Climate risk assessment and agricultural value chain prioritisation for Malawi and Zambia

Working Paper No. 228

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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Abstract

Climate change is projected to have serious impacts on the agriculture of southern Africa, affecting food availability, creating local production shortfalls and resulting in rising commodity prices. This report highlights the risks to agriculture and food systems that may occur in two counties of the region, Malawi and Zambia. The analysis uses the conceptual framework of climate-related risk from the Fifth Assessment Report of the Intergovernmental Panel on Climate Change to examine the impacts that climate change is likely to have on agriculture and food security. Country-specific trends in temperature and rainfall and projected impacts are summarised from the literature. The vulnerability of the agricultural sector in each country is discussed in relation to its sensitivity to change and coping and adaptive capacity, and the risks of climate change on agriculture and small-scale farmers in the two focus countries assessed. A prioritisation process is then carried out to rank different commodities in each country, with respect to four dimensions: the importance of the commodity to the economy of the country, the national yield gap compared with the regional average, the importance of the commodity in people's diet, and the projected impact of climate change on yield. The results of the analysis highlight three commodities that could be prioritized for agricultural development interventions: maize, potatoes and beans in Malawi, and maize, pulses and sorghum in Zambia.

Keywords

Climate change; climate risk; Malawi; Zambia; agriculture

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Contents

Introduction

Climate variability and climate extremes already make agriculture in southern Africa difficult, and climate change will exacerbate these challenges (Niang et al. 2014). Projected temperature increases, more extreme weather, and uncertain rainfall changes are likely to have impacts on agriculture such as increased crop losses, crop failures and increased and new pressures from pests, weeds and pathogens (USAID 2016). These impacts on agriculture will in turn impact the food systems of the region by affecting food availability, creating local production shortfalls and resulting in rising commodity prices (Thornton et al. 2011).

This report highlights the risks to agriculture and food systems in Malawi and Zambia that are likely to occur under climate change. Identifying these risks can help target those areas of each country that are likely to be most affected by climate change. Reviewing the key agricultural value chains in both countries can help identify priority crop value chains of importance for adaptation programs and national prioritisation.

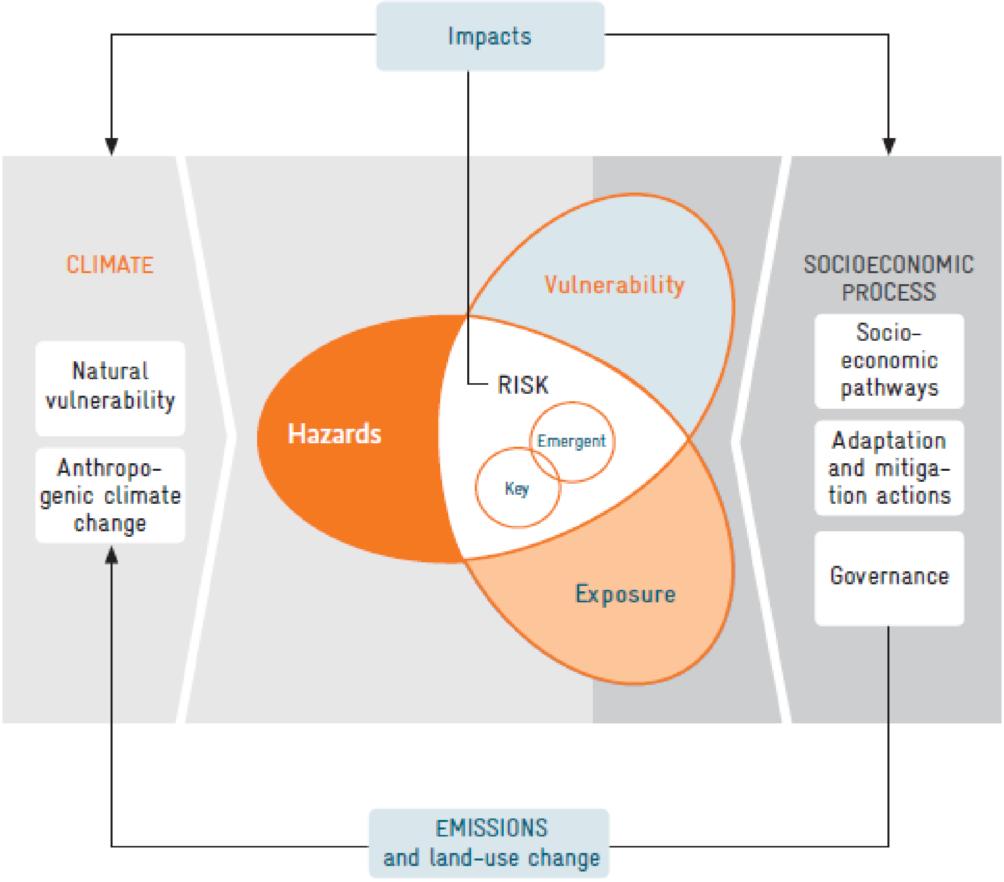
Conceptual framework

We use the conceptual framework of climate-related risk from the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) Working Group II (WGII) to examine the impacts that climate change is likely to have on agriculture and food security (Fig. 1). These results can help inform decision makers in selecting adaptation activities relevant to small scale farmers in these countries.

In AR5, the concept of vulnerability has been expanded to a broader concept of risk of climate change impacts. This risk concept has been adopted from the approach and practices of risk assessment in the disaster risk reduction community. The AR5 risk concept focuses on assessing the risk of specific consequences or impacts that may harm a system. The vulnerability of the system is now one of three components of the risk, with exposure and hazard being the other two components. Consequently, this assessment is called a ‘climate risk assessment’ instead of ‘climate change vulnerability assessment’ as it takes into account the hazards and exposure of agriculture (GIZ and EURAC 2017).

Figure 1: Illustration of the core concepts of the IPCC WGII AR5.

The risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems.



Source: IPCC 2014, p. 1046 (in GIZ and EURAC 2017)

The IPCC (2014) defines **risk** as the “potential for consequences where something of value is at stake and where the outcome is uncertain” (p. 1772). The risk is determined by the interactions between hazards, vulnerability and exposure, so we briefly define these concepts.

In this context, a **hazard** can be defined as the “potential occurrence of a [...] physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources” (IPCC 2014, page 1766). It is important to note that hazards encompass both extreme weather events (e.g. a one-day tropical storm) and slow climate trends (e.g. the annual average temperature increasing over decades). In this study, the focus will be on hazards affecting agricultural production and food security of people.

Exposure is defined by the IPCC (2014) as the “presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected" (p. 1765). An example of exposure in the context of this study would be the number of smallholder farmers and the area they farm.

The use of the concept **vulnerability** has changed with the publication of AR5 and is now defined as the "propensity or predisposition to be adversely affected" (IPCC 2014, p. 1775). The concept now encompasses both the sensitivity of people to climate impacts and their capacity to prepare for and respond to them. Capacity is composed of both coping and adaptive capacity. The **coping capacity** is the "ability of people, institutions, organizations, and systems, using available skills, values, beliefs, resources, and opportunities, to address, manage, and overcome adverse conditions in the short to medium term" (IPCC 2014, p. 1762). An example of this would be the establishment and use of early warning systems. **Adaptive capacity** is the "ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC 2014, p. 1758). This entails for example, the ability of farmers to react aptly to an early warning.

Structure of the paper

This analysis follows the conceptual framework outlined in Figure 1. We first identify the hazards (Section 2), exposure (Section 3) and vulnerability (Section 4) in Malawi and Zambia in relation to agriculture and food security under climate change. We then summarize the risk in Section 5. Building on this information, we present in Section 6 an analysis of crops and livestock in each country that takes into account the value of production at the national level, the production amount, the extent to which the national yield differs from the regional average yield, the contribution to the average per capita day in terms of kilocalories and protein, and the estimated impact of climate change on expected yield. The analysis builds on that used in the CSA country profiles (CIAT and World Bank 2017, 2018). These variables are combined and the products ranked to determine the top three that should be prioritized by agricultural development interventions. We also offer additional information related to the prioritized value chains and the advantages and disadvantages posed by each. Conclusions are presented in Section 7.

Hazards

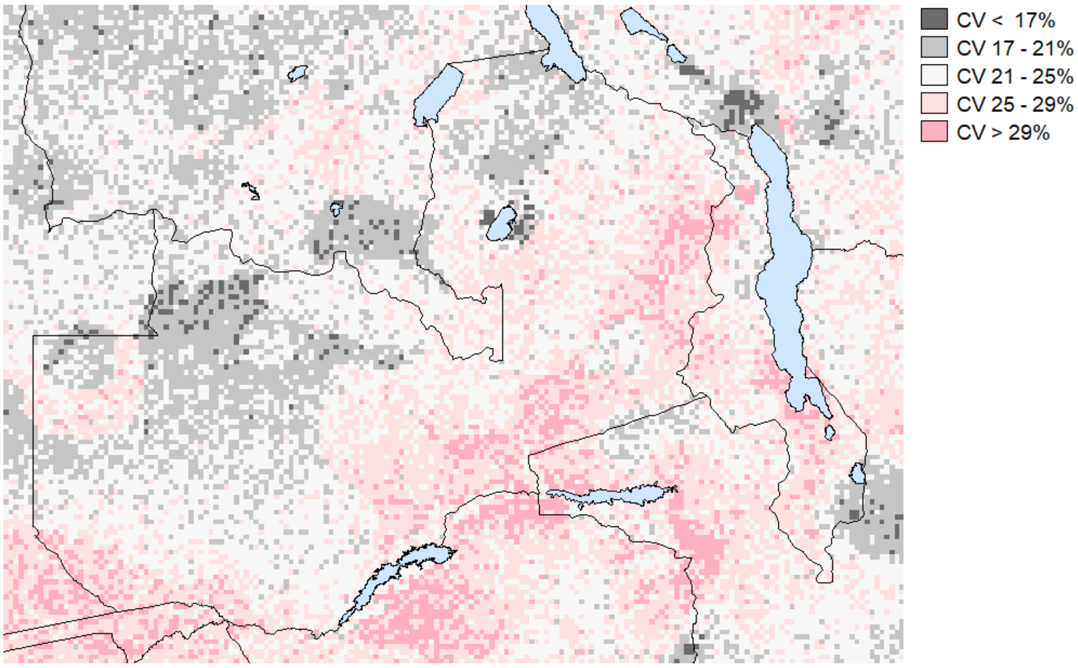
General climate

Malawi is located in eastern southern Africa, with Zambia bordering the country in the west, finding itself in central southern Africa. Both Malawi and Zambia have tropical climates, but with relatively cool temperatures due to their high elevation. Malawi's topography is highly varied, with the Great Rift Valley running from north to south, peaks reaching 3,000 m and Lake Malawi laying in the east at approximately 470 m above sea level. Zambia's topography is set by the East African Plateau on which most of the country lays (McSweeney, New and Lizcano 2012a; 2012b).

