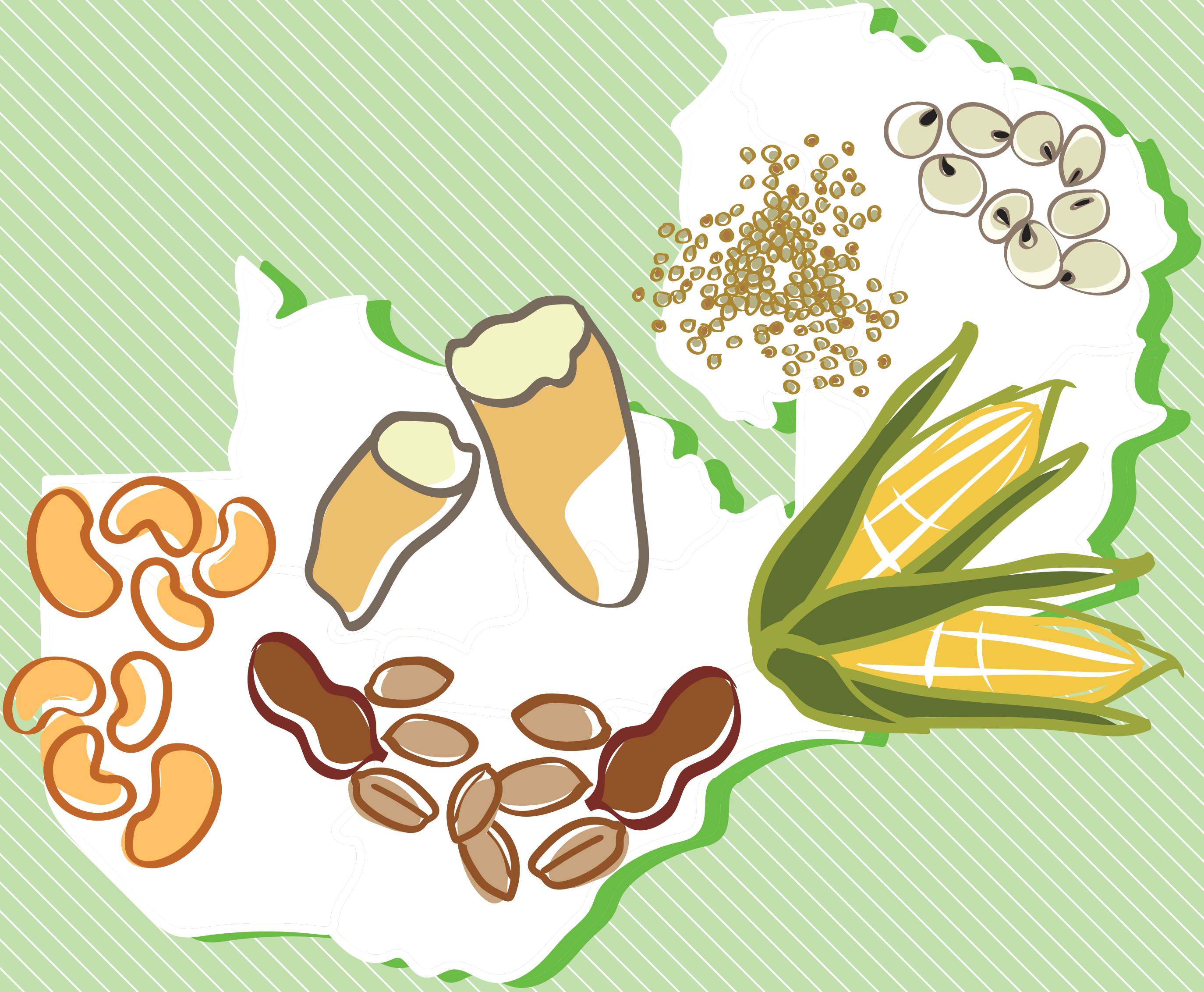
RESEARCH HIGHLIGHTS

CLIMATE CHANGE AND FUTURE CROP SUITABILITY IN ZAMBIA



IFAD
Investing in rural people

Research Highlights – Climate Change and Future Crop Suitability in Zambia

Funded by 'Adaptation for Smallholder Agriculture Programme' (ASAP) Phase 2.
International Fund for Agricultural Development (IFAD)

Produced by the University of Cape Town

Undertaken in support of the International Fund for Agricultural Development (IFAD) by:
African Climate & Development Initiative (www.acdi.uct.ac.za)
Climate System Analysis Group (www.csag.uct.ac.za)
Environmental Policy Research Unit (www.epru.uct.ac.za)

Recommended citation: Hunter. R., Crespo. O., Coldrey, K, Cronin, K, New, M. 2020. Research Highlights – Climate Change and Future Crop Suitability in Zambia. University of Cape Town, South Africa, undertaken in support of *Adaptation for Smallholder Agriculture Programme' (ASAP) Phase 2. International Fund for Agricultural Development (IFAD), Rome.*

 The project team gratefully acknowledges the support of IFAD towards this research and in particular the IFAD country office and project staff. The project team thanks the various stakeholders and contributors who have shared their knowledge and time during this study.

