and the maximum is 45°C, with water requirements of 500 to 800mm. For Cassava, the optimum temperature is between 25 and 29 °C, while its water requirements are just above 400 mm. The growing period for these crops vary according to the seed variety being grown. Hotter and drier conditions are negatively affecting the production of these crops, while also giving rise to pest and disease, most notably the fall army worm. Besides the plant stress this causes, it also affects the soil. Crusting and other types of soil erosion are increasing in prevalence, especially as periods of intense rain are followed by prolonged periods of dryness. This sort of rainfall variability in rainfed systems have been considerably hard to manage by smallholder farmers, who lack access to irrigation, extension support, quality inputs, financial resources, and climate information. Finally, with these challenges, the produce is mainly used for own consumption, there is limited capacity to generate a surplus for trade. However, when this is possible, there are limited post-harvest techniques and technologies available to preserve the produce, while also limited access to market opportunities, which also discourage farmers from trading. (Chapman et al., 2020)	• Dependence on low input-output, rainfed systems that are weather sensitive, with limited agricultural practices to optimize production. • Reliance across the country on maize, which has a very high sensitivity to rainfall deficits during the flowering and grain-filling stages. A short but intense dry spell can have a large impact in an otherwise normal rainfall season. • Poor access to services that can assist with making agriculture more productive even in a changing climate, such as extension support, water and transport infrastructure, market and climate information, financial resources, and market opportunities (input and output) • Cultivation done in drought prone areas, which places both plants and soil under stress. • Emergence of disease and pests with limited capacities to manage these. • Crop varieties for hotter and drier conditions are few and not readily accessible to smallholder farmers, so there is a reliance on weather sensitive crops. • Postharvest losses are considerable with limited access and knowledge about the appropriate techniques and technologies to use.	• Quantity and quality of crops being compromised as they are under a lot of stress during critical stages of crop growth. • Building on the above, the potential for surplus for processing and trade is diminishing, negatively affecting the profitability of farmers. • Soil fertility being lost, driving the intensification of negative practices in plots that are increasingly of smaller size, as farmers cannot afford inputs needed. • Duration of growing period, with optimal rain and temperatures, is becoming more variable and generally shorter, negatively affecting the seasonal calendar. • As the bulk of the sector is smallholder-based, the incidence of food and income insecurity is increasing, with many having to rely on limited incomes to ensure their basic needs are met. Poor nutrition is also being driven by this. • Existing water infrastructure also being degraded given the higher temperatures and drier conditions, further reducing their potential. • In terms of the natural water resources available, these are diminishing, and salinity is becoming increasingly an issue. • A positive impact is the diversification of crop types and varieties used by farmers as they try to adapt to the hotter and drier conditions.

(Continued...)

(...Continued)

Sector	Climate sensitivity	Current Vulnerability Factors	Observed Impact
Forestry	Forests provide protection from soil erosion, contribute to stabilizing temperatures, and enable ground water recharge. Forests also provide non-timber forest products (NFTPs) that local communities rely on for food, medicine, and energy. Reductions in farm production has led to a greater demand for NFTPs. In addition, forest land is being converted into farmland. With limited management practices, the forest resources are being diminished, affecting the overall ecosystem. Besides negatively impacting the productivity of the system, it makes it more vulnerable to natural disasters.	• Growing demand for NTFPs and alternate sources of income to meet basic household needs. • Forest products, especially for meeting fuel needs, are highly lucrative. • Low incentives and knowledge about the benefits of the forest to the overall productivity and stability of the ecosystem. • Forest management, including policies and practices, are limited. • Prevailing hotter and drier conditions are being exacerbated by the loss of forests and forest resources. • High rates of deforestation already recorded, making the ecosystem vulnerable to external hazards, like drought or floods.	• Marked reduction in ecosystem health and diversity, affecting the productivity of production systems. • Reductions in resources for food and fuel, among other forest-based products, which is driving food, nutrition, and health issues. • Higher competition for resources, resulting in intensification of practices. • Mangroves are also being poorly managed affecting coastal zones, resulting in salt water infiltration and destabilization of nearby soil structures.
Fishery	The reduction in fish stocks compromises the stability of the overarching ecosystem. Higher sea temperatures are driving this negative trend. As such, the capacity of the marine ecosystem to cope with these stressors has been markedly reduced. In this context, climate change and variability pose a great threat to fisheries. With poor practices and limited resources, the largely artisanal sector is made more vulnerable to these variations, including hazards such as cyclones and tropical storms. Comprehensive management plans and infrastructure to protect the ecosystem are largely missing within the sector. Extractive industries focusing on coastal areas, eroding the natural asset base.	• Dependence on poor management and fishing practices that can negatively affect the ecosystem. • Some key fishing areas are located in high risk areas where there is a high incidence of natural hazards, such as cyclones and tropical storms. • Infrastructure and regulation implementation lacking to support enhanced practices for fisheries management. • Markets are underdeveloped and fishing communities have limited resources to invest in enhanced practices. • Lucrative industries competing for space along the coastline.	• Reduced reproduction of fish stocks, resulting in negative impacts on trophic levels (loss of diversity), as well as the larger ecosystem. • Coping capacity of natural systems is further limited, resulting in reduction of fishing areas. • Fishing communities experience more food and income insecurity, while health hazards also possible as the health of the environment is also comprised.

3.3.

Baseline assessments of climate zones A, B and C

This assessment draws together specific analysis of the baseline climate in each of the climate zones with the information about the dominant livelihoods and their climate sensitivities (as defined in Sections 3.1 and 3.2). The climate analysis focuses on average annual rainfall amounts and average daily maximum temperatures and how they vary across the zones (using the maps shown in Figure 6 and averages per climate zone in Table 23) and throughout the year (using the annual profiles shown in Figure 7). For all climate zones, the general shape of the annual profiles of both temperature and rainfall is fairly consistent from year-to-year, however, there is variability in the specific values. Year-to-year variability is higher for rainfall amounts compared to temperature, and specifically during the rainy season, whereas variability in temperatures occurs throughout the year (Figure 7). Maps of exposure to key natural hazards from the ICA are also used to define these baseline assessments (Figure 8).

FIGURE 6

Maps of the average total annual rainfall from the CHIRPS dataset (Funk et al., 2015; left panel) and annual average daily maximum temperature from the WATCH dataset (Weedon et al., 2014; right panel) in Mozambique for the baseline period (1981-2010)

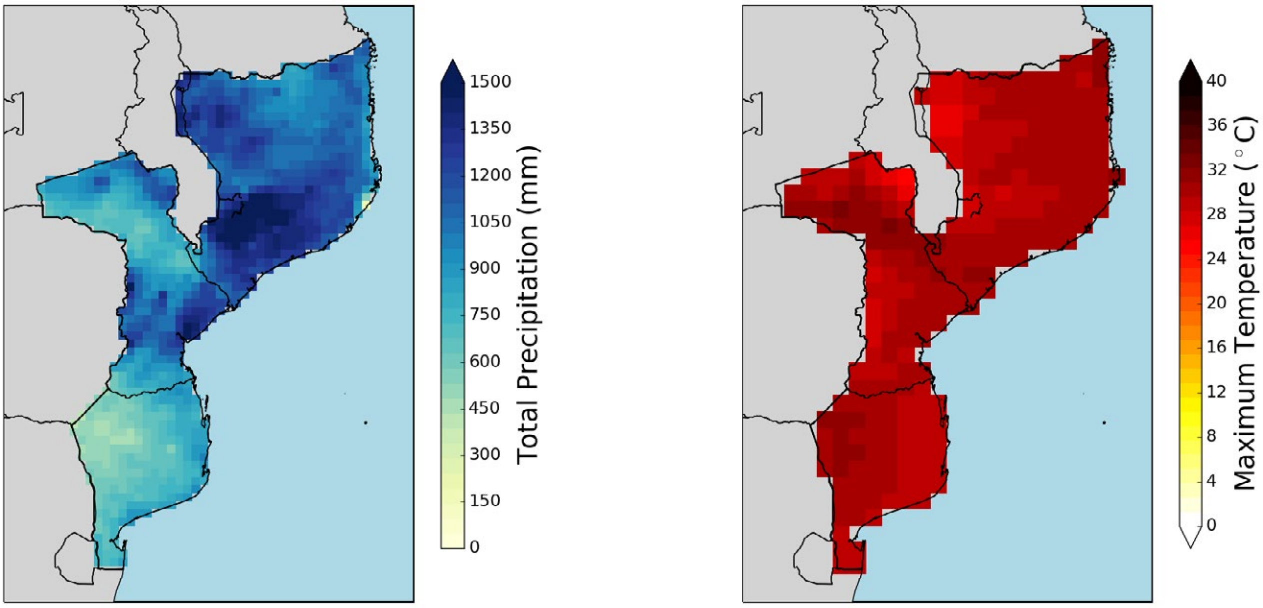


TABLE 3

Baseline climatology values (± standard error) for the whole of Mozambique and climate zones A, B and C

Region	Average annual rainfall (CHIRPS; Funk et al., 2015)	Average value of daily maximum temperature (WATCH; Weedon et al., 2014)
Mozambique	995.1 ± 25.3 mm	29.8 ± 0.1 °C
Climate zone A	1164.7 ± 29.2 mm	29.7 ± 0.1 °C
Climate zone B	937.0 ± 33.8 mm	29.9 ± 0.1 °C
Climate zone C	677.2 ± 30.0 mm	30.0 ± 0.1 °C

FIGURE 7

Annual cycles of rainfall (left panels) and maximum temperature (right panels) for the baseline period (1981-2010) for climate zones A (top panels), B (middle panels) and C (bottom panels). Individual years from 1981-2010 are shown with coloured lines (ranging from brown to blue for rainfall, and blue to red for temperature), and the mean monthly values are shown in black. This highlights the year-to-year variability in rainfall and temperature values