Two main seasons can be distinguished in Malawi: a rainy season from November to April and a dry season from May to October. Average daily temperatures vary with seasons and elevation, with the coldest temperatures (12–15°C) found in the highlands in July and the hottest (25–26°C) experienced in the Lower Shire Valley in October. Annual rainfall varies from 500 mm in low-lying areas to more than 3,000 mm in the northern highlands. The Inter-Tropical Conversion Zone controls the wet season rainfall and brings approximately 150–300 mm of rain per month between November and February. Overall rainfall is highly influenced by the El Niño Southern Oscillation and exhibits high interannual variability. In large parts of Malawi, the coefficient of variation of annual rainfall is greater than 25%, as can be seen in Fig. 2.

In Zambia, the temperature highs are reached in the hot, dry season running from September to November (22–27 ˚C), and lows are experienced in the winter months from June to August (15–20 ˚C). The average amount of annual precipitation varies from about 1250 mm in the northern parts of the country to just 500–750 mm in the southern parts of the country; almost no rainfall is received during the hot summer months. As with Malawi, the wet season rainfall is mainly determined by the Inter-Tropical Conversion Zone, and this moves between the northern and southern tropics on an annual basis, bringing rain between October and April of approximately 150–300 mm per month. In addition to the variations brought about by the Inter-Tropical Conversion Zone, the El Niño Southern Oscillation causes further inter-annual variability of rainfall (McSweeney, New and Lizcano 2012b). This variability causes large parts of the eastern and southern regions of Zambia to have a coefficient of variation of annual rainfall greater than 25%, as can be seen in Fig. 2.

Figure 2. Annual rainfall Coefficient of Variation in Zambia and Malawi.



Source: Authors. Data and methods as in Jones & Thornton (2015)

Climate signals in southern Africa

This section is based on the Africa chapter (Ch. 22) of the Fifth Assessment Report (AR5) from Working Group II of the Intergovernmental Panel on Climate Change (IPCC) (Niang et al. 2014).

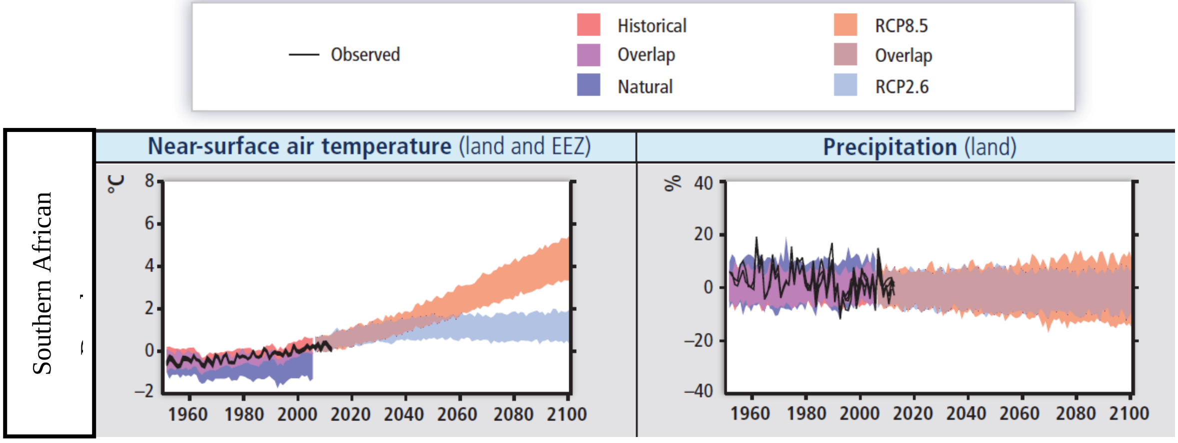
Already, average temperatures over most of southern Africa have increased in the second half of the 20th century and especially in the last two decades. Maximum and minimum temperatures have also risen, with minimum temperatures increasing more rapidly in relation to maximum temperatures throughout inland southern Africa.

The projected rise in the mean annual temperature in Africa, compared to the late 20th century mean annual temperature, is dependent on the global emissions pathway of greenhouse gases (GHGs). For higher-emission scenarios, the projected rise is likely to exceed 2 °C by the end of this century. In addition, it is “likely that land temperatures over Africa will rise faster than the global land average, particularly in the more arid regions, and that the rate of increase in minimum temperatures will exceed that of maximum temperatures” (Niang et al. 2014, p. 1202).

The projections for changes in rainfall are less certain, but in general there are projections for drier winters in southern Africa. The southern spring months may also experience decreases in rainfall, causing later onset of the rainy season. For southern Africa, there is medium confidence that “droughts will intensify in the 21st century in some seasons, due to reduced precipitation and/or increased evapotranspiration. There is low confidence in projected increases of heavy precipitation" (Niang et al. 2014, p. 1206).

Fig. 3 illustrates projections in temperature and precipitation for an optimistic (RCP2.6) and pessimistic (RCP8.5) scenario of GHG emissions. The temperature changes vary greatly under different emissions scenarios, particularly in the latter half of the century. There is no clear trend in increase or decrease of precipitation, but a larger uncertainty under the higher emissions scenario.

Figure 3. Observed and simulated variations in past and projected future annual average temperature.



Black lines show various estimates from observational measurements. Shading denotes the 5th to 95th percentile range of climate model simulations driven with "historical" changes in anthropogenic and natural drivers, historical changes in "natural" drivers only, the RCP2.6 emissions scenario, and RCP8.5. Data are anomalies from the 1986–2005 average of the individual observational data or of the corresponding historical all-forcing simulations.

Source: Adapted from Niang et al. 2014, p. 1208.

Country-specific trends: Temperature

Some of the information in this section comes from the same source, allowing direct country comparisons of temperature and rainfall changes to be made: McSweeney, New and Lizcano 2012a (Malawi) and 2012b (Zambia). These authors analysed climate observations of multiple sources and the multi-model projections made available in phase 3 of the Coupled Model Intercomparison Project (CMIP3), utilising low (B1), medium (A1B) and high (A2) GHG emissions scenarios. More recent regional and country projections from different sources are included below, which essentially confirm the earlier projections (without allowing a direct-to-country comparison to be made). The differences between CMIP3 and CMIP5 projections are actually fairly muted for large areas of the globe (for example, see Sun et al., 2015a for the USA and Sun et al., 2015b for China). Most of the differences have been attributed to the fact that the CMIP5 scenarios cover a larger range of possible future GHG concentrations, resulting in a wider range of climate outcomes in the CMIP5 simulations, rather than to substantial changes in climate model specification and performance (Sun et al., 2015a).

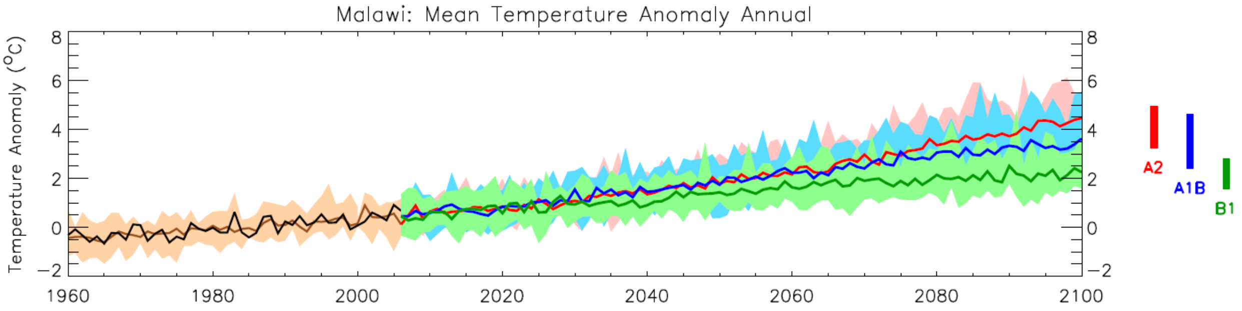
Recent temperature trends in Malawi

Between 1960 and 2006 the mean annual temperature in Malawi has increased by 0.9 °C, as can be observed in Fig. 4. The temperature increase has been most rapid in the summer months of December to February and slowest in the months of September until November. In line with this increase, the frequency of hot days and nights has also increased significantly. ‘Hot’ days or nights are those with a temperature higher than that exceeded on 10% of days or nights in current climate of that region and season. Between 1960 and 2003, the number of hot days has increased 8%, while the number of hot nights has increased 11%. In both cases the highest increase has been observed in summer. At the same time, the number of ‘cold’ days and nights, during which the temperature drops below the temperature of the coldest 10% of days or nights of the current climate, has decreased significantly.

Temperature projections for Malawi

In line with the recent trends, the mean annual temperature in Malawi is projected to increase by 1.1 to 3.0 °C by the 2060s, and 1.5 to 5.0 °C by the 2090s, as can be observed in Fig. 5. All scenarios indicate substantial increases in the frequency of hot days and nights. By the 2060s, 14–32% of the days and 27–53% of the nights will have a temperature considered hot in relation to the current climate. The number of days and nights that are considered cold in the current climate will become exceedingly rare, and not occur at all by the 2090s under the highest emissions scenario (A2).

Figure 4: Trends in annual mean temperature for the recent past and projected future in Malawi.



All values shown are anomalies, relative to the 1970-1999 mean climate. Black curves show the mean of observed data from 1960 to 2006, Brown curves show the median (solid line) and range (shading) of model simulations of recent climate across an ensemble of 15 models. Coloured lines from 2006 onwards show the median (solid line) and range (shading) of the ensemble projections of climate under three emissions scenarios. Coloured bars on the right-hand side of the projections summarise the range of mean 2090-2100 climates simulated by the 15 models for each emissions scenario.