CONTENTS

RESEARCH HIGHLIGHTS

CLIMATE CHANGE AND FUTURE CROP SUITABILITY IN ZAMBIA

BACKGROUND AND CONTEXT

The Adaptation for Smallholder Agriculture Programme (ASAP) is a flagship programme within the International Fund for Agricultural Development's (IFAD's) portfolio of activities aimed at channelling climate and environmental finance to smallholder farmers, and which allows IFAD country programmes to design projects which integrate considerations of the impacts of climate change on smallholder farmers. To support the integration of climate information and improved knowledge of climate related risks to the smallholder agriculture sector, IFAD commissioned a Climate Risk Analysis to assess the potential impacts of climate change on several crops and commodities in Zambia.

The full Climate Risk Analysis report (accessible via the IFAD Country page[1]) provides an analysis of inter alia i) the current and future climate characteristics of Zambia; ii) the potential change in the suitability of various crops under projected climate changes; and iii) potential risks and economic impacts related to climate change, as well as potential adaptation options and opportunities to increase climate resilience. The following report provides a brief summary of highlighted results for Zambia, including: i) projected changes to temperature and precipitation as a result of climate change; and ii) impacts of climate change on the future suitability of several major crops and resulting impacts on production across each of the country's ten Provinces.

AGRICULTURE IN ZAMBIA

Zambia's agricultural sector is characterised by moderately low productivity of a wide selection of staple crops, a diverse variety of annual and perennial horticultural products, and cash crops (most prominently, tobacco). Rainfed agriculture, practiced by smallholder farmers, accounts for the vast majority of the planted area. In addition to rainfed production of staple crops, there are complex mixed farming practices that include various fruit trees adjacent to households (bananas, mango, cashew and citrus) and mixed kitchen-scale gardens for production of diverse vegetable species, and grazed production of cattle and small ruminant livestock.

[1] https://www.ifad.org/en/web/operations/country/id/Zambia

SUMMARY RESULTS

The likely effects of climate change are not fully consistent between each of Zambia's ten provinces or the crops assessed, however, several general observations can be made. For example, all provinces in the study area are predicted to experience increasing temperatures throughout the year, indicated by increased average monthly 'Mean Temperature' as well as average 'Minimum Temperature'. Furthermore, all provinces are predicted to experience increasing delays or inconsistencies in the onset of rainfall, and an overall decrease in the annual and seasonal precipitation between the present day and the 'Mid-Century' future (defined by the period ~2040–2069). Average monthly rainfall is predicted to decrease in all provinces, including during the months of September, October and November which are considered to be the start of the rainy season. These results may be indicative of a delay in the onset of the traditional rainy seasons, or alternatively a decrease in the effective duration of the rainy season. Overall, the predicted trend for annual precipitation is a long-term trend of decreasing rainfall, as well as possible shifts in the timing of rainy seasons. Modelled predictions for national average precipitation indicate a decrease of mean annual rainfall from ~970 mm to ~880 mm, representing a decrease of ~88 mm or 9%

The full study includes analyses of the predicted effect of climate change on various crops, particularly cereals (maize, millet, sorghum), legumes (beans, cowpeas, and groundnuts), and root crops (cassava) in each of Zambia's ten Provinces. The annual production of multiple crops is expected to be negatively impacted by increased temperatures and reduced or delayed rainfall, thereby causing a reduction in the extent of suitable production areas as well as reducing the productivity of remaining areas.

Production of maize, one of the most climate-vulnerable of Zambia's staples, is predicted to undergo minor or moderate decreases depending on the choice of varieties. Long-maturing varieties are predicted to undergo particularly negative impacts resulting from climate change, where it is predicted that annual production may decrease from ~33-35% (Luapula, Northwestern) up to ~80-90% (Copperbelt, Muchinga). Production of beans, one of the most important subsistence crops, is predicted to undergo a decrease in annual production in all provinces, ranging from ~20 – 28% (Northwestern, Muchinga, Northern, Copperbelt, Luapula) up to 50 – 65% (Eastern, Southern, Western). Conversely, certain climate-resilient species such as finger millet, sorghum, cowpeas and groundnuts are comparatively less affected by the predicted climate changes and may serve as appropriate alternative staples to be promoted in areas where production of traditional staples is expected to become marginal or unsustainable. Valuable oil crops such as sunflowers and soyabeans are anticipated to maintain widespread areas of good or excellent suitability, while in the case of cassava, results indicate that some provinces may experience positive changes to potential production of cassava.