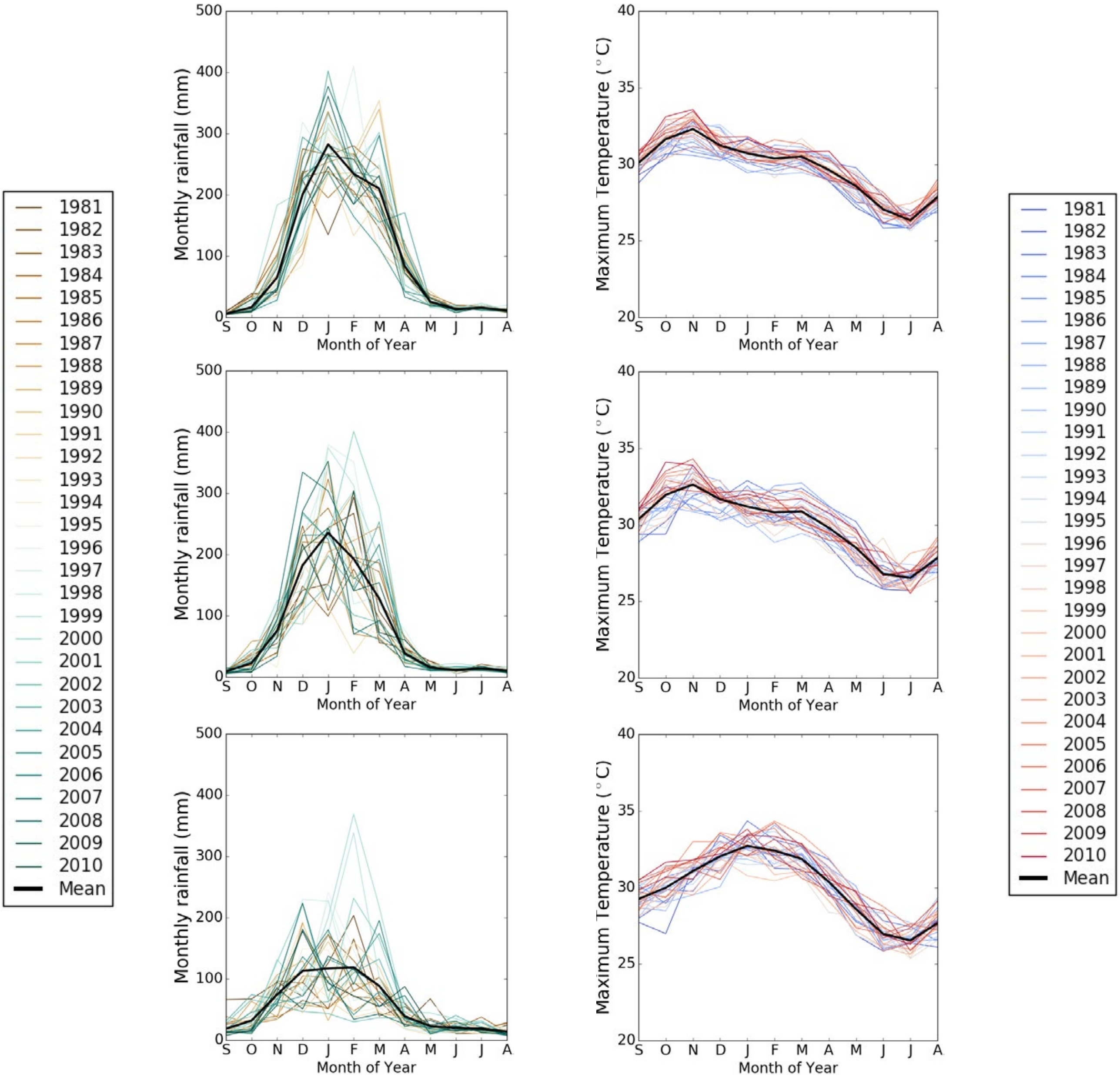
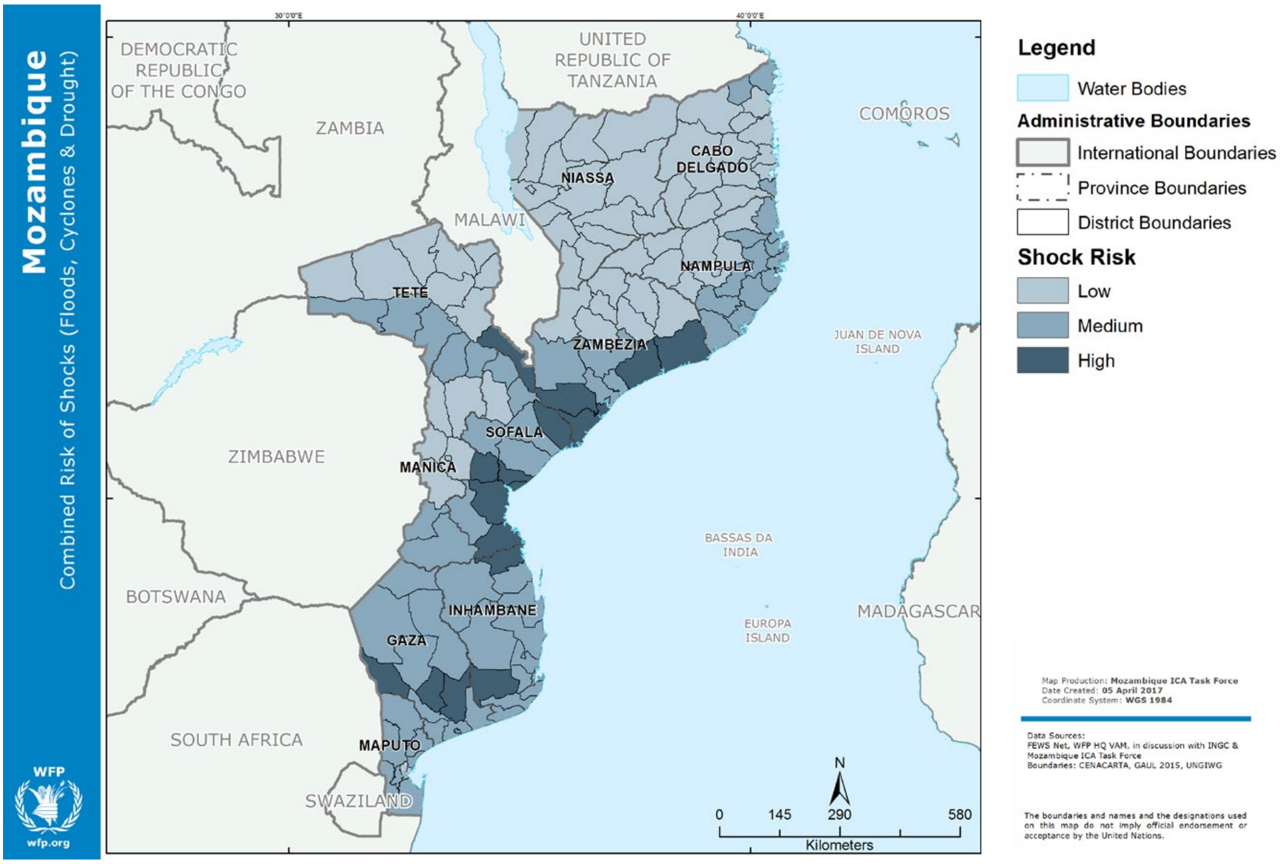


FIGURE 8
Maps of exposure to floods, droughts and storms from the ICA



Map Production: **Mozambique ICA Task Force**
Date Created: **05 April 2017**
Coordinate System: **WGS 1984**

Data Sources:
FEWS Net, WFP HQ VAM, in discussion with INGC & Mozambique ICA Task Force
Boundaries: CENACARTA, GAUL 2015, UNGIWG

The boundaries and names and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Source: WFP, 2017.

CLIMATE ZONE A

The topography of climate zone A is predominantly highlands with lowlands along the east coast (Figure 1). Climate zone A is the wettest of the three climate zones with around 1165mm of rainfall per year (Table 3) and these amounts range from around 1000mm in the south and north-west of the zone to around 1500mm in the south (Figure 7, left panel). The peak of the rainy season occurs during December to March, with around 200mm to 300mm per month on average (Figure 7, top left panel). Rainfall amounts vary from year-to-year, with some years the rainy season peak reaching around 400mm per month and others only around 150mm per month (Figure 7, top left panel). The average value of daily maximum temperature is highest (around 32°C) in November at the start of the rainy season, and lowest (around 26°C) in July (Figure 7, top right panel). Climate zone A has the highest exposure to tropical cyclones compared to climate zones B and C, and there is a high risk of flooding events in the Zambezi River basin in the southern part of climate zone A (WFP, 2017).

The main livelihood activities in climate zone A are a mix of fishing, cropping, and forestry. Although fishing is the key livelihood activity in these LHZs, other livelihood activities are also undertaken to supplement and diversify income, such as growing crops for sale or own consumption, sale of timber, or working in the tourism industry.

The key risks facing coastal fishing livelihoods (MZ08) are declining fish stocks, as a result of destructive fishing methods, and storm and flooding impacts due to the high exposure to tropical cyclones in this climate zone. LHZ MZ10 in the southern part of climate zone A is most affected by frequent and heavy flooding of the Zambezi River (FEWS-NET & SETAN, 2014).

The LHZs which are dominated by agricultural production grow a range of subsistence and cash crops. The main subsistence crops grown are maize, cassava and rice (MZ03, MZ05, MZ07, MZ09, MZ10), and the main cash crops include tobacco and cashew (MZ03, MZ07). Other crops are also produced both for own consumption and sale but to a lesser extent, and some livestock is also reared (FEWS-NET & SETAN, 2014). Agricultural livelihoods are often supplemented by forest-based livelihoods, such as sale of timber or charcoal, particularly for the poor (MZ02, MZ04, MZ06).

Agricultural production across many of the LHZs in climate zone A is relatively high due to the high and reliable rainfall amounts in this climate zone. Dry spells and flooding events can impact crop production across many of these zones, particularly in drier years and wetter years respectively, but the risk is lower in this climate zone compared to others. However, flooding from the Zambezi River (Figure 8) in the south of the climate zone can significantly impact agricultural production as well as fishing in MZ10. The forest dominated LHZs MZ04 and MZ06 are also at risk of wildfires, which are of particular concern during dry years and drought conditions.

With reference to the ICA, climate zone A has experienced the least recurrences of food insecurity across all three zones (Figure 3). However, given the high exposure to hazards. like floods and cyclones along the costs of Zambezi, Nampula, and Cabo Delgado, and to a lesser extent dry spells in the mainland of these same provinces, there are some hotspots, which are vulnerable to food insecurity. This type of food insecurity is more acute in nature due to the relationship to climate shocks. Malnutrition is highest in this climate zone.

Climate hazards disproportionately affect the most vulnerable individuals in Mozambique, for whom even a small weather event can quickly escalate into a food and nutrition crisis.

CLIMATE ZONE B

Climate zone B features a mixture of highlands in the north-west and lowlands in the east, with the Zambezi River running from west to east though the zone (Figure 1). The annual rainfall pattern is more mixed across this zone compared to the other climate zones, with annual rainfall of around 940mm per year (Table 3) which ranges from around 500mm in the north of the zone to around 1200mm in some areas in the south of the zone (Figure 7, left panel). The peak of the rainy season occurs during December to February, with around 150mm to 250mm per month on average (Figure 7, middle left panel). Similarly, to climate zone A, rainfall amounts vary from year-to-year with some years receiving around 100mm per month and others around 350mm. (Figure 7, middle left panel). Daily maximum temperatures are very similar in this zone compared to climate zone A, with the peak (around 32°C) occurring in November at the start of the rainy season, and lowest values occurring (around 26°C) in July (Figure 7, middle right panel). Climate zone B has a high risk of drought events across the central and western part of the zone, which correspond to southern parts of Tete and northern parts of Manica and Sofala (Figure 8). In addition, there is a high risk of flooding events, particularly in the eastern part of the zone and around the major river basins, for example the Zambezi and Buzi rivers (Figure 8). This generally affects Sofala and to a lesser extent Tete's south-eastern regions. The eastern coast is also exposed to tropical cyclones, although the frequency has been lower over the recent climate compared to climate zone A (Figure 8).

Livelihood activities in climate zone B are predominantly agricultural and include a mix of subsistence and cash crops. In general, there are more cash crops produced in this climate zone compared to the other climate zones. Subsistence crops are mainly maize and sorghum, with some cassava, beans, sweet potatoes and vegetables. These crops are grown all over the region, therefore, due to the range of climate conditions across the region the crops produced in the wettest regions (e.g. MZ13, MZ16, MZ17 and MZ18) are less vulnerable to climate impacts than crops grown in other drier parts where there is a high risk of drought (e.g. MZ14, MZ15 and MZ19). Drought risk in the zone is concentrated in parts of southern Tete and northern parts of Sofala and Manica (Figure 8).

Household level assets being promoted to strengthen climate resilience.

Cash crop production includes tobacco, cotton, sesame, cashew, pineapple and sugarcane. Tobacco is mostly grown in relatively wet regions (MZ13 and MZ16) resulting in low food insecurity risk for these LHZs. Cotton production is grown across a range of climate types within climate zone B; MZ16 is has good climatic conditions for cotton production, whereas MZ14 and MZ15 experience drought and semi-arid conditions making cotton production more vulnerable to climate variability. Similarly, cashew and pineapple production in the semiarid region in the south of climate zone B (MZ19) is at risk of drought conditions.

In addition to agriculture, fishing is another key livelihood in climate zone B. Livelihoods in the Zambezi and Buzi river basins (MZ12) are predominantly fishing but there is also some diversification of livelihood activities across crop and livestock production. Flooding is a major risk for livelihoods in these regions, and low market access due to poor transport infrastructure (FEWS-NET & SETSAN, 2014). Fishing is also the dominant livelihood activity in the Cahora Bassa Dam (MZ14).

Food insecurity in climate zone B compared to climate zone A is greater (Figure 3). Chronic levels of food insecurity are higher, but also acute cases, the latter driven by the higher occurrence of climatic shocks, including drought, floods, and cyclones (Figure 8). In Tete province, the districts most food insecure (taking into account occurrence of food insecurity and hazard risks) include Mutarara, Changara, Chiuta, Magoe and Moatize. For Sofala province, the most food insecure and at-risk districts are Bazi, Chemba, Machanga, and Muanza. Finally, for Manica, this includes Tambara district. Food insecurity still occurs in other districts of the province, but these are the ones that have the highest risk to food insecurity given the prevailing food insecurity levels and hazard risks.

CLIMATE ZONE C

Climate zone C is the driest of the three climate zones with annual rainfall amounts of around 680mm per year (Table 3), and these range from around 300mm in the north-west of the zone to around 700mm in the north-east (Figure 7, left panel). The peak of the rainy season occurs during December to February, with around 100mm to 150mm per month on average (Figure 7, bottom left panel). Rainfall amounts are highly variable from year-to-year in this climate zone (WFP, 2018; Figure 7, bottom left panel), and since there is less rain expected on average in some years the rainy season peak only reaches around 50mm per month, whereas other years rainfall amounts can be up to around 300mm per month (Figure 7, top left panel). Daily maximum temperatures in this climate zone are within the same range of values as the other climate zones, but the distribution throughout the year is different as the highest values (around 32°C) occur later in the year during January (Figure 7, right panels). The coolest part of the year (around 26°C) also occurs in July, consistent with the other climate zones Figure 7, right panels). Climate zone C has high exposure to drought conditions across most of the zone (WFP, 2017). In addition, flood risk is high in this zone, particularly around the major river basins, for example around the Limpopo basin in the south and the Save river basin in the north-east of the zone (WFP, 2017). Similarly, to climate zone B, the eastern coast is also exposed to tropical cyclones, although the frequency has been lower over the recent climate compared to climate zone A (WFP, 2017).

Similarly, to the other climate zones, the main livelihood activities in climate zone C are cropping, livestock, and fishing. Livelihood activities are focused mainly on the production of subsistence crops, such as maize, rice and cassava, and also livestock production, which is more prevalent in climate zone C, compared to the other climate zones. Of the cropping LHZs, those located in the driest parts of the region are more susceptible to heat stress and water stress impacts on crop production, particularly during drier years when the risk of drought conditions is higher. In addition, maize is the most vulnerable crop as its water requirement is higher than other crops. However, sorghum is not grown in this part of the country for cultural and food preference reasons.

MZ22 in the central dry part of the climate zone has lower and less reliable rainfall amounts. Cattle are also a key livelihood activity in this LHZ and are impacted by lack of water and pasture availability due to the climate conditions.