Source: McSweeney, New and Lizcano 2012a

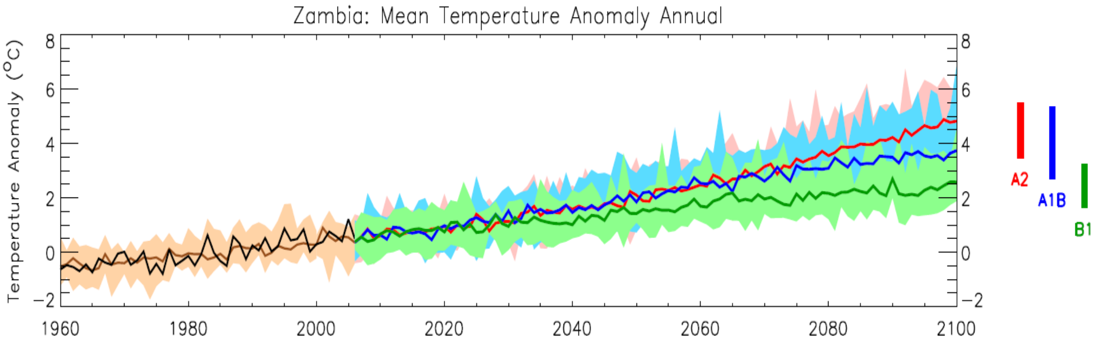
Recent temperature trends in Zambia

Between 1960 and 2006 the mean annual temperature in Zambia has increased by 1.3 °C, which translates into an average rate of 0.3 °C per decade. The temperature increase has been most rapid in the months of September until November. In line with this increase, the number of hot days and nights has increased 12% between 1960 and 2003, while the number of cold days and nights has decreased by respectively 6 and 10%.

Temperature projections for Zambia

In line with recent trends and the projections for Malawi, the mean annual temperature in Zambia is projected to increase by 1.2 to 3.4 °C by the 2060s, and 1.6 to 5.5 °C by the 2090s, as can be observed in Fig. 5. The rate of warming is projected to be highest in the southern and western regions of Zambia. All projections indicate substantial increases in the frequency of hot days and nights as well. By the 2060s, 15-29% of the days and 26-54% of the nights will have a temperature considered hot in relation to the current climate. The number of days and nights that are considered cold in the current climate will decrease to a maximum of 1-4% days in the year by the 2060s and not appear at all by the 2090s in many of the projections.

Figure 5: Trends in annual mean temperature for the recent past and projected future in Zambia. See Figure 4 for details.



Source: McSweeney, New and Lizcano 2012b

Country-specific trends: Precipitation

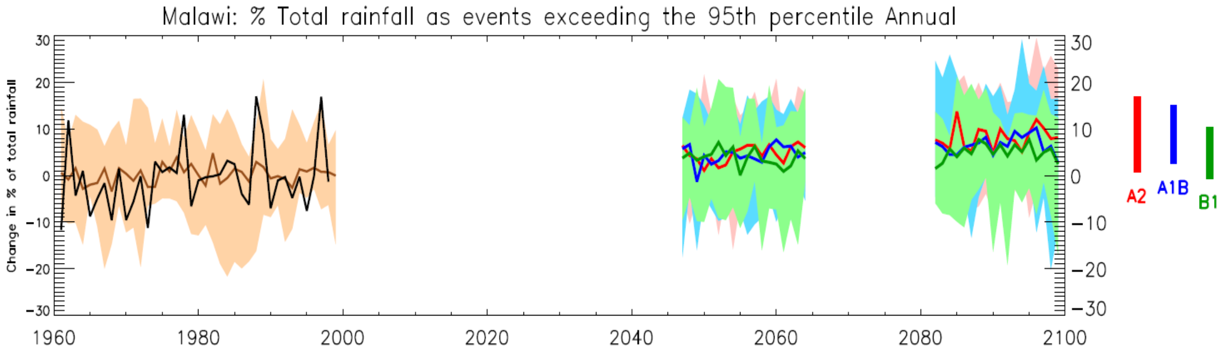
Recent precipitation trends in Malawi

The year-to-year variability of rainfall in Malawi is so great that observations do not indicate statistically significant trends. The wet-season from December 2005 to February 2006 showed particularly little rainfall, causing an apparent decreasing trend in that season, but there is no evidence of consistent decreases. Similar to seasonal and annual trends, no statistically significant statements can be made about the indices of extremes calculated on the basis of daily precipitation observations.

Precipitation projections for Malawi

Projections for the mean annual rainfall in Malawi are so diverse that no clear trends can be noted. Different models project changes in rainfall ranging from a 13% decrease to a 32% increase. With regard to seasonal changes, the projections tend towards decreases in dry season rainfall (January-August and September-November) and increases in wet season rainfall (December-February and March-May). Projections are also consistent with regard to the proportion of rainfall that falls in heavy events, which is projected to reach up to 19% under emissions scenarios A2, as can be seen in Fig. 6.

Figure 6: Trends in the proportion of precipitation falling in ‘heavy’ events for the recent past and projected future in Malawi. All values shown are anomalies, relative to the 1970-1999 mean climate.



Source: McSweeney, New and Lizcano 2012a

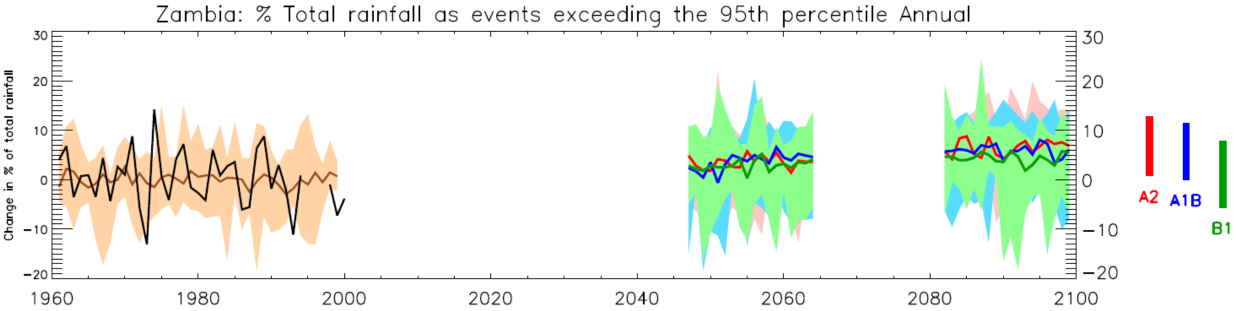
Recent precipitation trends in Zambia

In Zambia, the mean annual rainfall has decreased by an average rate of 2 mm per month every decade since 1960. Most of this annual trend can be explained through the decrease of rainfall in the months of December to February, during which rainfall has decreased by 7 mm per month every decade since 1960. Different from Malawi, the proportion of rainfall falling in heavy events decreased slightly, but not as much as to be statistically significant.

Precipitation projections for Zambia

The mean annual rainfall is not projected to change significantly. The projections of different models with regard to seasonal changes vary considerably, but a model ensemble indicate that in the north-east of the country rainfall will decrease from September to November. Just as in Malawi, the proportion of rainfall falling in heavy events is projected to increase annually, as can be seen in Fig. 7.

Figure 7: Trends in the proportion of precipitation falling in 'heavy' events for the recent past and projected future in Zambia. All values shown are anomalies, relative to the 1970-1999 mean climate.



Source: McSweeney, New and Lizcano 2012b

Climate extremes

The results from recent regional climate modelling research confirm the projections outlined above. For global warming of 2.0 °C, southern Africa is projected to experience a robust increase in temperature compared to the control period (1971–2000) ranging from 1.5 °C–2.5 °C, with higher values particularly from September to November. Rainfall projections remain uncertain and regionally differentiated (Maúre et al., 2018), with some areas projected to undergo significant reductions and others small increases. Importantly, in the areas projected to undergo significant reductions in rainfall, this will be accompanied by increases in the number of consecutive dry days and decreases in consecutive wet days. Rainfall events will tend to become less frequent, while more intense rainfall events, separated by a large number of dry days, will tend to become more frequent. Overall, the proportion of total rainfall coming from extreme precipitation events is expected to increase (FCFA, 2016). In both countries, stronger inter-annual variability in rainfall is likely, along with more likely flooding and drought events. Projections further suggest increases in the mean number of days with temperatures greater than 30°C, consistent across the majority of the climate models. For Malawi, models are in agreement concerning decreases in the mean number of rain days and increases in the amount of rainfall on each rainy day. Malawi experienced serious flood events in 2015, resulting in several hundred fatalities and substantial displacement of people, highlighting the need for real-time flood prediction (Kruczkiewicz et al., 2015). All in all, in the coming decades, rainfall is expected to be more variable, with increased likelihood of both dry spells and intense rainfall events (often associated with flooding), as well as increased likelihood of very hot days (FCFA, 2016; 2017).