However, despite these common trends, there are also several province-specific effects on climate variables and resultant crop suitability that will necessitate the development of tailored local-level adaptation plans and strategies for agricultural development. For example, production of groundnuts in the southern provinces associated with Agro-Ecological Zones I and II are predicted to experience negative impacts on production, whereas those provinces associated with Agro-Ecological Zone III (Northwestern Copperbelt, Luapula, Northern and Muchinga) are predicted to remain unchanged or even to benefit from positive impacts on groundnut production. Similarly, cereal crops such as sorghum and millet are predicted to experience small positive impacts in certain provinces, while simultaneously experiencing negative changes in other provinces

The climate-related risks to agricultural households in each province are a function of both the impact of climate change on crop production, as well as the adaptive capacities of each community to manage and respond to climate risks. This study found that the Central, Northern and Lusaka provinces were characterised by the highest adaptive capacity scores (i.e. these three provinces have the greatest capacity to respond and adapt to climate change impacts), while the North-Western, Western and Eastern provinces have the lowest overall adaptive capacity scores and therefore are anticipated to be least able to respond or adapt to climate change-related impacts.

It is important to note that the following analyses are based on consideration of a narrow range of modelled variables and the resultant effects on crop suitability. Consequently, this study cannot account for local-level factors such as differences in performance, climatic suitability and yield potential between local land races or improved cultivars. In addition, the study cannot consider or predict the effect of different cultivation methods and technologies that may be practiced within the study area. Finally, in terms of predicting the likely effects of climate change and resultant risks to crop production, this study cannot account for indirect effects of climate change on crop production, such as increased vulnerability to pests and disease, soil degradation or flooding/ waterlogging. However, the study does find that climate change is likely to result in multiple negative effects on smallholder farmers in the study area, through disruption of familiar seasonal trends, increased water and heat stress and a reduced growing season.

METHOD AND APPROACH

The analyses presented in this study are intended to provide an illustrative comparison of the potential effects of future climate change on production of economically important crops, as well as the differential impacts of climate change on agricultural households in each of Zambia's ten provinces. For each of the crops considered in this study (maize, millet, sorghum, beans, groundnuts and cassava) the relative ***Climate Change Vulnerability (V)*** of crop production is considered at the province level and aims to identify those provinces which are likely to be most or least vulnerable to climate change impacts on the given crop.

The relative vulnerabilities of each province can be expressed as a **Vulnerability Index** (**VI**) score, derived by comparison of the relative scale of:

- **Impacts** (**I**) of climate change on crop production (estimated through analysis of climate models and resulting changes to crop suitability); and
- the **Adaptive Capacity** (**AC**) of agricultural households to respond and adapt to the impacts of climate change (derived through statistical indicators of socio-economic, developmental and agronomic context) in each of Zambia's ten provinces

Vulnerability is considered to be proportional to the relative size of **I**, and inversely proportional to **AC**. The product of the scores for **AC** and **I** are used to calculate a standardised score for V, thereby allowing comparisons between each province and allowing the identification of those provinces and households which are likely to be most vulnerable to climate change impacts on each crop.

IMPACTS

The **Impacts (I)** of climate change on crops were estimated by projecting the likely future changes to Zambia's climate, and then analysing the effects of those projected climate changes on economically important crops. Firstly, the potential future changes to Zambia's climate were computed through analysis of 29 General Circulation Models (GCMs) downloaded from the AgMERRA dataset [2], based on the methods described by Ramirez-Villegas et al (2013) [3]. Future climate changes were computed assuming the scenario of 'RCP 8.5' (where 'RCP 8.5' refers to one of four hypothetical scenarios for future global greenhouse gas emissions proposed by the Intergovernmental Panel on Climate Change). This analysis was used to generate predictions of the effect of climate change across Zambia, comparing the historical baseline (the average climate for the period 1980–2010) to the Mid-Century future (2050, the average climate for the period 2040–2069). In particular, the analysis compares the climatic variables of *Mean Monthly Precipitation* (i.e. the average precipitation for each month), *Monthly Mean Temperature* and *Monthly Minimum Temperature* (Tmin).

Analyses of current and future crop suitability were generated using the Food and Agriculture Organisation's EcoCrop Suitability model[4] combined with the most recent statistics available for annual crop production and demographics. The EcoCrop model estimates the suitability of a given crop to the defined environmental conditions based on the known preferences of each crop such as: i) minimum, optimum and maximum temperature; ii) minimum, optimum and maximum monthly rainfall; and iii) minimum and maximum growing period. Therefore, EcoCrop defines the area of suitability for a given crop based on whether there are adequate climatic conditions (temperature and precipitation) within the growing season and calculates the climatic suitability of the resulting interaction between rainfall and temperature. Readers are referred to the full project report and the work of Ramirez-Villegas et al (2013) for detailed description of methodology.