Coastal fishing (MZ20) is exposed to the impacts of tropical cyclones, whereas there is a high flood risk in LHZs dependent on river fishing (MZ24).

There has been a high level of food insecurity recurrences in climate zone C, particularly in the central parts of Gaza and Inhambane (WFP, 2017). Like in climate zone B, food insecurity in climate zone C, is both chronic and acute in nature. In Gaza, drought is a key driver of food insecurity, while flooding along the Limpopo River Basin is also a hazard affecting local production (Figure 8). The districts most at risks (of both food insecurity and hazards) include Guija, Mabalane, Chicualacuala, and Massangena. In Inhambane, flood risk is also found along the Limpopo River Basin, and drought risk closer inland. Govure and Panda districts in Inhambane province are the most at risk for food insecurity.

Communities receive hands-on trainings and support to transition to drought tolerant crop production as a suited climate adaptation measure in parts of Gaza province.

4. Scenarios of projected climate change and outcomes for livelihoods and food security for the 2050s

WFP speeding up food distributions, WFP's food is part of a multi sectoral support package which will be dropped at each location side. Food and health are the priority. WFP Helicopter being loaded in Beira airport.

For the purpose of this study, two plausible scenarios of projected climate change for Mozambique have been considered. Scenarios are not predictions but are a sample of what is plausible across the range of modelled changes. They provide a useful basis for exploring what different levels of climate change might mean for future food security in Mozambique.

The scenarios were chosen to represent two different possible futures that sample the range of projected outcomes. The scenarios are results from analysis of two global climate model simulations for the 2050s (2041-2070) under the RCP8.5 greenhouse gas concentration pathway (van Vuuren et al., 2011). These scenarios are presented in this section, along with assessments of the associated pressure on livelihoods and indications for food security. More detail on the methods and choice of scenario is given in Appendix B.

4.1.
Summary of scenarios and outcomes

The projected climate change in Mozambique for each of the scenarios considered is summarised below. Along with the projected trends in each of these scenarios, year-to-year variability will continue to bring hotter, cooler, wetter and drier years as a result of natural variability in the climate system. In addition, sea levels are projected to rise and tropical cyclones will continue to impact the country with increased intensity compared to the baseline.

- Scenario 1 represents a future that is hotter and drier compared to the baseline climate. The increased temperatures mean higher levels of heat stress, more frequent and intense heatwaves, and an increase in evaporation. Less annual rainfall means a drier climate over most of the country and combined with the higher evaporation rate can exacerbate water availability issues. The number of consecutive dry days is projected to increase, indicating higher drought risk in this scenario, particularly in drier years.

Many smallholder farmers lost a significant percentage of their produce due to poor storage facilities and poor-storage techniques.

- Scenario 2 represents a future that is warmer than the baseline climate, slightly wetter on average and with more extreme rainfall events. The increased temperatures will also impact heat stress and increase evaporation, meaning that the small increases in annual rainfall are likely to be offset. The increase in frequency and intensity of extreme rainfall events can exacerbate current flooding and tropical cyclone risks, particularly in wetter years.

The specific values of the projected changes in average daily maximum temperature and average annual rainfall are given in Table 4. Summaries of the climate, livelihoods and food security outcomes for the baseline and future scenarios can be found in Table 5. Further detail for each of the scenarios and climate zones is given in Section 4.2.

TABLE 4

Projected change in the baseline climatology values (± standard error) from Table 3 for the 2050s (2041-2070) for the whole of Mozambique and climate zones A, B and C under the two future climate scenarios. The baseline values from Table 3 are also shown for reference

	Climate zone A		Climate zone B		Climate zone C	
	Average annual rainfall	Average value of daily maximum temperature	Average annual rainfall	Average value of daily maximum temperature	Average annual rainfall	Average value of daily maximum temperature
Baseline	1164.7 ± 29.2 mm	29.7 ± 0.1 °C	937.0 ± 33.8 mm	29.9 ± 0.1 °C	677.2 ± 30.0 mm	30.0 ± 0.1 °C
Scenario 1	-181.5 mm (-15.6%)	+3.3 °C	-141.9 mm (-15.1%)	+3.5 °C	+0.2 mm (0%)	+2.8 °C
Scenario 2	+171.7 mm (+14.7%)	+2.2 °C	+134.6 mm (+14.3%)	+2.2 °C	+29.2 mm (0%)	+2.3 °C

TABLE 5

Summary of climate, livelihoods and food security for the baseline and each of the future scenarios

	Climate zone A	Climate zone B	Climate zone C
Baseline	**Climate:** • wettest climate zone; ~1200mm per year • high tropical cyclone risk; • high flood risk in Zambezi River basin **Livelihoods:** agriculture, fishing, forestry **Food security:** lowest, acute	**Climate:** • wet and dry regions; ~900mm per year • high flood risk in river basins • high drought risk in dry regions **Livelihoods:** agriculture, fishing **Food security:** high, acute and chronic	**Climate:** • driest climate zone; ~700mm per year • highest variability in annual rainfall • high flood risk in south • high drought risk in dry regions **Livelihoods:** agriculture, livestock, fishing **Food security:** high, acute and chronic
Scenario 1	Scenario 1 represents a hotter and drier future compared to the baseline, with continued year-to-year variability resulting in more frequent and intense extreme events such as heatwaves and droughts. This climate will result in reduced water availability and increases in heat stress across the country, which will exacerbate the current water and heat stress impacts on crop and livestock production, particularly in drier areas. These conditions will also increase the risk of wildfires, which will negatively affect forestry-based livelihoods. Cropping and fishing livelihoods in coastal regions are at higher risk of storm damage and flooding from tropical cyclones, with damage to transport networks reducing market access and further increasing food security issues across the country. Inland flooding will continue to be a risk in flood prone areas. Chronic food insecurity is likely to increase in the absence of adaptation measures as a result of the long-term trend and slow onset extremes such as droughts. Furthermore, acute instances of food insecurity will also increase due to the continued and increased exposure to the impacts of extreme events such as tropical cyclones and flooding.		
Scenario 2	Scenario 2 represents a warmer future with more extreme rainfall events. The key feature in this scenario is the increased risk of flooding associated with higher intensity rainfall. These flooding events can damage crop production and transport infrastructure, impacting cropping and fishing livelihoods in flood prone regions. As in scenario 1, similar impacts are experienced in coastal regions due to continued exposure to tropical cyclones but with higher intensity and increased coastal flooding associated with these events. Heat and water stress impacts on crop and livestock production are still a feature of this scenario, particularly in drier areas and in drier years, however to a lesser extent than in scenario 1.		

4.2.
Detailed assessment of livelihoods and food security outcomes in each of the climate scenarios

SCENARIO 1

In the 2050s under scenario 1, daily maximum temperatures are projected to be 3.3˚C higher and the annual average rainfall is projected to be 130mm lower compared to the baseline values (around 30˚C and 1000 mm), when averaged across the whole of Mozambique (Table 4). These values vary regionally across the climate zones; this can be seen in the maps of the projected changes shown in Figure 9 and specific values are given in Table 4. Maps of the projected changes on seasonal timescales are also shown in Figure 10.

Protection of tree seedlings planted in drought-affected areas as an adaptation measure.

FIGURE 9

Projected changes in annual average rainfall and daily maximum temperature in Scenario 2 for the 2050s (2041-2071) relative to the baseline (1981-2010)

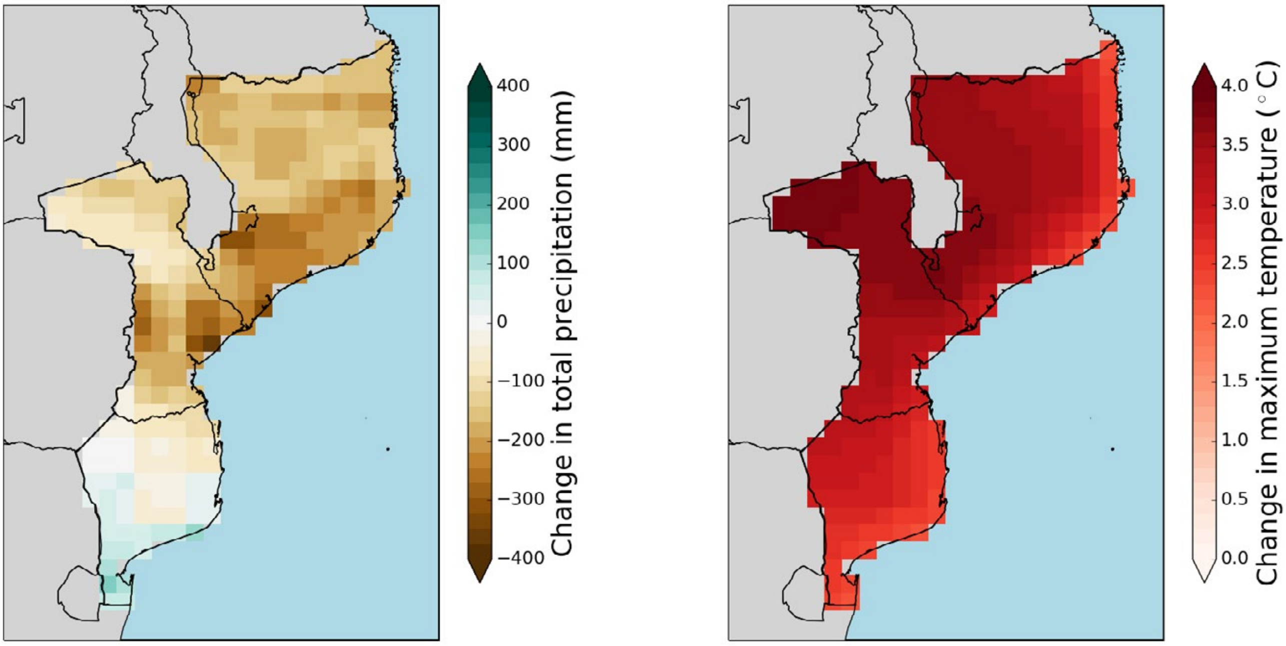
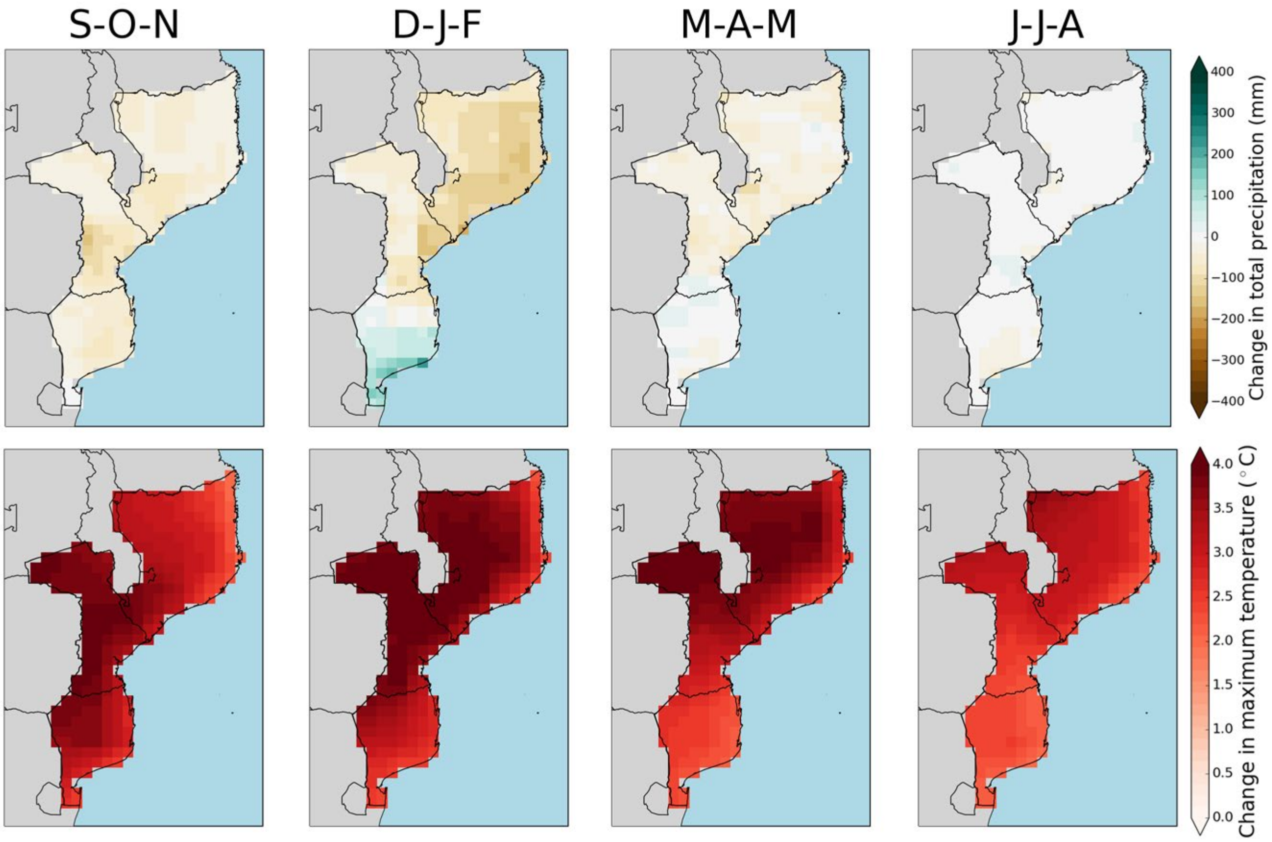


FIGURE 10

Projected changes in seasonal total rainfall (top panels) and seasonal average daily maximum temperature (bottom panels) for Scenario 2. The four seasons are September to November (column 1), December to February (column 2), March to May (column 3) and June to August (column 4)



CLIMATE ZONE A

Climate zone A is currently the wettest of the three climate zones and the projected decrease in annual average rainfall in scenario 1 is largest in this climate zone compared to the other climate zones. The average annual rainfall is currently around 1200 mm per year, and is projected to decrease by around 180mm, or around 15% (Figure 9; Table 4). This decrease occurs during the wettest time of the year, particularly in December to February (Figure 10). Daily maximum temperatures are currently around 30˚C and are projected to increase by around 3.3˚C across the climate zone (Table 4). The highest increases occur during December to February (Figure 10), which can further exacerbate the reduced water available during this period due to higher evaporation rates associated with higher temperatures.