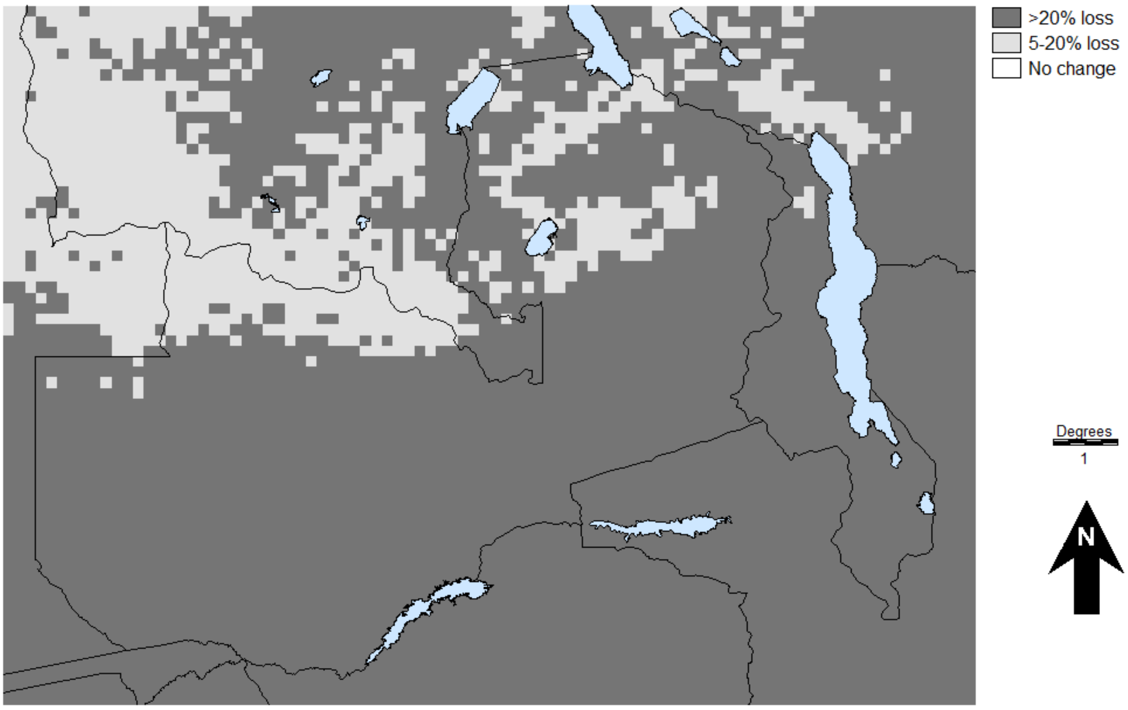
Exposure

Projected effects of climate change on agriculture

Implications for the growing season

The changes in temperatures and in rainfall amounts and patterns in both Malawi and Zambia will affect the length of the growing season. Throughout both countries, and in particular in the central and southern regions, the length of the growing period (LGP) is projected to decrease by more than 20% by the end of the 21st century, as can be seen in Fig. 8. The LGP is the average number of growing days per year, whereby growing days are those with an average air temperature over 6.8 °C and the ratio of actual to potential evapotranspiration greater than 0.35. The decrease of LGP will not only affect cropping systems, but also livestock keeping, as growing days can be seen as a proxy for forage availability in water-limited systems (Thornton et al. 2011).

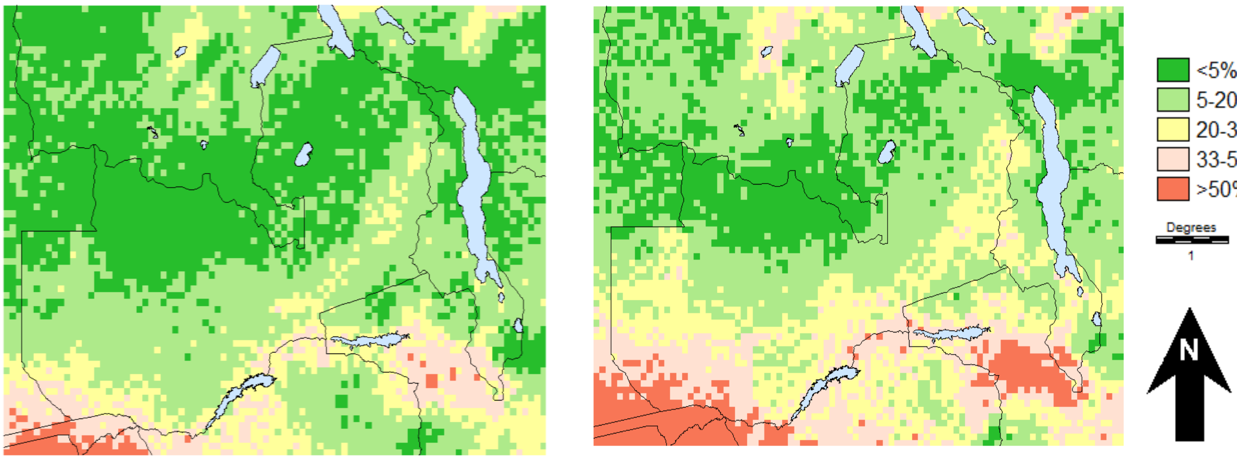
Figure 8. Change in length of growing period in Malawi and Zambia in a +4 C world.



Source: Authors. Data and methods as in Jones & Thornton (2008, 2015)

At the same time, the probability of season failure is likely to increase. Using the definition in Jones & Thornton (2008), a season is considered to fail when it consists of fewer than 50 growing days or if more than 30% of the days with the season are non-growing days. By the 2050s, it is projected that in parts of southern Malawi and southern Zambia, one in every two or three years will have a failed season, as can be seen in Fig. 9. Taken together, the shortening of the growing season and increased crop failure may have serious implications for farmers' ability to adapt; the varieties and crops currently grown may not be suitable under future climates. This highlights the importance of crops and crop varieties that are drought- and heat-tolerant and can adapt to shorter, more erratic growing seasons.

Figure 9. Probability of main season failure in Malawi and Zambia.



Current conditions

Ensemble mean values, 17 climate models, RCP 8.5, 2050s

Source: Authors. Data and methods as in Jones & Thornton (2008, 2015)

Implications on pests and diseases

In general, it is projected that climate change, particularly higher temperatures, will cause increased risks of pests and diseases within Africa's agricultural systems (Hachigonta et al. 2013). The effects will likely be felt in crop, livestock and fishery subsectors (Dinesh et al. 2015). It is anticipated that rising temperatures will increase pests and diseases (USAID 2013). Climate change is also likely to cause greater frequency of new pests and major pest outbreaks (Dinesh et al. 2015). Specific impacts for Malawi and Zambia are not possible to determine at this time.

Implications for water resources

The impacts of climate change on water availability in Malawi are already being felt. In a country that once had an abundance of water, there is now water scarcity due to erratic rainfall, extended dry periods, and increased evaporation (USAID 2013). The lakes and rivers in the country are very sensitive to changes in climate, and the reduced rainfall has led to lower lake levels and less water in the river systems (USAID 2013). Lower rainfall also affects farmers who mostly rely on rainfed agriculture.

In Zambia, water resources are also under threat from climate change. Due to increased temperatures, there is likely to be lower recharge rates of groundwater, leading to lower water tables and the drying up of boreholes. Increased dry spells may also cause water shortages. There is a projected increase in the proportion of rain falling during intense events, which may lead to flooding and/or greater siltation and sedimentation of rivers (USAID 2016).

Implications for livestock and fisheries

Climate change is likely to affect livestock production in southern Africa through a reduction in forage availability and quality and therefore lower productivity (Dhanush et al. 2015). Also, most livestock species perform poorly at higher temperatures because they reduce their feed intake at temperatures of about 30 °C (Dhanush et al. 2015). Climate change is expected to reduce the quantities of fish caught because of higher water temperatures (Allison et al. 2009). According to a vulnerability analysis by Allison et al. (2009), the national economies of Malawi and Zambia are both ‘highly vulnerable’ to climate change-driven impacts on fisheries.

Small scale farmers in Malawi and Zambia

The effects of climate change on agriculture will be compounded by the magnitude of importance that agriculture plays in the economy of Malawi and Zambia. The population of Malawi was estimated at 18 million in 2016, with 84% residing in rural areas (World Bank 2018a). By 2050, Malawi’s population is projected to reach 43 million inhabitants, with 67% of the population living in rural areas (UN DESA 2015). The economy of Malawi is highly dependent on agriculture, with the sector being responsible for 65% of employment and 80% of exports, the main crops by export value being tobacco, sugar and tea (FAO 2018). The agriculture sector contributes 40% of the country’s GDP (USAID 2017). Farming is the livelihood for an estimated 80% of the population, making the sector crucial to the well-being of the country as a whole (FAO 2018).

The agricultural sector in Malawi is overwhelmingly made up of small farms: of the 2.6 million holdings in the country (Lowder et al., 2016), more than 94% are less than 2 ha in size, and 60% are less than 0.8 ha (Julien et al., 2018). Even so, farms of < 2 ha produce 36% of the cereal protein nationally and nearly 40% of the protein from roots and tubers (Herrero et al., 2017).

In addition to the cash crops in Malawi cultivated for export, the main staple crops grown are maize and groundnuts. Maize is grown by 97% of farmers (USAID 2013). The land under agriculture has been increasing in recent years, and 61% of total land area in the country is now under crops or pasture (FAO 2018). Most of the agriculture in Malawi is rain-fed subsistence agriculture (USAID 2013), and the average farming household owns just 0.5 hectares of land. Less than 5% of agricultural land is under irrigation (Saka et al., 2013). Livestock production is also mainly subsistence level and is lower than other regional levels. Approximately 4% of Malawi’s GDP comes from its fisheries, and animal protein in the local diet is 60-70% from fish (USAID 2013). Malawi has a relatively large share of farming households that are headed by women at almost one third of households (FAO 2018). Given the documented disadvantages that women have in agriculture (Huyer 2016), this increases the exposure of the small-scale farming community to the impacts of climate change.

The situation is slightly different in Zambia, where approximately 60% of the population of 16.2 million lives in rural areas (CIAT and World Bank 2017). Just as in Malawi, Zambia’s population is also projected to reach 43 million in 2050. With high urbanization rates, only 37% of all Zambians are still expected to live in rural areas in 2050 (UN DESA 2018). However, agriculture will remain an important source of livelihoods for many people. Currently there are about 1.6 million small scale farmers in Zambia, and the average land holding is 1.5 ha (CIAT and World Bank 2017). Most of these farmers rely on rainfed agriculture, leading to a high susceptibility to climate change impacts (USAID 2016; Kanyanga et al. 2013). The agriculture sector contributes approximately 8% of Zambia’s GDP (CIAT and World Bank 2017), which is less than in Malawi but still a significant proportion. It is estimated that women provide 70% of agricultural labour (CIAT and World Bank 2017).

Like Malawi, the agricultural sector in Zambia is made up of a considerable proportion of small farms. Of the 1.6 million holdings in the country, 82% are less than 5 ha in size, and 52% are less than 2 ha (Sitko and Chamberlin, 2015). Farms of < 2 ha produce 22% of the cereal protein nationally and 38% of the protein from roots and tubers (Herrero et al., 2017). Unlike Malawi, Zambia has a significant number of farms (>19,000) from 20-100 ha in size, located mostly in the centre and south of the country (Sitko and Chamberlin, 2015; Herrero et al., 2017).