---

2 https://data.giss.nasa.gov/impacts/agmipcf/agmerra/

3 Ramirez-Villegas J, Jarvis A, Laderach P 2013 Empirical approaches for assessing impacts of climate change on agriculture: The EcoCrop model and a case study with grain sorghum. Agricultural and Forest Meteorology 170(15):67-78

4 https://ecocrop.fao.org/ecocrop/srv/en/home

A suitability index score, ranging from 0 – 1, indicates the relative suitability of a given area for each of the crops assessed (where a suitability score of 0 is considered to be totally unsuitable, a score of 1 is considered excellent, with a continuous spectrum of marginal, moderate and good suitability types in between). In this study, analyses of the distribution of suitable areas for a given crop allows for the estimation of the total suitable production area, as well as the average suitability index score, within each of Zambia's ten Provinces. The EcoCrop approach also allows for map-based visualisations of crop suitability zones across the country. The use of colour-coded maps to depict the distribution of various categories of crop suitability index scores can be used to demonstrate the distribution of crop-suitable areas, as demonstrated in Figure 1.

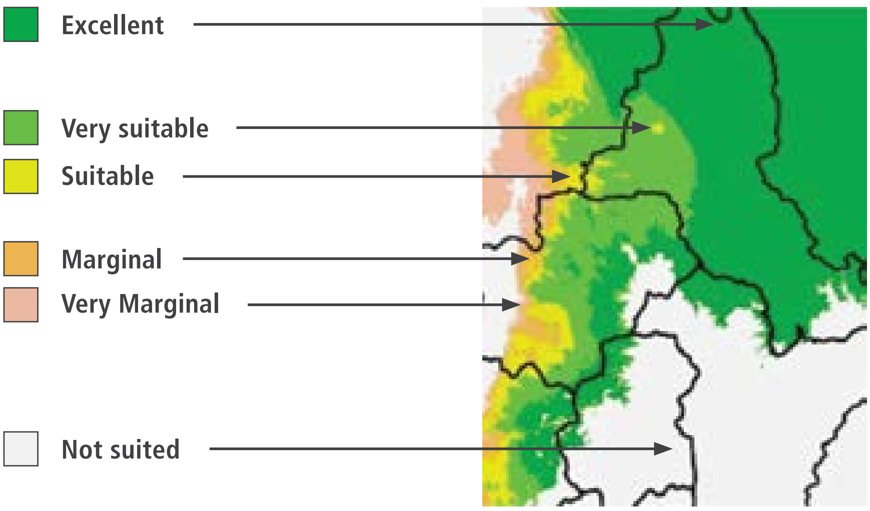
The comparison of maps of 'Historical' and 'Future' distribution of crop suitability can be used to estimate the potential changes to the size and relative productivity of crop-suitable areas. In addition, this approach allows for the identification of specific areas which are likely to undergo positive or negative changes (anomalies) as a result of climate change, and may be used to inform decision-making such as identification of climate-vulnerable areas and value chains to be prioritised for additional support. The potential impacts of climate change on each crop were estimated based on:

- the changes to total suitable area (km^2) and average suitability index score between the historical baseline and 'mid-century' future[5];
- and estimated historical crop production in each Province, derived from national agricultural production statistics [6].

The potential impacts of climate change on each crop can be quantified in several ways, for example, in terms of changes to "production per capita", "production per household" and "production per Province". It should be emphasised that no further calibration or validation of EcoCrop analyses was carried out in support of this study and that results should be considered as indicative guidelines only, to inform additional local-level decision-making and further research.

FIGURE 1. DEMONSTRATION EXAMPLE OF THE DISTRIBUTION OF CROP SUITABILITY INDEX.

GENERATED USING ECOCROP



[5] Total suitable area was calculated as the sum of all areas with a suitability index score higher than 0, and average suitability index score is calculated as the average score of all areas with a suitability index score higher than 0

[6] Derived from the Post-Harvest Survey (2017) published by the Central Statistical Office (CFO) https://www.zamstats.gov.zm/index.php/publications/category/12-agriculture?download=720:phs-report-2014-2015-final-pdf

ADAPTIVE CAPACITY

Indicators for **Adaptive Capacity (AC)** – the relative ability of agricultural households to respond and adapt to predicted climate change impacts – were derived from the most recent statistics available at the sub-national level. Provincial statistics and indicators were primarily derived from studies undertaken by the Central Statistical Organisation (CSO), technical studies undertaken by the Indaba Agricultural Policy Research Institute (IAPRI), and open-source statistics published on the Zambia Data Portal [7]. In the case of Zambia, the indicators used to estimate AC in each Province included

- **Access to Education** (% literacy rate);
- **Access to alternative (non-agricultural) income:** (% employment rate);
- **Adoption of improved agricultural practices:** (fertiliser use among small-holder farmers, manure use, herbicide use, households using improved maize seed, and adoption of intercropping.)