Although agricultural production in climate zone A is some of the highest across the country, and the risk of drought events is relatively low, these projected reductions in rainfall and increases in temperature are likely to impact crop production in this region through increased levels of heat- and water- stress. The drought risk in this zone is currently low, however, the number of consecutive dry days is projected to increase on average (Figure B1[5]), which could increase the risk of drought conditions. The continued year-to-year variability in rainfall amounts will result in the drier years being even drier than in the current climate, and hotter years resulting in potential exceedance of maximum temperature thresholds for some crops (e.g. sorghum and rice). Drought conditions could also impact river fishing livelihoods through reductions in river and lake levels and could exacerbate wildfire risks in the forest areas.

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[5] Located in Annex B.

Despite scenario 1 representing a drier future on average, a hotter climate is also associated with more extreme rainfall events. This will increase the flood risk in the Zambezi River basin, particularly during the wetter years associated with La Niña conditions. In addition, tropical cyclones will continue to impact this high-risk region. The winds and rain associated with the cyclones will be more intense and the coastal flooding associated with the storms is likely to be higher as a result of rising sea levels. These projected changes will increase the risk of fishing livelihoods along the eastern coast due to increased damage to coastal infrastructure, ecosystem destruction and changes in fish stocks.

Current food security instances in climate zone A are low, but with continued and increased risk of extreme events, this risk could be exacerbated, especially if current livelihood and subsistence practices continue. Malnutrition is highest in climate zone A. This trend is likely to prevail, supported by the evidence that malnutrition is exacerbated following climatic shocks (WFP, 2018).

CLIMATE ZONE B

The projected decrease in annual average rainfall in scenario 1 is similar in climate zone B to climate zone A (around 140mm or around 15% of the baseline amount of around 900 mm per year; Figure 9; Table 4). Similarly, this decrease occurs during the wettest time of the year (Figure 10) and also the highest decreases occur in the wettest regions in the baseline climate (Figure 6). Daily maximum temperatures are currently around 30˚C in climate zone B, and this zone is projected to experience the highest increase across all climate zones and future scenarios considered; an increase of around 3.5˚C across the climate zone (Table 4). The highest increases occur throughout most of the rainy season (Figure 10) and are particularly important in the driest regions of climate zone B, where the highest temperatures are already experienced (Figure 6). This combination of increased temperatures in the hottest regions with reductions in rainfall can further exacerbate water availability issues, particularly in the drier regions of climate zone B, due to higher evaporation rates associated with higher temperatures.

The impacts of scenario 1 on climate zone B are most significant to the livelihoods in the drier parts of climate zone B (MZ14, MZ15), where there is already a high risk of drought conditions. The increased number of consecutive dry days in this region (Figure B1), will exacerbate the current high drought risk, particularly in the drier years associated with El Niño events. This increased risk is likely to impact crop production within these LHZs through increased water stress, particularly for crops which have a higher water requirement (e.g. cotton and maize). The significant increase in temperature in this region is also likely to increase heat stress impacts on most crops, and some years could result in the daily maximum temperatures for some crops being exceeded during the growing season, resulting in reduced yield.

Drought conditions could also impact fishing livelihoods in the Cahora Bassa Dam through reduced water levels impacting the fish quality and quantity. These conditions could also reduce the capability for energy production in the Dam, which may have a knock-on effect on other livelihoods across the country.

As with climate zone A, despite the general trend in scenario 1 representing a drier climate on average, flooding will continue to be a risk due to higher intensity rainfall events associated with a warmer climate, particularly in wetter years. This will exacerbate the existing high risk of flooding in the major river basins (MZ12), and also in other parts of the climate zone. In addition, although the current exposure to tropical storms and cyclones is lower in this climate zone compared to others, this risk will increase due to the increased intensity of tropical cyclones when they do make landfall, and the increase in associated coastal flooding due to rising sea levels.

Both chronic and acute instances of food insecurity, which currently occur within many districts across climate zone B, could increase under scenario 1. This is due the combined impact of long-term trends of increasing temperatures and reductions in rainfall further impacting chronic levels of food insecurity, particularly with no adaptation to current livelihood activities, and the subsequent increased risk of extreme events during specific periods in the year, such as droughts and floods (which could be related to tropical storms and cyclones) further increasing acute instances of food insecurity.

CLIMATE ZONE C

Climate zone C currently receives the lowest annual rainfall amounts of around 700 mm per year, and the highest variability in rainfall amounts from year-to-year. Under scenario 1 there is very little projected change in average annual rainfall in climate zone C when averaged across the zone (Table 4), however there is an indication of slight decreases in the northern part of the zone, and slight increases in the southern part of the zone (Figure 9). The decreases are projected to occur during the start of the rainy season (September to November; Figure 10), potentially indicating a delay to the onset of the rainy season in this region. Daily maximum temperatures are currently around 30˚C, and the highest increases of around 2.8 ˚C are also projected to occur at this time of the year (Table 4; Figure 10), potentially exacerbating water availability issues which have accumulated over the dry season. The increases in this zone are projected to occur during the peak of the rainy season (December to February; Figure 10) and the projected increase in temperature at the same time is likely to offset any benefits that the slight increases in rainfall will bring.

This future climate with increased lack of water availability will significantly impact crop production and livestock rearing livelihoods, particularly in the driest regions (MZ22). There will be continued and potentially increased issues with lack of water availability and pasture availability for livestock production, and the increased temperatures will further impact milk production and animal body condition. Heat stress and water stress will continue to impact crop production in this LHZ, particularly as the year-to-year variability will continue to bring drier years, and the variability is highest in this climate zone compared to others. In addition, the indication of a delay or shortening of the rainy season may require a shift to crops with lower rainfall requirements and a shorter growing season. Other LHZs within climate zone C are currently less exposed to drought conditions, however, similar impacts are likely to be felt for both cropping and livestock livelihoods across the zone, due to the increased lack of water availability.

The high flood risk in the southern part of the climate zone (MZ14, MZ25 and MZ26) is likely to be exacerbated due to higher rainfall on average in this region and higher intensity rainfall events, as a result of the warmer climate. In addition, more intense tropical storms, cyclones and increased coastal flooding will impact LHZs along the eastern coast.

Similarly, to climate zone B, both acute and chronic levels of food insecurity could increase in climate zone A under scenario 1 due to the combined impact of the projected long-term trends and increase in risk of extreme events, particularly drought conditions. Dependence on livestock and crop production in this climate zone, where rainfall amounts are highly variable and the impacts of changes in the rainy season and lack of water and pasture availability are already felt, could significantly increase the risk of food insecurity for these livelihoods.

SCENARIO 2

In the 2050s under scenario 2, daily maximum temperatures are projected to be 2.2˚C higher and the annual average rainfall is projected to increase by 130mm compared to the baseline values (around 30˚C and 1000 mm), when averaged across the whole of Mozambique (Table 4). These values vary regionally across the climate zones; this can be seen in the maps of the projected changes shown in Figure 11 and specific values are given in Table 4. Maps of the projected changes on seasonal timescales are also shown in Figure 12.

Climate change and climate-related disasters and shocks pose a particular threat to already food insecure communities like in Mozambique.

FIGURE 11

Projected changes in annual average rainfall and daily maximum temperature in Scenario 2 for the 2050s (2041-2071) relative to the baseline (1981-2010)

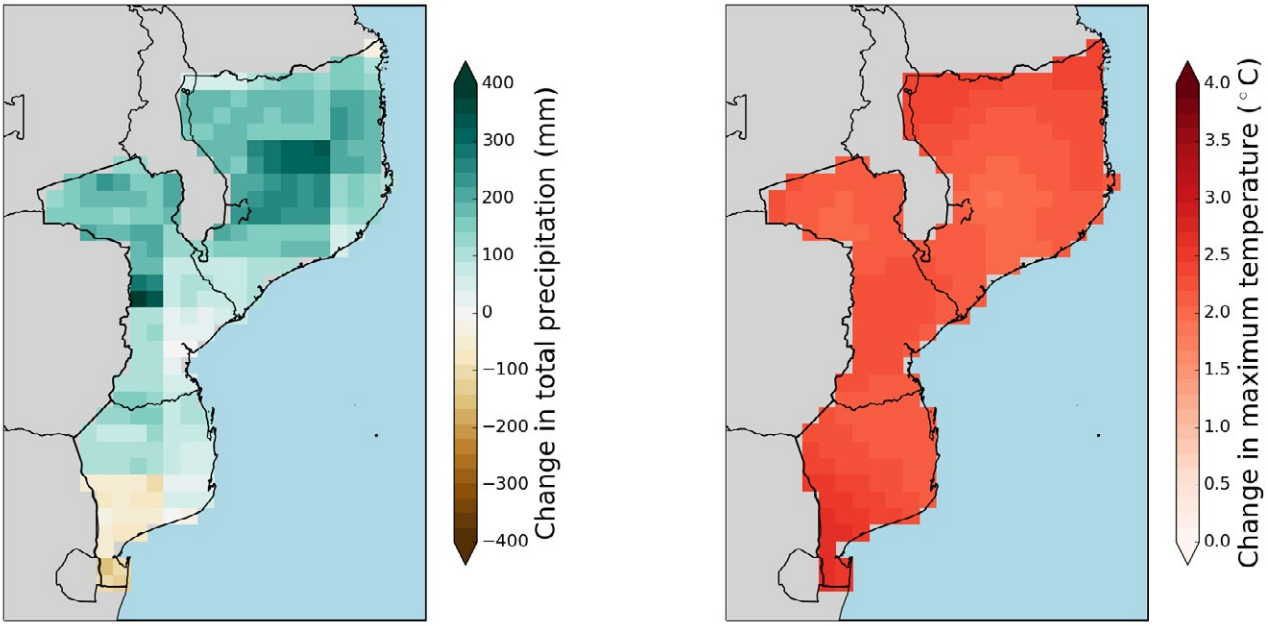
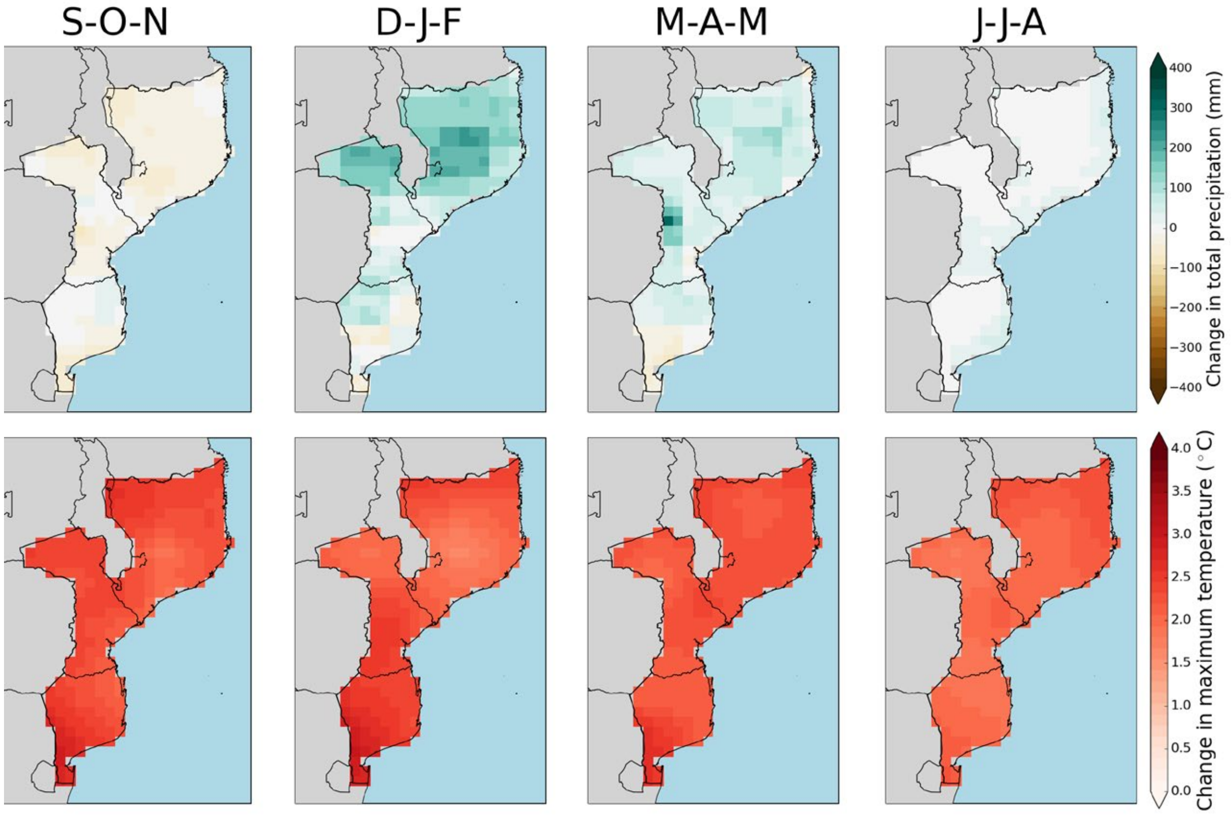


FIGURE 12

Projected changes in seasonal total rainfall (top panels) and seasonal average daily maximum temperature (bottom panels) for Scenario 2. The four seasons are September to November (column 1), December to February (column 2), March to May (column 3) and June to August (column 4).