The main staple food crops in Zambia are maize, cassava, millet, sorghum and beans (CIAT and World Bank 2017). Of these, maize, millet and sorghum are particularly sensitive to changes in climate (USAID 2016). Maize is especially vulnerable to fluctuations in climate due to its physical characteristics that result in sensitivity to changes in moisture and temperature (Kanyanga et al. 2013). The high dependence on maize in the diet of Zambians and the lack of diversification in production systems means that food security in the country is very vulnerable to climate change (CIAT and World Bank 2017). Livestock is also at risk from increased pests and diseases and reduced forage and feed availability predicted as a result of increased droughts (CIAT and World Bank 2017).

Vulnerability

Sensitivity in Malawi

Malawi ranks 170 out of 188 countries in the Human Development Index (HDR 2016) and is classified as a low-income country. The population is largely rural (84%) and faces high poverty rates (70%); poverty rates are on the increase in rural areas (FAO 2018). High poverty levels are a result of the limited base of livelihoods in the country (CIAT and World Bank 2018). Its vulnerability to climate change is influenced by its dependence on rainfed agriculture, high levels of malnutrition and HIV/AIDS, and rapid population growth (USAID 2017).

The agricultural sector is extremely sensitive to climate change because of its reliance on rainfed crops. Other constraining factors are small land sizes, degraded soils, and low usages of agrochemical inputs (USAID 2017). Maize is the key staple crop (FAO 2018) but is highly sensitive to changes in temperature and rainfall (Ramirez-Cabral et al. 2017; see box 1 on recent droughts). Another key contributor to the diet and to agricultural exports is groundnuts (CIAT and World Bank 2018). Climate change may affect the export potential and the food safety for this crop through increased growth of aflatoxins following more frequent heavy rains (USAID 2017). Fish from the lakes of Malawi provide a significant portion of the protein in the diet (28% of animal protein intake) and form an important part of the livelihood for 10% of the population; the inland fisheries of Malawi are under threat from climate change (USAID 2017).

Box 1. Humanitarian crisis in 2016

Erratic weather in the last three years has demonstrated how vulnerable Malawi and Zambia are to changes in the climate. Malawi was hit by floods in the season 2014-2015, and both Malawi and Zambia were plagued by dry spells in the consecutive season, with rainfall at 40% of the required volume in the hardest hit areas. As a result, 6.5 million Malawians were left in need of humanitarian aid in 2016 (CSIS 2016), while Zambia imposed a ban on the export of maize and the price for this staple food doubled in some regions (Reuters 2016).

The country's sensitivity is also compounded by the high levels of malnutrition and HIV/AIDS. According to the 2015-16 Malawi Demographic and Health Survey (DHS), 37% of under 5 are stunted, and 63% are anaemic (NSO 2017). HIV prevalence is higher in urban areas (14.6%) than rural areas (7.4%) and higher among women (10.8%) than men (6.4%) (NSO 2017). In terms of population, the growth rate in 2016 was 2.9% (World Bank 2018a).

Sensitivity in Zambia

Zambia has undergone considerable development since 2000, and the World Bank graduated Zambia to low middle-income status in 2011 (Guardian 2011). Most of this economic growth was due to a surge in the price of copper of which Zambia is a major exporter. However, the economic growth and massive Chinese investments have failed to improve the lives of most Zambians, with almost 57.5% of the population still living under the international poverty line of US$1.90/day (World Bank 2018b). The poverty rate in rural areas has increased from 2010 to 2015, rising from 73.6% to 76.7%; 82% of those in poverty live in rural areas (World Bank 2018b). Reasons for this are the rapid population growth, high prevalence of HIV (with 14% of the Zambians aged between 15 and 49 infected), and most Zambians rely on subsistence farming for their livelihood (UNICEF 2018).

The sensitivity of Zambia's population to climate change impacts on agriculture is further exacerbated by the dominant role of maize and cassava. These two crops provide over 50% of the population's intake of energy and protein intake (FAOSTAT 2018). However, agriculture in Zambia is predominantly rainfed, making the yields of these crops directly dependent on the timeliness of the rainy season and stability of temperatures (USAID 2016). Also, the productivity of livestock is directly affected by the climate, as poor pasture and land management, disease prevalence and inadequate veterinary services, make the animals highly sensitive to drops in quality and quantity of feed. Fisheries are often subject to changes in fish stocks caused by rain and temperature.

Independently of climate change, Zambian farmers face other challenges to keep their yields up. In the northern regions of Zambia, farmers typically cultivate cassava using slash-and-burn techniques and face problems related to humidity and waterlogging. The central part of Zambia, running as a strip from the city of Mongu in the west to the border of Malawi in the east, is dominated by maize and livestock. The productivity of these are hampered by recurring droughts. The southern part of Zambia, bordering Namibia and Zimbabwe, is agriculturally more diverse and is also affected by water availability issues. Here reduced water availability also impacts the provision of hydro-power, on which the country is largely dependent (USAID 2016).

Another aspect, enlarging the sensitivity of agricultural production to climate change, are post-harvest losses. Losses of grains have been as high as 35% at national grain storage facilities. In general, losses occur due to high humidity, pest attacks and pilfering. In the central and northern parts of Zambia, sporadic rain showers sometimes lead to losses of grains in storage sheds and open storage platforms.

For vegetables, post-harvest losses are estimated at up to 50%, due to a lack of processing and storage facilities after harvest and a lack of market incentives for small farmers (CIAT and World Bank 2017).

Coping and adaptive capacity in Malawi

The coping capacity of agriculture in Malawi is determined to a large extent by the access to agricultural technology, such as irrigation. Only 1.5% of the farmland of smallholders is irrigated, resulting in a high vulnerability to weather variability and extremes. However, motorized equipment is even rarer, with only 0.4% of the smallholders using this. The access and use of other inputs, however, is relatively high in Malawi, compared to other African countries. This is mostly due to the governmental Farm Input Subsidy Program (FISP), which provides input vouchers and extension services. As a result, 76% of the smallholders has access to fertilizers, 57% to improved seeds and 39% to extension services or other knowledge sources. This program has improved food self-sufficiency of farmers considerably, while the average value of crop production is still relatively low, with USD 321 per year (FAO 2018).

Malawian smallholder farmers have a slim adaptive capacity, due to several reasons. The first is that they only sell a minor part of their produce on the market. This is partly caused by infrastructural limitation, with the average distance of smallholders to a road amounting to 23 km. A second reason is because, trade happens mainly through informal, local marketing channels, which offer low prices. A third reason is because ownership of lands is greatly fragmented, which hampers investments and intensification. This last aspect is worsened by the fact that only 6% of small family farmers have access to credit (FAO 2018).

Coping and adaptive capacity in Zambia

Compared to its surrounding countries, Zambia is fairly stable in terms of national food security. On a national scale, the country experienced good yields in the last five years, being a net exporter of maize to neighbouring countries. Zambia also sells part of this surplus of maize to organizations that purchase it to support their food aid emergency programmes in sub-Saharan Africa, such as the World Food Programme. However, food insecurity remains particularly high in southern parts of the country, which have been affected by prolonged droughts and poor agricultural production in 2016. Other factors contributing to food insecurity are price volatility (driven by inflation) and input and output markets.

As a result, 49% of the population is still malnourished, while 15% and 6% of children under five are underweight and stunted respectively (CIAT and World Bank 2017).

There is ample room to increase production however, as only 15% of the land that is suitable for agriculture is being cultivated. In addition, only 29% of the land that can be irrigated is equipped for irrigation. Currently, sprinkler irrigation is mostly used by commercial farmers for arable crops, such as sugar cane. Most family farmers however, rely on a combination of buckets, watering cans, traction pumps and motorised pumps to water their crops (CIAT and World Bank 2017).

The adaptive capacity of the Zambian population is slim, with almost 60% living below the poverty line and most of them in rural areas. Despite its importance for the livelihood and food security of the population, the agricultural sector plays a secondary role in the country's economic development agenda, after mining. In order to ensure equitable growth and address current poverty and food and nutrition security challenges, it is essential that small farmers stimulate agriculture through policies and programmes (CIAT and World Bank 2017).

Although much research is available on conservation agriculture, more evidence on the implementation and impact of other CSA practices and technologies is needed to ensure the applicability of practices in the different agricultural and socioeconomic contexts of the country. The high dependence on maize as a food security crop discourages farmers to a large extent from diversifying their production system. As a result, even where intercropping and crop rotation are promoted, the farmers' focus and priority are largely on maize. There is a need to develop input and output market systems for a range of agricultural products within diverse and climate-smart production systems (CIAT and World Bank 2017).

The adaptive capacity is also affected by the low access to long-term credit. As only 2% of small farmers have a formal title for their business, many farmers do not qualify for ordinary loans. If credit is available, interest rates are high because of the perceived risk associated with small-scale rainfed agriculture. Nevertheless, agricultural credit will be essential for farmers to take adaptation measures.

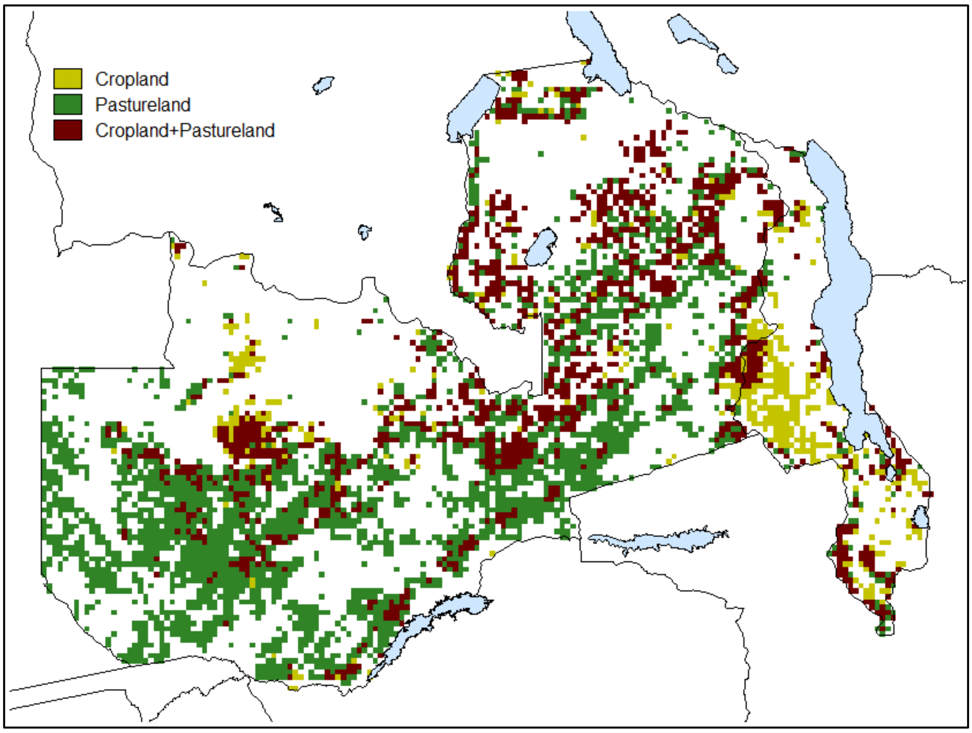
Although different stakeholders are involved in the provision of agricultural extension, efforts are embedded in a project-based, rather than a programmatic approach, leading to fragmented and uncoordinated results. Cooperation between development partners on adaptation and mitigation initiatives for agricultural climate has improved in recent years, but there is scope for further information and sharing of experience and joint programming (CIAT and World Bank 2017).