The national statistics collected to assess AC – which are summarised in the Appendix (Table A.1) – were used to calculate an average AC score for each Province. The indicator category **'Adoption of improved agricultural practices'** was assigned a weighting of 50% towards the final **AC** score, and the remaining 50% was contributed equally by the remaining indicator categories. These are presented in Table 1.

The **AC** scores generated indicate that smallholder farmers in the Central, Northern and Lusaka provinces have the highest overall capacities to respond to climate change's impacts (ranking 1st, 2nd and 3rd, respectively). The North-Western, Western and Eastern provinces have the lowest overall **AC** scores (ranking 8th, 9th and 10th, respectively) and therefore are anticipated to be least able to respond or adapt to climate change-related impacts. However, the range is low (13%) suggesting little variation in the capacity to adapt between Zambia's 10 provinces.

TABLE 1. RANKED ADAPTIVE CAPACITY (AC) INDICATOR SCORES FOR ALL PROVINCES OF ZAMBIA

	Adaptive capacity Indicator category				
	Adoption of improved agricultural practices	Access to alternative income	Education	**Adaptive capacity score**	**Adaptive capacity rank**
Contribution to index	50%	25%	25%		
Central	40	87	85	63.2	**1**
Copperbelt	36	78	94	60.7	**5**
Eastern	22	91	67	50.2	**10**
Luapula	34	92	78	59.6	**6**
Lusaka	38	80	94	62.3	**3**
Muchinga	36	94	78	60.8	**4**
Northern	42	94	76	63.2	**2**
North-Western	32	90	76	57.7	**8**
Southern	32	88	85	59.4	**7**
Western	19	92	73	50.6	**9**

[7] CSO (2016). Post-Harvest Survey https://www.zamstats.gov.zm/index.php/publications/category/12-agriculture?download=720:phs-report-2014-2015-final-pdf ; CSO (2018) Zambia In Figures http://www.zamstats.gov.zm/phocadownload/Dissemination/Zambia%20in%20Figure%202018.pdf ; IAPRI (2015) Rural Agricultural Livelihoods Survey https://agriprofocus.com/upload/post/RALS_2015_Survey_Report__Finalv-_edited1456827249.pdf; IAPRI (2017) Zambia Agriculture Status Report https://www.researchgate.net/publication/322676437_Zambia_Agriculture_Status_Report_2017

CLIMATE PROJECTIONS

PROJECTED CHANGES TO TEMPERATURE IN ZAMBIA BY 2050

The predicted changes in Mean Monthly Temperature (TMean) during the period from 'Historical' to 'Future 2050' timepoints indicate that climate change will result in consistent increases in Mean Temperature across spatial and temporal dimensions in Zambia. A common prediction across each of the country's provinces is that TMean will increase in all provinces during the period from 'Historical' to 'MC 2050' timepoints by at least 1.8°C. The hottest months of September, October, November and December are predicted to increase by 2.3–2.6°C, relative to a Historical average of 23.9–25.7°C. Similar increases of 1.8–2°C are predicted for all other months of the year, including the peak summer months that support the rainfed agricultural season (from September/October up until March/April) as well as the colder winter months of May–August.

The overall effect of these increases in TMean and TMin is likely to result in complex impacts on the agricultural sector, particularly when considered in combination with the predicted decreases in precipitation.

The large increases in temperature (2.1–2.6°C) in the months of October–December will increase crop water demand and evapotranspiration losses of water from agricultural soils, coinciding with the reduced rainfall predicted for the same months. This effect is likely to increase the risks of crop failure as a result of inadequate or erratic rainfall during the establishment of rainfed crops, particularly for climate sensitive or marginal crops such as maize and horticultural/vegetable crops such as tomatoes and peppers. Furthermore, the increased average temperatures are likely to include increased frequency or severity of heat waves and unusually hot days, further contributing to evapotranspirative losses of water and crop stress.

Taken cumulatively over the entire growing season, the combination of reduced rainfall and increased temperature is likely to reduce agricultural production, either as a result of decreased yield or outright crop failure, particularly in the case of heat- and drought-sensitive crops such as maize and wheat.

TABLE 2. PROJECTED INFLUENCE OF CLIMATE CHANGE ON MEAN MONTHLY TEMPERATURE (°C) IN ZAMBIA AT HISTORICAL AND MID-CENTURY PERIODS, AND MONTHLY ANOMALIES BETWEEN THE TWO TIME PERIODS [8]

Tmean (°C)	**MONTH**											
	J	F	M	A	M	J	J	A	S	O	N	D
Historical	23.3	23.3	23.3	22.4	20.5	18.4	18.1	20.6	23.9	25.7	25.2	23.7
Future	25.1	25.1	25.2	24.5	22.7	20.5	20.3	22.6	26.2	28.3	27.7	25.8
Anomaly	**1.8**	**1.8**	**1.9**	**2.0**	**2.2**	**2.2**	**2.2**	**2.0**	**2.3**	**2.6**	**2.5**	**2.1**

[8] Historical temperature based on the average of the period 1980-2010, and projected Mid-Century temperature for the period 2040-2069. Anomalies are defined as the total change between Historical and Mid-Century projections

CLIMATE – PROJECTED CHANGES TO RAINFALL IN ZAMBIA BY 2050

The predicted changes in mean monthly precipitation from the historical baseline to the mid-century (2050) future indicate that climate change will result in complex changes in rainfall across provinces and months (see Table 3). Province-level summaries of predicted monthly changes in precipitation can be found in the supplementary Appendix.