CLIMATE ZONE A

In scenario 2, climate zone A experiences the highest projected increase in average annual rainfall compared to the other climate zones. As climate zone A is the wettest of the three climate zones (receiving around 1200 mm per year), this projected increase of around 170mm only equates to around 15% of the annual average rainfall, and is projected to occur during December to March; the wettest part of the year (Table 4; Figure 11; Figure 12). More importantly, the average rainfall over the September to November period is projected to decrease slightly, suggesting a potential delay to the rainy season in this climate zone. Daily maximum temperatures are currently around 30˚C and are projected to increase by around 2.2˚C across the climate zone.

The main impact on agricultural production in this scenario is the increased flood risk associated with more extreme rainfall events. This risk is likely to increase across the whole region, but the most vulnerable LHZs are around the Zambezi River basin (MZ10), where flooding as a result of heavy rain is already a significant risk to both agricultural and fishing livelihoods. This increase in flood risk will also impact access to markets as transport infrastructure can be damaged and roads are often impassable during flooding events. Coastal fishing (MZ08) is also likely to be impacted by more extreme rainfall events, in addition to the increase in intensity of tropical cyclones and associated impacts of storm damage on coastal infrastructure and fishing livelihoods.

The increased rainfall on average is not likely to improve agricultural production in the region, as water availability is likely to remain around the same as a result of the increased evaporation associated with a warmer climate. The projected temperature increases could result in heat stress impacts on crop production, but not as much as in scenario 1. The potential shortening of the rainy season and the continued year-to-year variability in rainfall amounts and timings may result in the need to grow different varieties with shorter growing seasons, and improved communication of weather and seasonal forecasts for the start of the rainy season.

In the absence of these adaptation measures, food insecurity could increase in some regions in climate zone A under scenario 2, as a result of increased extreme rainfall events, continued year-to-year variability, and continued exposure to tropical cyclones, which could exacerbate acute instances of food insecurity.

Protection of tree seedlings planted in drought-affected areas as an adaptation measure.

CLIMATE ZONE B

In climate zone B, the annual average rainfall is projected to increase by around 130mm which is around 14% of the baseline amount of around 900 mm per year (Table 4; Figure 11). This projected increase in rainfall occurs during the wettest part of the year from December to March, and in the highland regions of the zone in the North which are currently the driest regions. However, this increase in rainfall is small and likely to be offset by the projected increase of around 2.2°C in daily maximum temperature, which are currently around 30˚C. In addition, similarly to scenario 1, there is an indication of a slightly drier start to the rainy season, which could exacerbate the existing water availability issues in this region.

More extreme rainfall events in scenario 2 will result in exacerbated flood risk in the regions, which already experience high flood risk (MZ12), particularly during wetter years. Similarly to climate zone A, flooding events also impact access to markets for these livelihoods due to roads becoming impassable. These coastal regions and predominantly fishing livelihoods are also likely to also be impacted by the continued tropical cyclone risk, with more intense wind and rain and increased sea levels increasing the risk of both storm damage to coastal infrastructure and coastal flooding.

The year-to-year variability in rainfall amounts will continue to bring drier years on average, and therefore the current drought risk in the driest parts of the climate zone is likely to increase during these drier periods. As in scenario 1, this will impact crop production in these drier LHZs (MZ14, MZ15), and the indication of a shorter and later rainy season may require different crop varieties with shorter growing seasons.

As with climate zone A, the projected temperature increases could result in heat stress impacts on crop production, particularly in the drier regions, but not as much as in scenario 1. Similarly, acute instances of food insecurity could increase due to the projected increased risk of extreme rainfall events in this scenario.

CLIMATE ZONE C

Similarly, to scenario 1, the projected change in annual average rainfall for climate zone C is mixed. There is very little change in annual average rainfall projected when averaged across the zone (around 4%; Table 4), and the spatial pattern of these changes is the reverse of that in scenario 1; slight increases projected in the north and slight decreases projected in the south (Figure 11). This small change in rainfall and projected increase in daily maximum temperature of around 2.3°C (which is marginally higher than the other climate zones in this scenario) is likely to result in little change to the current water availability issues already experienced in this region.

Impacts of scenario 2 in climate zone C are fairly similar to those in scenario 1. The main differences are that rainfall events are more extreme in this scenario, resulting in higher flood risk particularly in regions already at risk of flooding (MZ14, MZ25 and MZ26), and even higher risk during wetter years. Impacts on transport infrastructure will become more severe with more frequent and intense flood events, resulting in decreased access to markets for key livelihoods in this area.

Similarly, to scenario 1, the continued water availability issues will impact crop and livestock production in drier regions, particularly during drier years. The indication of a shorter rainy season with a later start may also require crops with lower rainfall requirements and shorter growing seasons. Further impacts on water availability subsequently pasture availability will reduce livestock milk production and reduce body condition of the animals. These impacts could exacerbate existing high levels of both chronic and acute food insecurity in climate zone C if current livelihood activities continue.

5. Building resilience: recommendations for long-term adaptation

Alice has 7 children. Their house was completely destroyed by the cyclone. Everything is gone, the walls and roof have collapsed. They managed to replace some metal sheeting on the roof. “It will take us a very long time to rebuild the house as it was before” said Konforme Alice’s husband, “I am waiting for the remaining waters to go away and for the weather to get better before starting to rebuild the walls”.

Through a process of consultation, building on the discussions around climate sensitivities of livelihoods (as discussed in Section 3.2 and Table 2) and the related impacts on food security, key stakeholders were asked to identify suited climate adaptation interventions. The adaptation measures were identified for each livelihood group (e.g. crop, livestock, fishery, and forestry), exploring different timescales for action, namely short, medium, and long term and related responsible actors. In addition, for each adaptation measure, inputs into the action were identified, as well as related barriers to further assist with adaptation planning. Results from this consultation process are shown in Table 6. The table is not exhaustive, but indicative of key emerging priorities. These adaptation measures were identified through discussion around the future scenarios presented in Section 4; Scenario 1: hotter and drier, Scenario 2: warmer with more extreme rainfall. Hotter and drier conditions are prevalent in both scenarios and therefore particular focus was given to these conditions when identifying adaptation measures. However, more extreme rainfall events, with higher intensity rainfall that could exacerbate current flooding and tropical cyclone risk is also a feature of Scenario 2, requiring different adaptation measures.

Overall, it is clear that there is a dependence on practices that are no longer suited for the changing climate. The continuous use of prevailing practices, without adaptation will lead to an enhanced competition across sectors for resources, affecting all livelihoods and aspects of food and nutrition security. However, changes in practices require an enabling environment. Information is needed to understand the status quo, learn what is suited for the future, and ensure that this is all fitting with the local context (present and future). Financial resources are needed to support uptake, as well as economic opportunity to make these changes profitable and sustainable in the long term. Collaboration is also needed to work across sectors and administrative levels (national and sub-national). Commitment and accountability to these actions are also needed, which while emerging is difficult to ensure given the different stakeholders involved and the different timescales.

WFP provides school assistance to Mozambique children through the provision of daily school lunches and take-home rations for girls and orphans. WFP is supporting the government with the design of a nationally-owned school meals programme. In the photo: Sweepstake Winner Anifa with farmer.

TABLE 6

Adaptation measures

Sector	Adaptation Measure	Timescale			Inputs	Actors	Barriers to Adaptation
		Short	Medium	Long			
Cropping	Financial resources made available for smallholder investment in adaptation measures, supported by financial training and business planning	Needs assessment Supply capacity assessment Enabling regulatory environment Support linkages between formal and informal sectors to help grow financial capacities of smallholders, like the interactions of village saving and loan groups with financial institutions	Development of product options by Micro Finance Institutions Promotion of financial literacy and capacities among users Client education and protection initiatives Explore mobile solutions to enhance penetration in rural areas	Small holder investment supported by financial services provided by MFIs Mechanisms for interaction between consumers and service providers to foster the provision of demand-driven services and products	Understanding of farmer practices, financial capacities, and needs. Support to financial institutions to extend their coverage and reach	Central Bank, Banks, Financial institutions, Financial development organization, saving groups and associations	• Lack of products suited to farmers • Terms of products not suited to farmers • Financial institutions with limited resources and capacities to meet demand • Regulatory framework needs strengthening to protect both MFIs and farmers • Low penetration across the country, especially in rural areas
	Promotion of improved irrigation systems, water harvesting, and sustainable management of water resources, including small-scale asset development, such as reserves, wells, and ponds	Needs assessment, including a mapping of existing resources and infrastructure in place Promotion of sustainable water management practices among users/managers	Infrastructure rehabilitation, creation, and maintenance for different uses – agriculture, livestock, consumption – to manage resource competition Water and sanitation facilities and practices promoted alongside productive water uses/infrastructure Application of sustainable water management practices considerate of hotter/drier conditions, as well as risks for salinization. Enhance capacity of local communities and authorities to sustainably manage and use local water resources and related infrastructure		Information on the state of hydrological resources available and projected, including details of the demand, to develop suitable management strategies and practices. Plan for management and use of water resources considerate of ground water, surface water, and saline water	MADER, MTA, IIAM, MOPHRH, INGC, Academia, Provincial Government, Civil Society, NGOs, SDAE, extension officers, water resource committees	• Considerable financial resources needed to make effective use of irrigation infrastructure and to develop additional technologies. • Existing infrastructure has been underutilized and not well maintained. • High competition for water resources, including for consumption

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Sector	Adaptation Measure	Timescale			Inputs	Actors	Barriers to Adaptation
		Short	Medium	Long			
Cropping	New seed varieties and crop diversification promoted	Identification of adequate crops per location based on historical climate and climate model projections. Particular crops to explore include: banana, plantain, cassava, rice, and sorghum. Maize is in particular due to suffer under the changing climate. Conduct further research and development of locally appropriate seed varieties to promote	Promotion of climate-smart crops among users that are better suited to the climate, heat/drought tolerant, fast-maturing, etc. Enable access to seeds and related inputs to support change to different crop Integrate seed promotion and access with extension support offered to farmers Support seed banks and community seed multiplication Maintain roster of quality seed providers, making use of pre-established standards	Nutritional guidance and support to changing diets Market access and opportunities for drought-tolerant crops Foster public, private partnerships informed by climate data and user needs	Understanding of agricultural practices, environment, and local climate to develop a suitable range of options of seed varieties	MADER, Agrarian Investigation Institute (IIAM), INAM, MTA, Ministry of Industry and Commerce (MIC), Academia, Provincial Government, SDAE, extension officers, private sector	• Poor awareness and understanding among up-takers to support a transition to new seed varieties and crop diversification • Agricultural practices are limited, and extension support unable to reach out to all in need • Existing market options are limited especially in rural areas for vulnerable farmers • Limited market opportunities keep farmers from making investments in their livelihoods, since they are not sure they will get a return to their investment • Limited production level and capacity to store produce among farmers • Technologies not readily available locally to meet needs • Extension support limited in reach • Poor awareness and understanding among up takers to support the use of post-harvest loss management techniques and technologies • Limited market opportunities keep farmers from making investments in their livelihoods, since they are not sure they will get a return to their investment

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Sector	Adaptation Measure	Timescale			Inputs	Actors	Barriers to Adaptation
		Short	Medium	Long			
Cropping	Techniques and technologies for post-harvest loss management	Assessment of losses by crop and location Mapping of technologies available and additional needs Conduct research and development of suited post-harvest techniques and technologies Raise awareness and understanding about the need for the uptake of PHL technologies and techniques	Foster the provision of Post Harvest Losses (PHL) technologies locally such as hermetic bags Promote the PHL techniques, supported by access to technologies Training extension officers to support PHL activities Incorporate PHL into extension officer curriculum and core work Provide market information to smallholder farmers to enable effective planning for harvesting	Monitor and evaluate the performance of the techniques and technologies employed to define scale up options Promote market opportunities that enable farmers to accumulate and sell crops under favourable terms Provide storage, transport, and management support for growing needs of individual or groups of farmers, as productivity increase	Local businesses supplying technologies to farmers, with extension support providing training on uptake	MADER, MTA, MIC, IIAM, Private Sector, Provincial Government, extension officers, Civil Society, NGOs	• Limited production level and capacity to store produce among farmers • Technologies not readily available locally to meet needs • Extension support limited in reach • Poor awareness and understanding among up takers to support the use of post-harvest loss management techniques and technologies • Limited market opportunities keep farmers from making investments in their livelihoods, since they are not sure they will get a return to their investment