Risk analysis

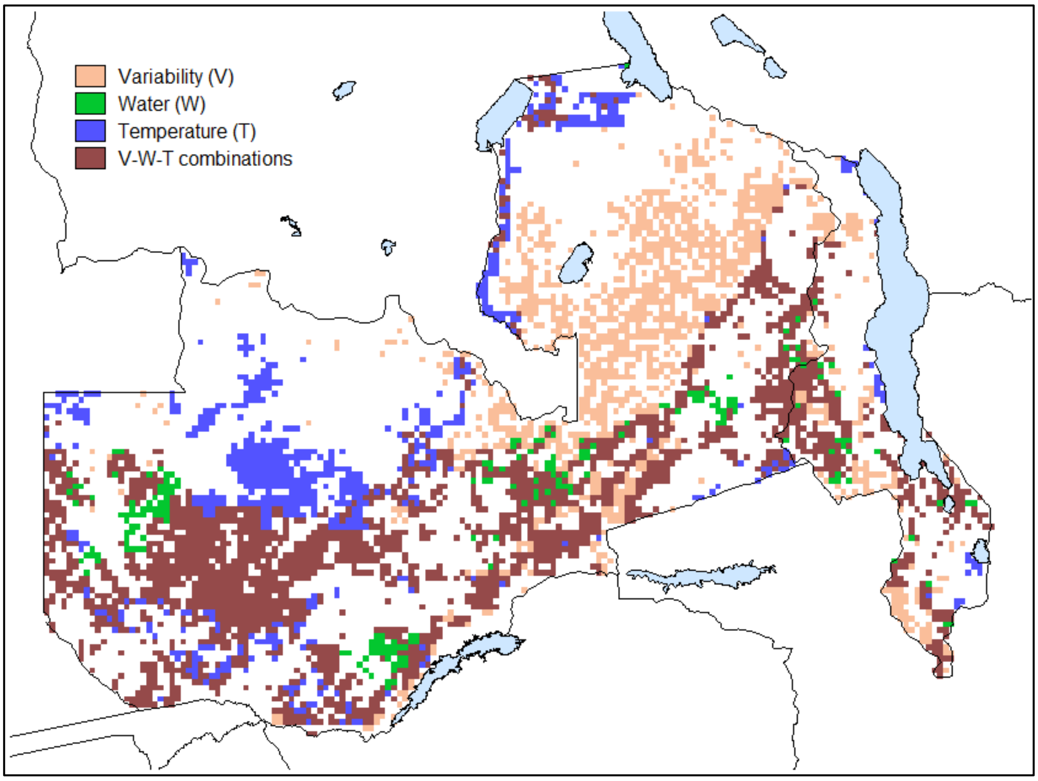
The previous sections have identified the hazards posed by climate change, and the exposure and vulnerabilities of the agricultural sector and small-scale farmers to face the anticipated changes. This information is now brought together to assess the risks of climate change on agriculture and small-scale farmers in the two countries of interest. The analytical scheme is that shown in Figure 1. In Figure 10 the risks posed by climate change on agriculture have been mapped in Malawi and Zambia (see Appendix 1 for methodology). Figure 10A shows "risk domains" in the two countries in relation to agricultural land use (cropland, pastureland, and both cropland and pastureland). Areas in white show land areas with crop and pastureland below a threshold, and can be interpreted as less important agricultural lands. For these risk domains, Figure 10B shows the principal risks to agriculture posed by climate change, in relation to increased climate variability, decreased water availability, increased temperatures, and combinations of these three risks.

Figure 10. Climate change effects on agricultural vulnerability

A. Climate change risk domains by major agricultural land use in Malawi and Zambia



B. Climate change risk domains and the major types of weather-related agricultural risks faced in Malawi and Zambia



Source: Authors

Based on the risk mapping results in Figure 10 A and B, it is evident that Malawi and Zambia both face immense challenges in adapting their agricultural sectors to climate change. Malawi will face challenges in the croplands arising from temperature-water-variability interactions as a result of climate change. Zambia will face challenges on both pasturelands and mixed-use lands. Eastern Zambia will face challenges mainly associated with increased rainfall variability, while the western part of the country will contend with higher temperatures and combinations of variability, water and temperature challenges that will affect agricultural production.

These stresses will be felt most intensely by small-scale farmers who rely on rainfed agriculture for their livelihoods. Farmers in the southern half of Malawi and the southern and eastern parts of Zambia are most at risk of climate-related impacts on their cropping systems. See Appendix 2 for a tabulation of risks by province in each country. Regardless of crop, the appropriate interventions to address these risks will vary according to the key risk. Water- and variability-related risks may be addressed via improved water use efficiency and water management (for example); temperature-related risks may better be addressed through switching varieties (heat tolerance) or using more heat-tolerant crops altogether. Other interventions that may help farmers cope include improved climate and agricultural advisory services, agricultural risk insurance, and better access to credit. These types of activities can help build the adaptive and coping capacity of small-scale farmers so they are better able to address the challenges posed by climate change.

Crop and livestock prioritisation

Although broad-based interventions like climate-informed advisories can help deal with stresses that cut across farming systems, there are specific crops and livestock as well as specific farming systems that will be more affected than others by climate change. It is important to analyse which commodities and types of livestock will be hit the hardest so that national development and investment plans can take these into account. In this section, we carry out a prioritisation process to rank different commodities in each country, with respect to several dimensions.

The method employed builds on that used in the CSA Country Profiles for Malawi and Zambia (CIAT 2018; CIAT and World Bank 2017). We began by selecting crops or livestock commodities within Malawi and Zambia that play a significant role in the food and nutrition security of the population. This was done through a review of the food balance sheet data from FAOSTAT and selecting food crops that contributed at least 5 kcal/capita/day. Oils, sugar and alcohol were not included in the list.

After establishing the list of most relevant crops and livestock products, we gathered data for each commodity based on selected variables. These variables are intended to help select the key crops or livestock to be prioritized for agricultural value chain interventions within each country. The dimensions used are the following:

- Value of production: this reflects the importance of the commodity to the economy of the country. In the case of food staples, this also links to food security, if the commodity accounts for a substantial proportion of the consumption of calories or protein. This is also a key dimension in relation to actual and potential involvement of the private sector, who are unlikely to be willing to invest in commodity value chains of only limited potential.
- Quantity of production: this is another indicator of the national importance of the commodity, specifically to farmers, in relation to its total harvested area multiplied by the average yield. For livestock commodities, this is the total number of animals multiplied by the production (of meat, milk or eggs) per animal.
- Regional yield gap: this dimension reflects the potential for increasing production of the commodity, by comparing the national yield with the average yield obtained in the eastern Africa

region[1]. A commodity with a large regional yield gap indicates that there may be high potential to increase yields nationally, utilising regional technology and know-how from neighbouring countries where yields are much greater.

- Importance of the commodity in the diet: this dimension addresses the importance of the commodity in national diets, in relation to the supply of energy and protein. While there may be considerable potential to introduce new crop and livestock products into national diets, these changes may take a great deal of time, education and input to bring about. In the short term, a concentration on commodities that are already contributing to national diets is more justifiable.
- Impact of climate change on yields: this dimension reflects the likely future impacts of climate change on production of the commodity, on the basis that the future adaptation investment needs of key commodities may be very substantial.

The data for the first four categories were gathered from FAOSTAT and the past five years of available data were averaged and then normalized. The values for the impact of climate change on yields were assigned based on a review of the climate change impact modelling literature (see Table 1 below). If modelled impacts could not be found in the literature, the value was estimated based on expert knowledge of agronomics and climate change. All five indicators were scored from 0 to 1, with the higher values indicating higher value of production, greater importance to farmers, larger growth potential, larger contribution to food and nutrition security, and more negative impacts of climate change. Final ranks were calculated using a set of weight: all were set to unity, except for contribution to food and nutrition security (a weight of 2) and climate change impact (a weight of 3).

Table 1. Climate change impacts on major commodities in Malawi and Zambia

Commodity	Impact range % yield change	Sources, scenarios, region	Impact index
Banana	-10 to +2	TR (2050s, A1B, southern Africa); L+ (2030s, southern Africa); TC (2020s, A2, E Africa)	1
Beans	-68 to -9	WC (2050s, A1B, Zambia); T+ (2090s, +4°C, southern Africa)	3
Beef	Assumed slight negative		1
Cassava	0 to +7	WC (2050s, A1B, Zambia); L+ (2030s, southern Africa); RVC (2050s, southern Africa)	0
Cow peas	-15	LU (2050s, A2, Kenya)	2

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[1] In the FAOSTAT database, both Malawi and Zambia are included in the group of countries of eastern Africa.