A common prediction across each of the country's 10 provinces is that mean monthly precipitation and total annual precipitation will be reduced in all provinces during the period from 'baseline' to 'future 2050' timepoints. Total rainfall at the onset of the rainy season in the months of October, November and December is predicted to be reduced from 29 to 17 mm/month, 108 to 87 mm/month and 204 to 192 mm/month (total reduction of rainfall of 12 mm, 21 mm and 11 mm) respectively. Further reductions in monthly precipitation are predicted for the mid-summer rainy season months from January–March ranging from 7 to 13 mm/month. The overall effect of these reductions to monthly precipitation throughout the rainy season is to reduce the total seasonal rainfall for the period October–April by 9 %, from 970 mm/season to 880 mm/season.

An additional effect, which is likely to vary on an interannual basis as well as spatially within each season, is the effective timing of the onset of rainfall at the start of the growing season. The average reduction in national rainfall predicted for the start of the rainy season is likely to vary between provinces and Zambia's AEZs but in some cases may result in inadequate rainfall to support effective establishment of crops during the months of October-November, which is traditionally associated with the start of the growing season.

These analyses indicate that climate change may delay the onset of rainfall relative to the traditional agricultural calendar, in turn resulting in changes to the timing of various agricultural activities such as field preparation and sowing of seed. The majority of the rainfed agricultural growing season is characterised by monthly rainfall deficits and is likely to result in fundamental changes to local crop choices and agricultural practices by the year 2050.

TABLE 3. PROJECTED INFLUENCE OF CLIMATE CHANGE ON MEAN MONTHLY PRECIPITATION (MM/MONTH) IN ZAMBIA AT HISTORICAL AND MID-CENTURY PERIODS, AND MONTHLY ANOMALIES BETWEEN THE TWO TIME PERIODS [9].

MM/MONTH	MONTH												TOTAL
	J	F	M	A	M	J	J	A	S	O	N	D	
Historical	225.0	194.5	152.2	43.9	5.4	1.4	0.5	0.7	4.5	29.2	108.0	204.0	969.3
Future	214.8	187.2	138.8	37.2	3.2	1.0	0.4	0.5	2.3	17.4	86.9	192.1	881.8
Anomaly	**-10.2**	**-7.3**	**-13.3**	**-6.8**	**-2.2**	**-0.4**	**-0.1**	**-0.3**	**-2.2**	**-11.7**	**-21.1**	**-11.9**	**-87.5**

[9] Historical precipitation based on the average of the period 1980-2010, and projected Mid-Century precipitation for the period 2040-2069. Anomalies are defined as the total change between Historical and Mid-Century projections. Province-level summaries of predicted monthly changes in precipitation can be found in the supplementary Appendix).

CLIMATE CHANGE AND ITS EFFECT ON BEANS

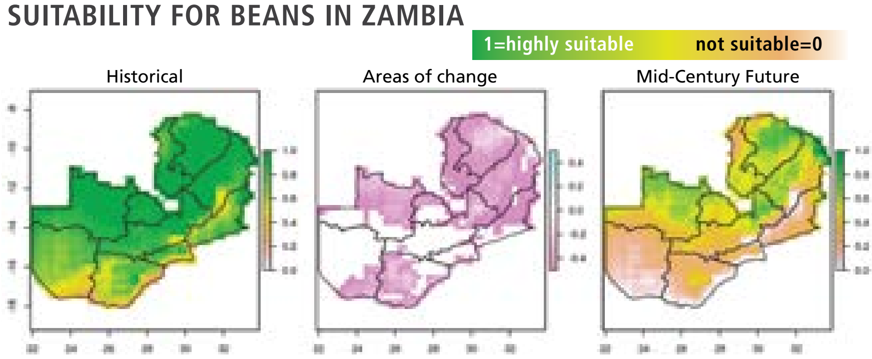
BROAD CONTEXT

Beans are widely grown as a staple subsistence crop across most of Zambia's provinces, where the majority of the country is considered to be suitable to some degree for bean production. The suitable range of beans is limited in the later months of summer (November-December onwards), where the provinces corresponding with Agro-Ecological Zones I and II are increasingly unsuitable for beans – this includes the southern regions of Western, Central and Lusaka provinces, and the entirety of the Southern province. Climate change is projected to result in a reduction in total area suitable for bean production, as well as a reduction in the average suitability index scores across most of Zambia. Most provinces across southern, central and northern Zambia are likely to undergo a transition from 'good'/'very good' suitability towards 'marginal'/'good'. As a result, all provinces will undergo a decrease in productivity, ranging from -20% (Northwestern) up to -63 % (Western).