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Sector	Adaptation Measure	Timescale			Inputs	Actors	Barriers to Adaptation
		Short	Medium	Long			
Cropping	Training and awareness raising on improved agricultural practices that are climate resilient	Scan of current practices, especially best practices Research into agricultural improvements Document and foster exchanges on practices that are proving to be effective under a changing climate Raise awareness about the need to adapt agricultural practices	Use historical climate data and model projections to help inform the selection of practices to pursue based on rainfall probabilities, as well as other agro-meteorological parameters Development of standard guidelines Dissemination of guidelines and application Integration of standard guidelines into extension officer curriculum	Application of guidelines, supported by access to finance, information, markets, etc., making adherence to climate resilient agriculture economically viable Monitor and evaluate the performance of the techniques employed to define scale up options Set up public-private partnerships to support the scale up of climate resilient practices	Understanding of current agricultural practices, environment, and local climate to develop a suitable range of options for improved climate-resilient agricultural practices	MADER, MOPHRH, MTA, IIAM, INAM, Provincial government, extension officers, Civil Society, Academia, NGOs, private sector	• Extension support limited in reach • Poor awareness and understanding among up-takers to support a transition to new practices • Current agricultural practices are not all well suited to the changing climate, requiring a significant shift in livelihood planning and activities • Limited market opportunities keep farmers from making investments in their livelihoods, since they are not sure they will get a return to their investment
	Information on weather, climate, and markets to inform livelihood activities	Collection of historical data for weather, climate, agricultural yields, and market performance Dissemination of historical probabilities to help inform livelihood planning	Enhance monitoring systems on weather, agricultural yields, and market performance Improved long and short-range forecasts for rainfall that can be downscaled to be relevant to the targeted communities Strengthen the production of agro-meteorological products including advisories	Analysis and packaging of this information to provide regular updates and advisories to farmers Establish different delivery mechanisms based on the needs of the target user Ensure climate and weather information that is going to farmers is also going to private sector to align demand and supply	Understanding of current agricultural practices, local environment, and market performance along with suited monitoring systems to inform farmers of changes	INAM, MADER, IIAM, MTA, extension officers, private sector	• Limited historical records (especially observational data) for many of the parameters needed, including weather, crop assessments, and market performance • Monitoring systems are limited in reach and data not readily of use to provide updates and advisories • Technical and operational capacities needed to develop and delivery timely information that farmers can act upon

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Sector	Adaptation Measure	Timescale			Inputs	Actors	Barriers to Adaptation
		Short	Medium	Long			
Cropping	Strengthening of local markets and opportunities for local procurement from smallholder farmers	Farmer organization and mobilization to enable technical support provision and aggregation of produce Support financial literacy and business training to farmers, farmer organizations, and unions	Strengthen the reach of financial services for farmers and their organizations to support their business plans Foster linkages across farmers (organizations) and markets (both input providers and off-takers) Invest in the capacity of processors and other uptake market actors Invest in local infrastructure to enable access to markets and information sharing to support sales	Identify and strengthen institutional procurement opportunities that can enable ongoing interactions across farmers and buyers	Mapping of farmers and their capacities against the needs of buyers /processors	MADER, IIAM, MIC, provincial government, private sector, Civil Society, NGOs	• Crop quality and quantity improvements needed for greater off take by buyers
	Enhanced pest and disease management	Enhanced crop assessments Establishment of pest monitoring systems Identification and scaling up of local successful pest management practices Research and development into techniques and technologies/ inputs that can meet local needs	Invest in information systems to disseminate early warning messages and advise Establish protocols to support action in advance, during, and after a pest/ disease outbreak	Ensure financial resources for the mobilization of protocols Monitoring and evaluation exercise to effectiveness of actions	Understanding of agricultural practices, environment, and local pest/disease situation to develop a range of options for management	MADER, MTA, IIAM, Academia, Provincial government, Civil Society, NGOs, extension officers, private sector	• Limited historical records • Monitoring systems are limited in capacity and reach • Technical capacities needed to develop suitable management strategies • Inputs needed to support pest management, which are not readily available through the market

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Sector	Adaptation Measure	Timescale			Inputs	Actors	Barriers to Adaptation
		Short	Medium	Long			
Forestry	Reforestation and afforestation	Needs assessment based on current status of forest cover, including mangroves Awareness raising about the important contributions of forests and mangroves to combat climate change Conduct capacity strengthening of local authorities and communities to sustainably manage forests and mangroves (more details below) Conduct research on the locally suited, climate-resilient tree varieties to promote	Demarcation of areas for re/afforestation and procurement of trees (seedlings) Afforestation/reforestation activities conducted linked to community sustainable management plans ensuring use of locally fitting varieties, adapted to the environment and climate of the targeted locations Monitoring systems in place to track changes in forest cover and resources Scope and invest in energy solutions for rural and peri-urban communities that normally rely on charcoal Grow income-generating activities for rural communities to curve the sale of charcoal	If fitting with context, explore carbon financing to support the continued sustainable management of forests, If fitting with context, explore payment for ecosystem services options to support continued sustainable management	Identification of suitable species and areas for reforestation/afforestation	MTA, Forestry Institute, MOPHRH, Communities Civil Society, NGOs	• Crop quality and quantity improvements needed for greater off take by buyers

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Sector	Adaptation Measure	Timescale			Inputs	Actors	Barriers to Adaptation
		Short	Medium	Long			
Forestry	Capacity strengthening and awareness raising for forest/ mangrove management and use of resources	Support the creation of forest management community committees Mapping of relevant stakeholders across private and public sectors Capacity needs assessments conducted among targeted stakeholders Conduct research and experience sharing to identify and scale up successful management strategies	Development of suited materials to promote forest management practices among targets stakeholders Conduct suited trainings and awareness raising Support interactions across stakeholders to identify opportunities to invest and grow sustainable forest management and use schemes	Implement monitoring systems to ensure practices are implemented and there is accountability Foster market-based incentives for sustainable management and user schemes, for example certification schemes	Capacity needs assessments to develop enhanced forest management plans and strategies for operationalization	MTA, Forestry Institute, MOPHRH, Communities Civil Society, NGOs, private sector	• Difficulties in ensuring uptake and application of sustainable forest management
	Alternative fuels	Energy needs assessment Overview of fuel alternatives suited to different contexts Fuel efficient technologies scoped and identified	Investment in alternative fuels Awareness raising and promotion of alternative fuels Promote fuel efficient technologies through local markets Grow employment/ income generating opportunities through the promotion of alternative fuels	Institutionalization of alternative fuels and fuel-efficient technologies	Identification of fuel needs and suitable alternatives	MTA, MIC, Communities Civil Society, NGOs	• Limited resources going to alternative fuel exploration • Potential for conventional fuels high • Current reach of energy resources among the population limited

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Sector	Adaptation Measure	Timescale			Inputs	Actors	Barriers to Adaptation
		Short	Medium	Long			
Forestry	Market opportunities that promote the valorization of forest and forest-based products	Identification of climate resilient non-timber forest products (NTFPs) Exploration of market opportunities for these NTFPs	Support the sustainable harvesting and processing of NTFPs Align use of NTFPs with sustainable forest management practices and structures	Make market linkages for NTFPs	Market assessment to support the identification of forest resources that can be commercialized in a sustainable manner to enhance the protection of forests	MTA, Forestry Institute, MIC, MOPHRH, Communities, Civil Society, NGOs, Private Sector	• Current use of NTFPs done in unsustainable ways, such as the production of charcoal • High demand for charcoal and for wood for fuel
Fishery	Strengthening mangroves	Mapping of mangrove areas and status of these Identify key threats to these – storms, clearing, temperature, other biomass, etc. Design strategies to rehabilitate and protect mangroves Awareness raising about the critical role of mangroves	Promotion of protection of mangroves and sustainable management Support local users to come together and manage mangroves resources in a sustainable manner Conduct capacity strengthening activities to ensure local user can manage mangroves sustainably Regular monitoring of mangrove resources Penalties imposed for mismanagement/ harm to mangroves	If fitting with context, explore carbon financing to support the continued sustainable management of mangroves Integrate mangrove management with fish and water management plans locally and regionally, fostering public and private partnerships	Identification of suitable species and areas for intervention	MADER, MTA, MAIP, MOPHRH, Communities, NGOs, Private Sector	• Current practices are not mindful of sustainable mangrove management approaches • Limited awareness about the contributions of mangroves

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Sector	Adaptation Measure	Timescale			Inputs	Actors	Barriers to Adaptation
		Short	Medium	Long			
Fishery	Training and awareness raising to support enhanced fishing practices with a focus on aquaculture	Mapping of existing practices, especially best practices worth replicating Identification of suited practices with sustainability considerations and local contexts Awareness raising about the need to sustainably manage fishing resources	Develop guidance according to suited best practices Support local users to come together and manage resources in a sustainable manner Conduct capacity strengthening activities to ensure local user can manage resources sustainably Regular monitoring of resources Penalties imposed for mismanagement	Ensure that there is a monitoring system in place to track fishing stocks state and user practices Integrate management plans with broader water and landscape management plans locally and regionally, fostering public and private partnerships	Capacity needs assessments to develop enhanced management plans and strategies for operationalization	MADER, MTA, MAIP, communities, private sector	• With limited market outlets, there are little capacities for small-scale fishing communities to invest in enhanced practices and technologies • Limited practices that require considerable change • Capacity to reach all who need training and to do follow up is limited
	Fishing population and diversity promotion	Stock taking of current stocks Projections of fish stocks under different climate scenarios	Identify suited management practices, which are supported by regulations on fishing conditions	Enforcement and monitoring of fishing regulations	Assessment of fishing stocks and link this to management plan/ strategies	MADER, MTA, MAIP, Private Sector	• Hard to estimate fishing stocks and to project these • Difficult to monitor fishing practices and ensure enforcement of regulations

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Sector	Adaptation Measure	Timescale			Inputs	Actors	Barriers to Adaptation
		Short	Medium	Long			
Fishery	Technical resources and infrastructure development	Needs mapping along the value chain for different Conduct research on locally tailored processing and storage techniques and technologies	Support the domestic provision of the necessary technologies for safe storage and processing Enhance local storage and processing capacities Promote financial services and opportunities to uptake storage and processing techniques and technologies Invest in local infrastructure to enable access to markets and information sharing to support sales	Enable investment (macro and micro) in the development oinfrastructure and technologies needed f infrastructure and technologies needed	Identification of technologies/ infrastructure and areas for intervention	MADER, MTA, MAIP, MIC, Private Sector	• Resources are limited • Markets are fragmented and limited to support large scale investments
Livestock	Water harvesting and management for livestock purposes	Assessment of livestock quantities and distribution including future projections Water demands calculated against water resources available	Infrastructure rehabilitation, creation, and maintenance for different uses – agriculture, livestock, consumption – to manage resource competition		Information on the state of hydrological resources available and projected, including details of the demand, to develop suitable management strategies and practices	MADER, IIAM, extension officers, water committees, MOPHRH	• Existing infrastructure has been underutilized and not well maintained. • High competition for water resources, including for consumption

(Continued...)

(... Continued)

Sector	Adaptation Measure	Timescale			Inputs	Actors	Barriers to Adaptation
		Short	Medium	Long			
Livestock	Fodder generation and management plans developed and enacted	Assessment of livestock quantities and distribution including future projections Feed demands calculated against water/ soil resources available Identify appropriate grasses and vegetation by location to be used for fodder Raise awareness about fodder generation practices	Capacity strengthening on fodder production Demarcation of land to be used for grazing regeneration Promotion, multiplication, and planting of vegetation for use in fodder production Sustainable management plans generated for grazing land Promotion of adequate supplementary feeding		Determine the current state of grazing areas, including details on the low sprouting as a result of hotter and drier conditions	MADER, MTA, IIAM, extension officers, MOPHR	• Currently not a widespread practice, so there is a lack of technical know-how • High competition for resources
	Veterinary services made more available and accessible	Map demand versus supply Identify barriers to access Establish the areas of veterinary expertise and technologies needed	Support the creation of relevant expertise at national and sub-national levels Establish mechanisms for accessing veterinary services, where and as needed Strengthen financial services and capacities of livestock owners	Support research and new technologies that help address issues with livestock health	Map out reach of current services and demand for these to determine an enhanced outreach plan	MADER, IIAM extension officers, Civil Society, NGOs, private sector	• Veterinary support limited in reach • Financial resources limited

(Continued...)