Commodity	Impact range % yield change	Sources, scenarios, region	Impact index
Eggs	Assumed slight negative	-	1
Fish	Assumed slight negative	-	1
Groundnuts	-17 to +2	A+ (2090s, A2, Malawi); WC (2050s, A1B, Zambia); TR (2050s, A1B, southern Africa); L+ (2030s, southern Africa); RVC (2050s, southern Africa)	2
Maize	-28 to -5	A+ (2090s, A2, Malawi and Zambia); WC (2050s, A1B, Zambia); L+ (2030s, southern Africa); TR (2050s, A1B, southern Africa); RVC (2050s, southern Africa); T+ (2090s, +4 °C, southern Africa); S+ (+2°C, southern Africa)	3
Poultry meat	Assumed slight negative	-	1
Milk	Assumed slight negative	-	1
Millet	-22	WC (2050s, A1B, Zambia)	3
Pig meat	Assumed slight negative	-	1
Pigeon pea	-20 to -10	B+ (2065s, India)	2
Plantains	-6	L+ (2030s, southern Africa)	1
Potatoes	-37	HI (2050s, southern Africa)	3
Rice	-18 to +5	A+ (2090s, A2, Malawi and Zambia); WC (2050s, A1B, Zambia); L+ (2030s, southern Africa); TR (2050s, A1B, southern Africa); RVC (2050s, southern Africa); S+ (+2°C, southern Africa)	2
Sheep/goat meat	Assumed slight negative	-	1
Sorghum	-35 to -1	A+ (2090s, A2, Malawi and Zambia); L+ (2030s, southern Africa); TR (2050s, A1B, southern Africa); RVC (2050s, southern Africa)	3
Soybeans	-14 to -8	A+ (2090s, A2, Malawi and Zambia); L+ (2030s, southern Africa); TR (2050s, A1B, southern Africa); RVC (2050s, southern Africa); S+ (+2°C, southern Africa)	2
Sweet potato	-7	WC (2050s, A1B, Zambia)	2
Wheat	-25 to -8	A+ (2090s, A2, Zambia); TR (2050s, A1B, southern Africa); RVC (2050s, southern Africa); S+ (+2°C, southern Africa)	2

Impact index, representing the median of multiple projection estimates (where these exist): 0 little or somewhat positive (>-3%); 1 some impact (-10% to -3%); 2 moderate impact (-20% to -10%); 3 severe impact (<-20%)

Where available, projection data are in the absence of the CO_2 fertilisation effect, given the prevalence of low-input cropping systems in the target countries and uncertainty as to whether crops would be able to express any CO_2-related yield benefit in such systems.

Reference code:

A+	Adhikariet al. (2015)	RVC	Ramirez-Villegas and Challinor (2018)
B+	Birthal et al. (2014)	TG	Thomas and Rosegrant (2015)
HI	Hijmans (2003)	T+	Thornton et al. (2011)
L+	Lobell et al. (2008)	TC	Thornton and Cramer (2012)
LU	Luedeling (2011)	WC	Wineman and Crawford (2017)
		S+	Schleussner et al. (2016)

Malawi

Based on the method described above, data for the selected variables of the major crops and livestock products for Malawi are shown in Table 2. The diet is primarily maize-based, with potatoes also providing a major source of energy. Protein is supplied through legumes (beans, cow peas, pigeon peas and soybeans) along with livestock products and fish. There is high production of cassava. Note that data for sweet potato in Malawi are not available through FAOSTAT but this might be an important crop to also consider when selecting value chains for prioritisation.

Table 2. Key agricultural statistics for main crops in Malawi

	Gross Production Value (current million US$)	**Production (tonnes)**	**Regional yield gap (%)**	**Energy Kcal/cap/ day (%)**	**Protein g/cap/ day (%)**
Bananas	188	414,103	318	1.5	0.9
Beans	200	183,311	64	1.9	4.5
Beef and Buffalo Meat	120	39,511	81	0.5	1.4
Cassava	1,576	4,920,820	301	6.5	2.5
Cow peas	23	34,094	84	2.2	4.7
Eggs	81	22,740	85	0.2	0.5
Fish	75	100,400	100	0.5	3.2
Groundnuts	324	339,266	115	2.8	4.3
Maize	828	3,276,492	107	48.2	46.6
Meat, Poultry	451	82,394	231	0.2	0.7
Milk, Total	42	169,065	46	0.4	0.8
Millet	25	33,806	59	0.8	0.8
Pig meat	277	109,760	59	1.9	1.8
Pigeon pea	228	310,071	129	2.2	4.7
Plantains	70	385,948	260	2.1	0.7
Potatoes	1,135	2,364,262	147	10.1	7.6
Rice, paddy	110	112,663	64	2	1.4
Sheep and Goat Meat	98	37,875	85	0.4	1.3
Sorghum	46	76,689	62	0.9	1.0
Soybeans	83	120,825	72	0.8	3.3
Wheat	1	1,375	54	3.2	3.5

Source: FAOSTAT 2018

The data from Table 2 were analysed as described above, and the prioritisation results for Malawi are presented in Table 3 below.

Table 3. Crop and livestock prioritisation results for Malawi

	Prod. Value	Prod. tonnage	Reg. yield gap	Food security	Impact of CC	Total	Rank
Bananas	0.12	0.08	0.00	0.02	0.30	1.14	21
Beans	0.13	0.04	0.80	0.06	1.00	4.08	3
Beef and Buffalo Meat	0.08	0.01	0.74	0.01	0.30	1.75	16
Cassava	1.00	1.00	0.05	0.09	0.00	2.23	12
Cow peas	0.01	0.01	0.74	0.07	0.70	2.99	11
Eggs	0.05	0.00	0.73	0.00	0.30	1.69	18
Fish	0.05	0.02	1.00	0.03	0.30	2.03	13
Groundnuts	0.21	0.07	0.64	0.07	0.70	3.15	6
Maize	0.53	0.67	0.66	1.00	1.00	6.85	1
Meat, Poultry	0.29	0.02	0.27	0.00	0.30	1.48	19
Milk,Total	0.03	0.03	0.86	0.01	0.30	1.83	15
Millet	0.02	0.01	0.81	0.01	1.00	3.86	5
Pig meat	0.18	0.02	0.81	0.03	0.30	1.98	14
Pigeon pea	0.14	0.06	0.59	0.07	0.70	3.03	9
Plantains	0.04	0.08	0.18	0.02	0.30	1.25	20
Potatoes	0.72	0.48	0.54	0.18	1.00	5.10	2
Rice, paddy	0.07	0.02	0.80	0.03	0.70	3.05	8
Sheep and Goat Meat	0.06	0.01	0.73	0.01	0.30	1.72	17
Sorghum	0.03	0.02	0.80	0.01	1.00	3.87	4
Soybeans	0.05	0.02	0.77	0.04	0.70	3.02	10
Wheat	0.00	0.00	0.83	0.06	0.70	3.06	7

Using the described ranking scheme, the crops that should be prioritized in Malawi for helping small-scale farmers adapt to climate change are maize, potatoes and beans. Maize comes out at the top because it is crucial for calorie and protein intake, it is grown by many farmers on large amounts of land, and the impact of climate change on its growth will be negative. Potato is also important for calorie and protein intake, its high value of production in the country, and the anticipated negative impact of climate change. Beans are also important for protein in the diet, offer a potential to raise yields in comparison to the regional average yield, and are likely to be negatively affected by climate change.

Interventions aimed at helping small-scale farmers adapt to climate change may wish to take a value chain approach to their development efforts because research has shown that farmers who are involved in value chains can increase their productivity and benefit from greater access to inputs such as seeds, fertilizers, and extension services (Dihel et al., 2018). Although maize is the top-ranked commodity in the priority list, it may be more advantageous to prioritize a value chain other than maize. There are many development projects that already target maize production. Also, the Government of Malawi has issued several policies that call for diversification away from the high dependence on maize. The Malawi National Nutrition Policy (2013) states that agricultural practices which encourage crop diversification should be encouraged, and the Malawi National Agriculture Policy (2016) acknowledges that “most policy instruments for agriculture have focused on these two crops [maize and tobacco], resulting in an undiversified crop, livestock and fisheries production mix” (p. 3). The Malawi Growth and Development Strategy III (2017) of Malawi cites lack of agriculture diversification as a challenge to the sector’s productive capacity. Increased agricultural diversification is set forth as a desired outcome. The Nationally Determined Contribution (NDC) of Malawi, its submission to the UNFCCC on targets for mitigation of and adaptation to climate change, mentions the need to increase the level of irrigation farming to deal with the challenges faced by rainfed agriculture. It also refers to the need for small-scale farmers to adopt new practices such as conservation agriculture, drought tolerant crops, and agro-forestry to deal with climate change. While there are drought-tolerant varieties of maize available, it may be more feasible to focus on the bean value chain as a way to diversify crops and introduce drought tolerant varieties of beans.

Given that the Government of Malawi has identified crop diversification in several policies and strategies, it could be strategic to focus on potatoes, beans, or even sorghum (ranked 4th) for value chain development to address climate change adaptation. The costs and benefits of selecting a particular value chain would need to be assessed in additional research along with the potential numbers of beneficiaries.

Zambia

The statistics for the main crops grown in Zambia are shown in Table 4 below. As with Malawi, the diet is largely maize-based. Cassava is also an important source of calories and protein. Protein also comes from groundnuts, livestock and fish products and soybeans. Livestock products (beef, eggs, poultry meat, milk and pig meat) are high in production value along with cassava. In addition to being used as a food crop, use of cassava in other industries such as brewing, metal extraction and starch making has increased as the value chain has developed in Zambia (Dihel et al., 2018). It should be noted that FAOSTAT data for Zambia do not separate out pulses (beans, cow peas, etc) except for soybeans, limiting the ability to disaggregate among those legumes.

Table 4. Selected agricultural statistics for main crops in Zambia

	Gross Production Value (current million US$)	Production (tonnes)	Regional yield gap (%)	Kcal/cap/day (%)	Protein g/ cap/day (%)
Beef and Buffalo Meat	779	193,294	118	1.3	3.6
Cassava	680	1,021,020	79	11.4	3.3
Eggs	122	52,153	90	0.6	1.8
Fish	63	84,000	100	0.5	3
Groundnuts	58	136,151	80	3.8	5.7
Maize	448	2,845,486	148	51.3	47.7
Meat, Poultry	127	46,204	82	0.6	2
Milk, Total	344	436,054	601	0.7	1.5
Millet	15	28,966	70	0.3	0.3
Pig meat	173	39,739	91	0.8	1
Potatoes	24	32,112	140	0.2	0.2
Pulses	25	31,455	52	0.9	2
Rice, paddy	56	38,379	50	1.5	1
Sheep and Goat Meat	32	10,361	108	0.1	0.5
Sorghum	9	12,827	56	0.4	0.4
Soybeans	32	186,270	126	3	12.2
Sweet potatoes	65	170,442	56	1.4	0.7
Wheat	88	220,475	280	5	5.3

Source: FAOSTAT 2018

The data from Table 4 were analysed as described above, and the prioritisation results for Zambia are presented in Table 5 below.