PRODUCTION OF BEANS IN ZAMBIA[10].

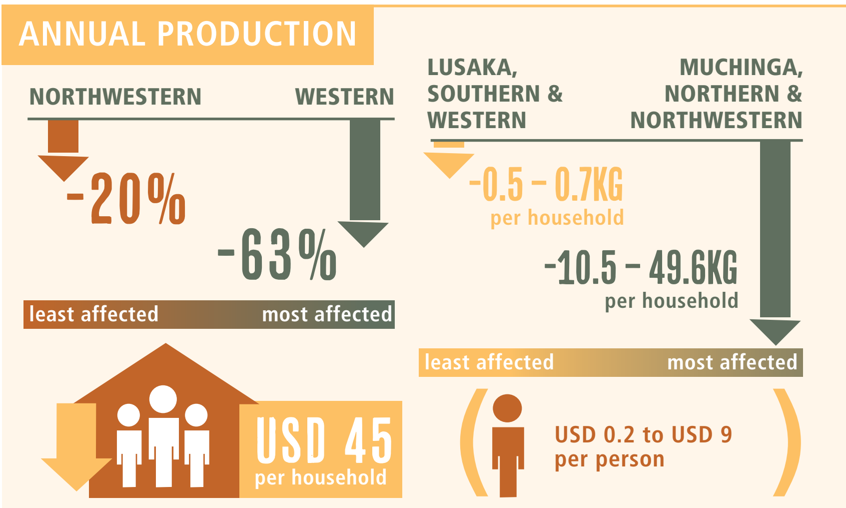
REGION	PRODUCTION AREA		ANNUAL PRODUCTION	
	TOTAL (HA)	% NATIONAL TOTAL	TOTAL (TONNES)	% NATIONAL TOTAL
Central	5,000	5.1	1,972	3.5
Copperbelt	1,534	1.6	943	1.7
Eastern	3,515	3.6	1,086	2.0
Luapula	5,516	5.6	3,000	5.4
Lusaka	1,069	1.1	70	0.1
Muchinga	11,087	11.2	6,214	11.2
Northern	56,663	57.4	36,087	64.8
Northwestern	9,028	9.1	6,008	10.8
Southern	3,188	3.2	169	0.3
Western	2,123	2.2	142	0.3
Total	**98,723**		**55,691**	

PROJECTED EFFECT OF CLIMATE CHANGE ON DISTRIBUTION OF SUITABILITY FOR BEANS IN ZAMBIA



HOUSEHOLD LEVEL IMPACTS

The potential impacts of climate change on total annual production per household are relatively minor in those provinces which are not significant producers of beans in the baseline scenario – for example, Lusaka, Southern and Western provinces are predicted to experience a decrease of production that is equivalent to 0.5 – 0.7 kg per household per year. In the provinces of Muchinga, Northern and Northwestern, which are relatively more important production areas for beans, the impact of climate change on annual production per household may result in decreases of 10.5 kg up to 49.6 kg per household per annum. The costs of reduced production of beans are estimated to range from USD 0.2 to 9 per person, or, up to USD 45 per household[11].



10 Including all farm types, ranging from smallholder subsistence farms up to largescale commercial farms, derived from the Post-Harvest Survey (2017) published by the Central Statistical Office (CFO) https://www.zamstats.gov.zm/index.php/publications/category/12-agriculture?download=720:phs-report-2014-2015-final-pdf

11 Market prices for beans were derived from district-level statistics provided by the Central Statistics Organisation. Central Statistical Office - https://www.zamstats.gov.zm. US Dollar:Kwacha exchange rate was estimated as 0.084. Market prices for beans varies between provinces – average price across all provinces was approximately USD 1.72 per kg.

PROVINCE AND NATIONAL-LEVEL IMPACTS

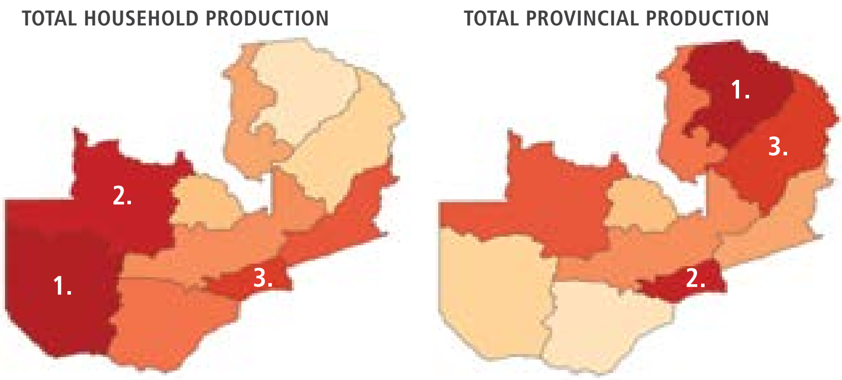
At the province level, the total impact of climate change on production of beans in the Lusaka, Southern and Western provinces (which are relatively unimportant areas for bean production) is predicted to range from a decrease of 45 – 97 tonnes per annum. In Muchinga, Northern and Northwestern provinces, the potential decrease of annual production ranges from 1,180 tonnes up to 8,960 tonnes per annum. In total, the cumulative loss of annual production of beans across all provinces is equivalent to 13,250 tonnes.