(... Continued)

Sector	Adaptation Measure	Timescale			Inputs	Actors	Barriers to Adaptation
		Short	Medium	Long			
Livestock	Technical resources and infrastructure development	Needs mapping along the value chain for different Conduct research on locally tailored processing and storage techniques and technologies	Support the domestic provision of the necessary technologies for safe storage and processing Enhance local storage and processing capacities Promote financial services and opportunities to uptake storage and processing techniques and technologies Invest in local infrastructure to enable access to markets and information sharing to support sales	Enable investment (macro and micro) in the development oinfrastructure and technologies needed f infrastructure and technologies needed	Identification of technologies/ infrastructure and areas for intervention	MADER, MTA, MAIP, MIC, Private Sector	• Resources are limited • Markets are fragmented and limited to support large scale investments

(Continued...)

(... Continued)

Sector	Adaptation Measure	Timescale			Inputs	Actors	Barriers to Adaptation
		Short	Medium	Long			
Livestock	Training and awareness raising on livestock management and climate resilient practices	Mapping of existing practices, especially best practices worth replicating Research into other suited practices worth promoting	Development of suited materials to promote sustainable management practices among target stakeholders Conduct suited trainings and awareness activities raising among targeted stakeholders	Support investment capacities and opportunities to enable changes in practices to more sustainable ways	Understanding of current practices, environment, and local climate to develop a suitable range of options.	MADER, IIAM, extension officers, Civil Society, NGOs	• Extension support limited in reach • Current livestock practices are not all well suited to the changing climate
	Grazing area regeneration and protection	Identification of suitable land and vegetation type to be promoted	Demarcation of land identified and placed under sustainable management regime	Monitor and follow up on the regeneration of grazing areas	Information to farmers on the protection and promotion of grazing areas linked to technical advice for grazing practices	MADER, IIAM, extension officers, MOPHR	• High competition for resources • Limited understanding and awareness of natural cover their contributions to the productivity of the environment

6. Conclusions/ summary/ recommendations

There is a need to adapt agricultural practices to the changing climate as temperatures increase, rainfall becomes more variable, and evaporation rates are increasing.

Food security and climate are closely linked in Mozambique. 70 percent of the population lives in rural areas and practices agriculture as a main livelihood. As crops are grown in largely rain-fed systems, this makes the sector highly vulnerable to natural hazards. The changing and more variable climate, if unmitigated and with lack of adaptation and risk management measures, will likely result in heightened food insecurity.

Analysis of observed climate trends shows that temperatures are already increasing, mostly concentrated within the rainfall season and more marked in the southern and central regions. There is no clear long-term trend for all-country annual rainfall as rainfall is dominated by year-to-year variability in amounts and timings, however small increases in the south and small decreases in the north have been observed. Accordingly, observed trends of vegetation shows decreases, especially matching the rainfall trends.

Livelihoods and agricultural production systems are already being affected by the changing and variable climate. Analysis of the rainfall trends on a monthly basis shows that the increases in seasonal rainfall fall with the wettest periods of the year. Decreases in rainfall is tied to decreases in rainfall events rather than in decreases in rainfall per rain day. Heavy rainfall events are becoming more frequent and concentrated in already wet periods. On the other hand, dry spells linger and are more variable. As a result, the growing season is becoming more unpredictable (start and end dates) and concentrated to fewer days (taking into account incidence of dry spells and heavy rainfall days). This makes it hard to plan and undertake agricultural practices, especially under rainfed conditions, as a principal livelihood.

Climate change projections for the 2050s for Mozambique all agree on a substantial warming trend of between 1˚C and 3˚C. In contrast, rainfall projections are mixed, with most models projecting decreases in average annual rainfall and some models projecting small increases. The projected changes in rainfall are small, and the year-to-year variability in rainfall amounts exceeds any climate change signal. Extreme weather events such as floods, droughts and heatwaves are projected to increase in frequency and intensity. Tropical cyclones will continue to impact the country with greater intensity than now, and with higher risk of coastal flooding due to rising sea levels.

Risk reduction measures at community level through asset creation contribute to climate resilience by helping households withstand large-scale shocks.

Two scenarios of climate change were studied, based on the projections from two different climate models that span the range of plausible future climates for Mozambique. Scenario 1 represents a hotter and drier future, where the key features are reduced water availability, increased heat stress and the increases in drought conditions. Scenario 2 represents a future climate that is warmer than now, with more extreme rainfall events. Increased evaporation as a result of higher temperatures means that any increases in average rainfall are likely to be offset, resulting in reductions in water availability under all future climate scenarios. Furthermore, increased heat stress and continued variability resulting in more frequent and intense extreme weather events, which are already drivers of food insecurity across the country, are likely to result in increases in food security under all climate change scenarios, with the scale of increase dependent on the scenario.

The need for climate adaptation action is great. Identified actions are multi-sectoral, working across different locations and time-scales, requiring the strengthening of adaptation plans and processing, including design and implementation. Building on this, some adaptation barriers identified include the lack of information on suited practices for the future, limited investments in new techniques and technologies, poor coordination and collaboration across stakeholders, and limited capacity to plan with long term horizons.

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Appendices

The waters are receding rapidly to reveal the amount of devastation that the cyclone has perpetrated to the farms and cultivated land in the affected areas.
A severe blow to the countries agricultural assets.

Appendix A.

Methods and data

The analysis presented in this report, to assess the impact of projected climate change on livelihoods and food security in Mozambique, has been a collaborative effort across climate science and food security disciplines. The approach taken here is based on an adaptation of the CLEAR methodology (WFP, 2014); a framework for assessing climate risk and food security, where a more narrative approach is taken to the food security analysis due to constraints of data availability.

The first step was to ensure a good understanding of the baseline climate and its relationship with current livelihoods and food security. Two plausible scenarios of projected climate change were then analysed, and the impact on livelihoods and food security were assessed in the context of the potential change from the present day. This section describes the methods and data used for this analysis.

A.1. Climate analysis methods

The climate analysis undertaken in this report considers two time periods. The first is an assessment of the baseline climate, covering the period 1981-2010 to represent the present day. Due to the sparsity of reliable direct observations of climate across the region, this assessment is based on reanalysis data (a blend of observed weather data and model data of past climate to provide gridded historical climate data). The analysis then goes on to consider projected changes in climate from climate model outputs for the period 2041-2070, as representative of the climate in the 2050s.

To define the baseline climate of Mozambique, monthly temperature data from the WATCH forcing dataset (Weedon et al., 2011) and rainfall data from the CHIRPS dataset (Funk et al., 2015) were analysed over the baseline period. For the future projections, change in these variables from two climate models were analysed for the future time period. Further detail about climate model projections and the use of individual models as scenarios of future climate change is given in Appendix B.

Due to the spatial resolution of the baseline and future climate data (i.e., the size of the data grid boxes relative to the area of the individual LHZs), it was not statistically meaningful to provide climatology data for individual LHZs. Instead, climatology data were grouped into three climate zones (A, B and C) that represent regions of similar climatological rainfall amounts. The climate zones relate to groupings of the LHZs defined by FEWSNET & SETSAN (2014) in Figure 4, and are mapped in Figure 5 and listed in Section 3.1.

A.2. Livelihoods and food security analysis methods

The assessment of the impact of climate change on food security and livelihoods in Mozambique in this report was based on a review of the relevant literature, expert interpretation, and extensive stakeholder consultation.

Firstly, the analysis focuses on the agriculture-dependent livelihood zones and on the prevailing food security situation (LHZs) (Figure 4; FEWS NET & SETSAN, 2014), which then is used to elaborate their relationship with the baseline climate conditions, and thus their sensitivity to climate change. This provides a starting point to assess future climate impacts on food security and livelihoods under the scenarios of projected climate change.

The baseline assessment of LHZ vulnerabilities follows the aggregation of the LHZs into the climate zones. The zones are aggregated according to their predominant livelihood strategies (i.e. agriculture, livestock, fishing and forestry) based on consultations and literature findings.

For each climate zone, the baseline climate vulnerability and related food insecurity conditions are described, based on the FEWSNET & SETSAN (2014) and WFP food security assessments (WFP, 2017; WFP, 2018). These baselines are supplemented with more in-depth descriptions of their various building blocks, based upon a review of the secondary literature.

This identification of the sensitivity to climate of the various livelihood activities within each climate zone, together with the description of the current climate, is then used to indicate the climate-related pressure on each of these LHZ activities, and the consequent risk to food insecurity in the present day. This then sets the context for evaluating the effect of climate change on food insecurity risk.

Finally, the climate change projections provide scenarios of possible future climates that could be experienced by the 2050s. These scenarios of future climate change are interpreted to understand what different levels of projected climate change could mean for livelihoods and food insecurity in the future. This analysis considers how climate could exert pressures on specific systems as a result of their sensitivity to climate change, and the potential risk to food security in the future, relative to the experience of climate impacts in the present day.

More on consultations: This report is characterized by a high level of national consultation leveraging the expertise available in country across different stakeholder groups, including academia, government, implementing partners, and others. There were four key activities under the consultation process, namely a questionnaire, focus group discussions, a stakeholder consultation workshop, and finally, a report review and validation workshop. Details on these activities as part of the report development process are noted in the table below.

Item	Description	Date
Questionnaire for experts on livelihoods, food security, and climate change	Explore how information about weather, climate variability and climate change is currently used in decision-making and adaptation planning related to food security	19-26 September 2018
Focus Group Discussions with experts on livelihoods, food security, and climate change	Present climate model projections and identify how these can be used for adaptation planning	22-26 October 2018
Stakeholder Consultation Workshop	Present and validate climate model projections and measures for adaptation planning	30 October 2018
Report writing	Interpretation of analysis and consultation outcomes	November-December 2018
Report review and validation workshop	Present report to national stakeholders for feedback and endorsement	January-February 2019
Report dissemination	Promotion of report nationally, regionally, and globally	March 2021 (*This report was originally meant to be published in April 2019, but due to various reviews, quality checks and improvements it was published in March 2021*)

A.3. Constraints and Limitations

There are four predominant agricultural livelihood strategies identified within Mozambique: agriculture, livestock, fishing and forestry. The climate zones that were used for the climate analysis each represent distinctly different climates and, as such, naturally align with different livelihood strategies. As a result, the climate zones are the aggregation of similar LHZs (defined by FEWS NET), based on predominant livelihood strategies.

Within each of the climate zones (and thus, LHZs) the climate sensitive aspects are linked to potential pressures that have a bearing on the performance of specific crops and livestock. Thus, climate change will have a direct link to livelihood success and, consequently, food security.

This analysis has been carried out using LHZs as a scale over which impacts of climate change on food insecurity are assessed. However, there are a limited number of sources that have data aggregated in this way. In addition, food security in Mozambique is greatly affected by conflict, with many areas classified as food insecure due to the presence of large numbers of internally displaced persons due to civil/resource-based conflict. As such, there are less data available to estimate the scale of food insecurity due to climate shocks for some populations.

A further limitation in our understanding of the specific meteorological characteristics of the region is the ability of the reanalysis and climate model data to accurately represent the climatology of the region. However, the limited observational record means that reanalysis offers the best source of information on the present day climate, by making use of the available observations. An added advantage is that it is compatible with the climate model data against which it is compared.

Climate data is low resolution, both temporally and spatially and, while trends are well represented, specific weather events in individual locations and years are not. The climate data is a useful way of identifying the scale and direction of change; viewed in the context of the relationship between climate and food security in the present day, this information can help guide understanding of the scale of the challenge that climate change presents.

This report makes use of scenarios for future climate. These are not predictions, but are a sample of what is plausible across the range of modelled changes, that provide a useful basis for exploring what different levels of climate change might mean for future food security in Mozambique.

Finally, based on the highly consultative nature of the process, many different opinions and perspectives were received, which not all could be validated through the literature review. To the extent possible all feedback received was triangulated with other data sources to ensure accuracy, but some limitations to this approach are recognized. In addition, consultations were principally held at the national level, with little interactions with sub-national experts (limited to the questionnaire) who could add more nuanced and context-specific information.

Appendix B.

Use of climate model projections

Climate models are a mathematical representation of the physical processes that govern the Earth's climate and are used to provide projections of climate change under different pathways of future greenhouse gas concentrations, known as Representative Concentration Pathways (RCPs; van Vuuren et al., 2011). However, there is no unique way of representing the key processes or solving the mathematical equations, meaning that there is inevitably some uncertainty in climate projections. It is, therefore, extremely important to quantify that uncertainty in order to provide context for climate projections. Indeed, many climate modelling groups around the world have developed their own climate models. Each model has strengths and weaknesses with some performing better than others in certain geographical regions (McSweeney et al. 2015).