Table 5. Crop and livestock prioritisation results for Zambia

	Prod. Value	Prod. tonnage	Reg. yield gap	Food security	Impact of CC	Total	Rank
Beef and Buffalo Meat	1.00	0.06	0.88	0.05	0.30	2.89	11
Cassava	0.87	0.36	0.95	0.14	0.00	2.32	12
Eggs	0.15	0.01	0.93	0.02	0.30	2.01	15
Fish	0.07	0.03	0.91	0.03	0.30	1.94	16
Groundnuts	0.06	0.04	0.95	0.09	0.70	3.25	6
Maize	0.57	1.00	0.82	1.00	1.00	6.39	1
Meat, Poultry	0.15	0.01	0.94	0.02	0.30	2.03	14
Milk, Total	0.44	0.15	0.00	0.02	0.30	1.51	18
Millet	0.01	0.01	0.96	0.00	1.00	3.98	4
Pig meat	0.21	0.01	0.89	0.02	0.30	2.03	13
Potatoes	0.02	0.01	0.84	0.00	1.00	3.87	5
Pulses	0.02	0.01	1.00	0.03	1.00	4.05	2
Rice, paddy	0.06	0.01	1.00	0.02	0.70	3.19	9
Sheep and Goat Meat	0.03	0.00	0.89	0.00	0.30	1.83	17
Sorghum	0.00	0.00	0.99	0.01	1.00	4.00	3
Soybeans	0.03	0.06	0.86	0.15	0.70	3.21	8
Sweet potatoes	0.07	0.06	0.99	0.02	0.70	3.24	7
Wheat	0.10	0.07	0.58	0.10	0.70	2.96	10

The most important value chains according to the analysis scheme are maize, pulses and sorghum. Maize is crucial for calorie and protein intake and is grown by many farmers on large amounts of land. The impact of climate change on maize production will be negative. Pulses are important source of protein and can also help improve soil fertility because of their nitrogen fixing ability. Crop rotation (maize and beans) has been promoted in Zambia as part of conservation agriculture. The climate change impact on pulses is anticipated to result in reduced production due to increased temperatures and rainfall variability. Sorghum offers the potential for small scale producers to enter the value chain through entering into contracts with buyers such as feed manufacturers or breweries. It is likely to be highly affected under climate change.

As in Malawi, maize ranks number one in the priority list. However, it could be more strategic to prioritize a value chain other than maize for similar reasons to Malawi. Zambia's National Agriculture Investment Plan (NAIP; 2014-2018) shows that one of the objectives of the crops component is "to increase sustainable crop production, productivity and value addition for a diversified range of competitive crops apart from maize" (p. 12). The NAIP also acknowledges that great need for improved dietary diversification among Zambians. Sorghum offers a potential for value chain development by involving small scale farmers in contract farming arrangements with processors. Although cassava ranks lower in the prioritisation scheme, there are also efforts underway in Zambia to increase the cassava value chain (Dihel et al., 2018). Zambia's NDC makes specific mention of promoting climate-smart agriculture practices and promoting crop land races of cassava, maize, sorghum, finger millet, beans and cowpea. CSA practices in the livestock sector are also mentioned. Development of an agricultural insurance market against climate change-induced risks is also written into the country's NDC.

Conclusion

This study assembled existing information on the hazards, exposure and vulnerability of agriculture in Malawi and Zambia. A prioritisation process was designed, building on methods used in the CSA Country Profiles for Malawi and Zambia (CIAT 2018; CIAT and World Bank 2017), to rank different commodities in each country, with respect to four dimensions: the importance of the commodity to the economy of the country, the national yield gap compared with the regional average, the importance of the commodity in people's diet, and the projected impact of climate change on yield. The results of the analysis highlighted three commodities that could be prioritized for agricultural development interventions: maize, potatoes and beans in Malawi, and maize, pulses and sorghum in Zambia.

Several caveats are in order. First, the results of the ranking exercise are somewhat dependent on the weights used. These could be modified for different stakeholders, if deemed appropriate. Second, there is some uncertainty associated with the climate risk analysis. For southern Africa, there is reasonable consensus between the different climate models as to projections of future temperatures, but rather less consensus with respect to changes in rainfall amounts and patterns. This is particularly the case with the future of the El Niño Southern Oscillation, which is one of the key drivers of climate variability in the region. Third, projected impacts of climate change on growing seasons and agricultural yields also have significant uncertainty attached, not only because of uncertainties arising from the climate modelling but also from the crop models used (which do not take account of possible changes in pest, weeds and diseases in the future, for example).

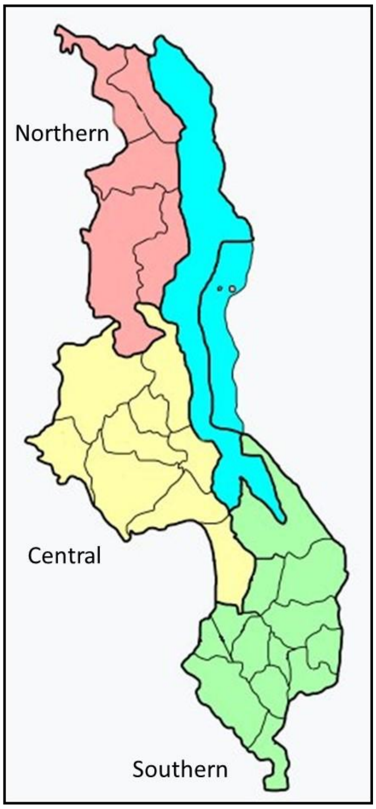
Nevertheless, the analysis has highlighted commodities in both countries that could be prioritized for agricultural development interventions, particularly if these are approached from a value chain perspective, as this can allow small-scale farmers to increase their productivity and benefit from greater access to inputs such as seeds, fertilizers, and extension services. While maize tops the list in both countries, there are calls for moves towards a more diversified crop, livestock and fisheries production mix. This could reduce the countries' high dependence on maize, potentially increase the agricultural sectors' productive capacity, and increase smallholders' ability to adapt to climate change. The costs and benefits of selecting specific value chains still need to be assessed, particularly in relation to intervention sites and the potential numbers of beneficiaries.

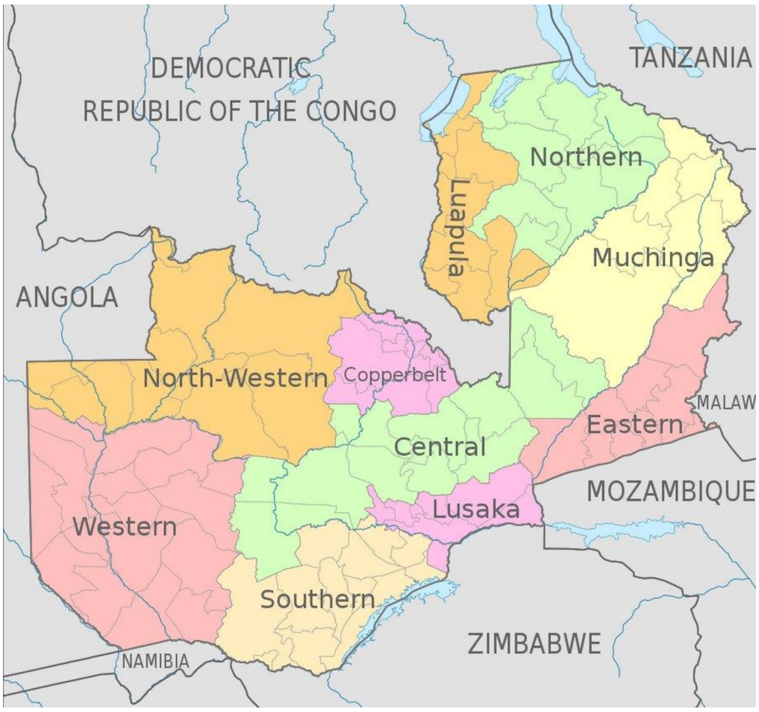
Appendix 1: Methodology for climate projections

The risk analyses presented in Figure 10 used different generations of climate models. For one set of projections, Jones and Thornton (2013; 2015) utilized a generalised downscaling and data generation method that takes the outputs of a General Circulation Model and allows the stochastic generation of daily weather data that are to some extent characteristic of future climatologies. These data can be used to drive any agricultural model that requires daily (or otherwise aggregated) weather data. The methods used combine unintelligent empirical downscaling, climate typing and weather generation (Jones and Thornton 2013, page 1). These methods were applied in Jones and Thornton (2015) to utilise data from 17 climate models from the Coupled-Model Intercomparison Project 5 (CMIP5) that were used in the Fifth Assessment Report in 2014 (IPCC, 2013). Yearly GCM data for the twenty-first century at very coarse scale were interpolated by bilinear interpolation from the original pixel sizes to 1-degree pixels. Monthly means were calculated for rainfall and maximum and minimum air temperature, all expressed as anomalies from the historical mean, and then bias corrected to WorldClim v1.3 (Hijmans et al., 2005). The GCM data thus provide annual deviations for the years 2006 to 2099. To facilitate application of the climate data, fourth-order polynomials for each variable were fitted to every pixel through time.

Appendix 2: Areas of high future climatic risk

The three regions of Malawi are shown in the top figure, and the ten provinces of Zambia are shown in the bottom figure.





The regions of Malawi and provinces of Zambia are tabulated below with respect to the major climatic risks they face in the future, as discussed above.

	Rainfall variability (current)	Loss of growing season to the 2050s	Increased probability of season failure by the 2050s	Major agricultural risks
MALAWI				
Northern	H	H	H	V
Central	H	H	H	C
Southern	H	H	H	C F
ZAMBIA				
Central	H	H		C
Copperbelt				T V
Eastern	H	H	H	C
Luapula		H	H	C
Lusaka	H	H	H	C F
Muchinga	H	H	H	C
Northern				T V
North-Western				T F
Southern		H	H	C
Western		H	H	C

H: Areas with prevalence of high rainfall variability, >20% loss of growing season, substantial increase in the probability of season failure between now and the 2050s.

Major agricultural risks: V, climate variability. T, high temperatures. C, combinations of high climate variability, high temperatures, and water stress. F, flooding.

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