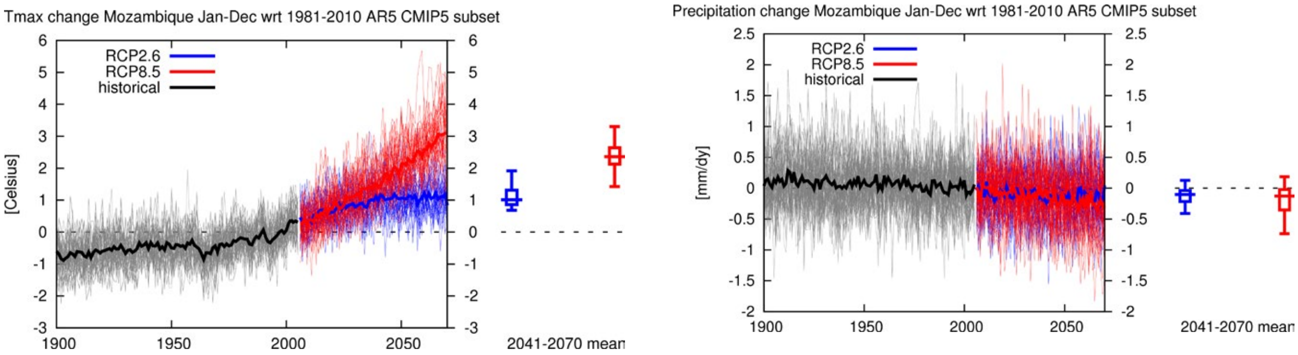
To be able to robustly compare outputs from different models, the models have to be run with the same experimental set up. This is achieved through the Coupled Model Intercomparison Project, now in its fifth phase (CMIP5; Taylor et al., 2012), which promotes a standard set of model simulations so that models can be compared and evaluated. Climate projections from around 40 CMIP5 models were used in the Inter-governmental Panel on Climate Change Fifth Assessment Report (IPCC AR5; IPCC, 2013; Niang et al., 2014), where the mean of the multi-model ensemble and spread across the models is used to communicate the projected change. One benefit of using many different models is that the spread of projections obtained provides a range of uncertainty for each variable of interest. For some variables, such as surface temperature, the projections from different models indicate a similar direction and magnitude of change. However, some other variables, such as rainfall for example, are more complex to model and the magnitude and direction of projected change may differ among different climate models.

For Mozambique, there is high confidence that temperatures are projected to increase as all models in the CMIP5 ensemble show a projected increase in temperature, but there is uncertainty across the models as to the exact value of the increase. For example, by the 2050s (2041-2070), the multi-model mean of the projected increase in the average value of daily maximum temperature is around 2.5°C above the baseline period (1981-2010) under the RCP8.5 greenhouse gas concentration scenario, with a 5%-95% range of around 1.5°C – 3.2°C (Figure A1, left panel). In contrast, the projected changes in rainfall across the models span both small increases and small decreases. In this case, focusing only on the multi-model ensemble mean results in the differences in the projected direction of change cancelling each other out. This means that the multi-model mean shows almost no change compared to the baseline (around -0.2 mm/day), but the spread across the model projections ranges from a decrease of 0.7mm/day to an increase of 0.2mm/day increase, (5%-95% range; Figure A1, right panel).

In addition to the multi-model mean acting to cancel out differences in projected changes, the multi-model mean also gives equal weight to all models, even those that are known to perform less well for certain geographic regions, such as Africa (McSweeney et al. 2015). A different way of presenting model projections is to take a scenario-based approach, where the outputs of individual models (selected based on criteria relevant to the task in hand) are considered as plausible scenarios of future change.

FIGURE B1

Time series of historical (black) and projected change in daily maximum temperature (left panel) and precipitation rate (right panel) relative to the 1981-2010 baseline period for Mozambique for the CMIP5 model ensemble. One line per CMIP5 model is shown for both the RCP2.6 (blue, 32 models) and RCP8.5 (red, 39 models) greenhouse gas concentration scenarios, and the multi-model mean is shown as a thick line. The box-and-whisker plots on the right show the range values for the 2041-2070 period across the models; the box represents the 25% - 75% range of the model values, the whiskers represent the 5%-95% range, and the 50% (median) is denoted by the horizontal line.



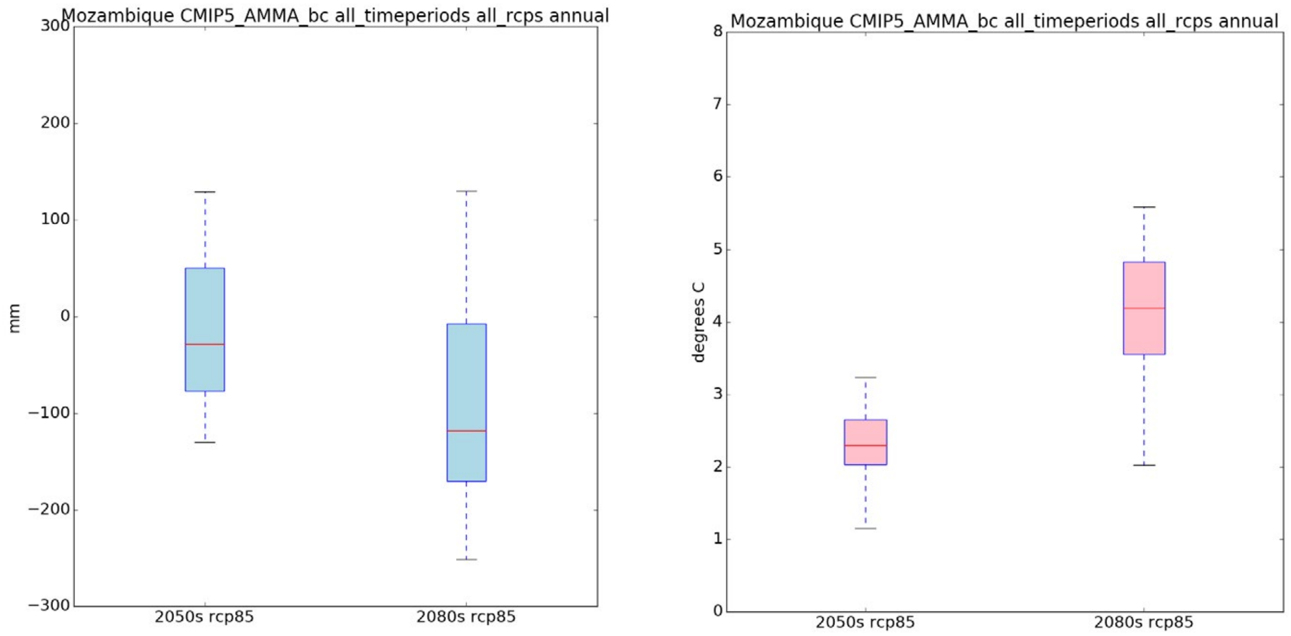
For the analysis in this study, 29 of the CMIP5 models were used that have been bias corrected on daily timescales across Africa as part of the Future Climate For Africa (FCFA) Africa Monsoon Multidisciplinary Analysis (AMMA-2050) project for the RCP8.5 greenhouse gas concentration scenario (Famien et al. 2018). This bias correction process interpolates the lower resolution CMIP5 model data onto the higher resolution grid of the observational dataset; hence the higher resolution of the maps shown in Section 3 compared to the original resolution of the CMIP5 models. This also enables analysis of specific climate indices where daily values above or below thresholds are counted as this daily data from raw climate model output cannot be used for this purpose.

The range of projections in daily maximum temperature and annual rainfall amounts for the 29 models from the AMMA-2050 project for the 2050s and 2080s and both the RCP2.6 and RCP8.5 greenhouse gas concentration pathways are shown in Figure B2. Two models were selected to represent the range of plausible scenarios of future climate for Mozambique. These were selected based on the resolution of the original CMIP5 models, their performance in the region, and the spread of rainfall projections; these are the models which showed the largest projected increases and decreases in average annual rainfall for the 2050s (Figure B2).

The models selected and used for this analysis were:
Scenario 1 - HadGEM2-CC
Scenario 2 – IPSL-CM5A-MR

FIGURE B2

Box-and-whisker plots showing the range of climate model projections of annual average rainfall (left panel) and daily maximum temperature (right panel) for Mozambique from the 29 CMIP5 models used in the AMMA-2050 project. Projection changes for the 2050s (2041-2070) and 2080s (2071-2100) relative to the baseline (1981-2010) are shown for both variables. The boxes represent the 25%-75% range, the red line indicates the median value, and the whiskers extend to the extremes of the range of values from the models.



B1. Supplementary information for the climate scenarios

In addition to considering the projected changes in the average annual rainfall and average daily maximum temperature, projected changes in the specific climate indices were also considered for each of the scenarios. In scenario 1, which represents a hotter and drier future climate for Mozambique, the number of consecutive dry days is projected to increase in this scenario, indicating a higher risk of drought conditions, particularly in October and November (Figure B3). In scenario 2, which represents a warmer climate with more extreme rainfall, the intensity of wet days is projected to increase, particularly during the wettest months of the year (Figure B4).

FIGURE B3

The average number of consecutive dry days per month in the baseline period (left panels) and the projected changes in this metric for the 2050s (right panels) under scenario 1.

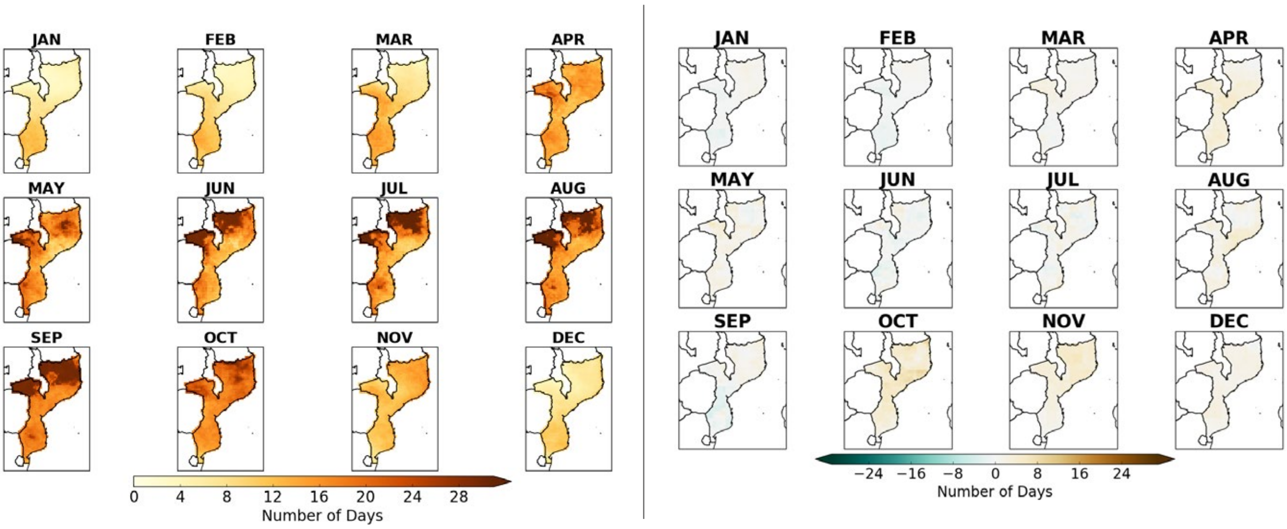
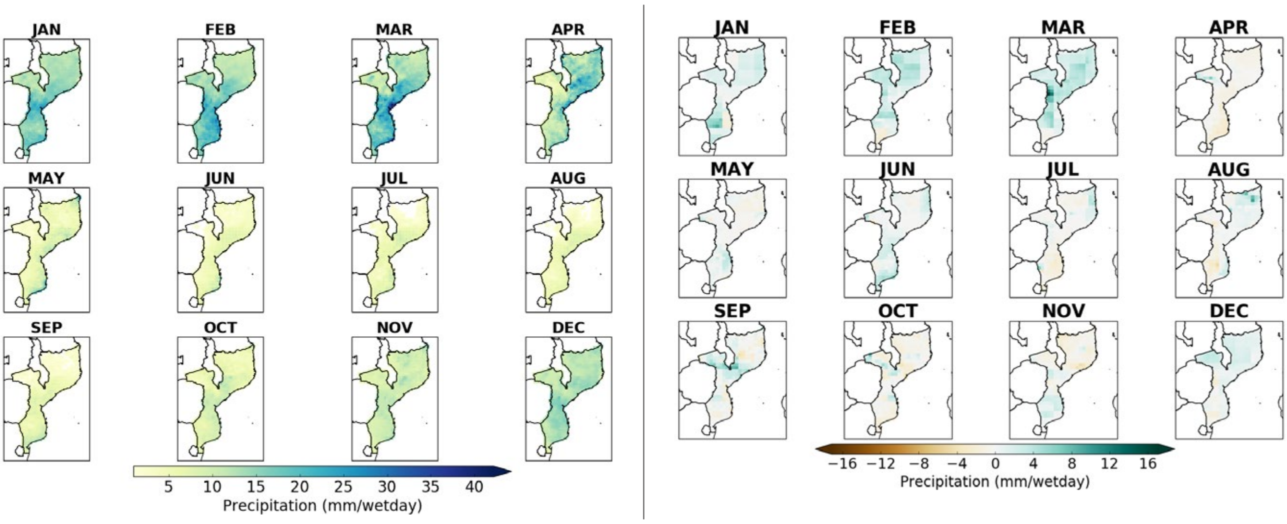


FIGURE B4

The average wet day intensity per month in the baseline period (left panels) and projected changes in this metric for the 2050s (right panels) under scenario 2.



Appendix C.

List of stakeholders

1	Dr. Carlos Quembo	IIAM - CZC
2	Dr. Magalhaes Miguel	IIAM - CZC
3	Dr. Filipe Vilela	IIAM - CZC
4	Dr. Eduardo Mulima	IIAM - CZC
5	Eng. Domingos Dias	IIAM - CZC
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