It is estimated that the loss of production of beans across all provinces is equivalent to 29 769 tonnes per annum. It is anticipated that the greatest costs for purchase of replacement food will be incurred in Northern (USD 8.1 million), Muchinga (USD 2.5 million), and Northwestern (USD 2.1 million) provinces. At a national scale, the total annual cost of climate-related impacts on beans is estimated to be USD 17.3 million per year.

CLIMATE VULNERABLE PROVINCES AND HOUSEHOLDS

At the household level, the provinces which will experience the most severe negative impacts on per capita production are Western, Lusaka and Eastern provinces. The most severe negative impacts on total production per province will likely be incurred in the Northern, Muchinga and Northwestern provinces.

MOST VULNERABLE REGIONS, BASED ON CHANGES TO:



KEY FINDINGS AND RECOMMENDATIONS

All provinces expected to experience negative impacts on beans.

Northern, Muchinga, Northwestern, Western, Lusaka and Eastern provinces likely to be particularly vulnerable.

Estimated decrease in annual production of 14,000 tonnes, total replacement costs incurred by households up to USD 17.3 million per year.

Recommended actions include additional investments in research and development to identify locally appropriate cultivars to be promoted as an alternative/complementary crop to vulnerable staples such as maize.

[12] Based on current market prices and annual crop production statistics

CLIMATE CHANGE AND ITS EFFECT ON CASSAVA

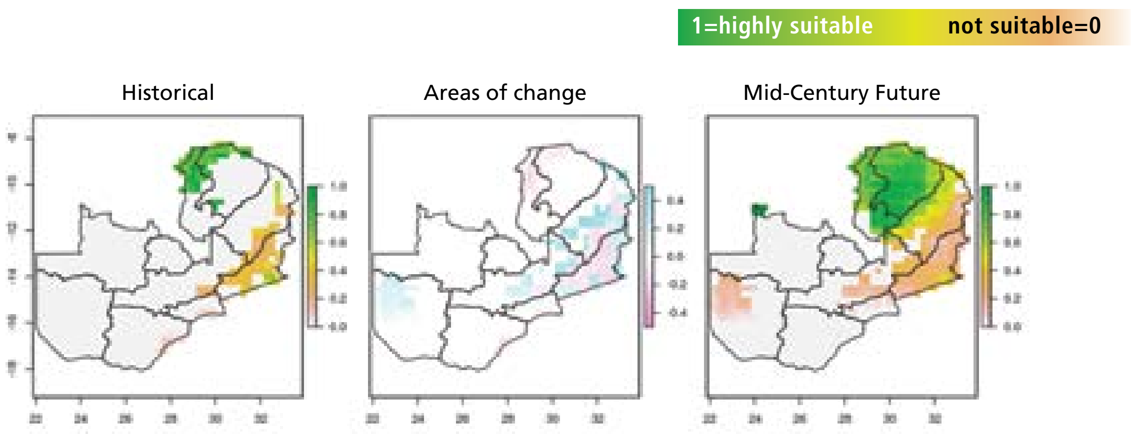
BROAD CONTEXT

Cassava is an important staple crop grown in several provinces of Zambia, primarily in the northern regions corresponding to AEZ III and, to a certain extent, in the central and eastern regions of the country. The baseline suitability for production of cassava is mainly confined to the northern extents of Luapula, Northern and Muchinga provinces, where suitability is good or excellent, in addition to some comparatively marginal production areas in Eastern and Central provinces. The southern provinces and all areas corresponding to Agro-Ecological Zone I are considered to be wholly unsuitable for cassava in the 'Historical' baseline scenario.

PRODUCTION OF CASSAVA IN ZAMBIA[13].

REGION	PRODUCTION AREA		ANNUAL PRODUCTION	
	TOTAL (HA)	% NATIONAL TOTAL	TOTAL (TONNES)	% NATIONAL TOTAL
Central	9,113	2.6	106,620	2.6
Copperbelt	2,236	0.6	26,164	0.6
Eastern	530	0.2	6,201	0.2
Luapula	117,486	34.1	1,374,590	34.1
Lusaka	400	0.1	4,680	0.1
Muchinga	30,557	8.9	357,516	8.9
Northern	86,470	25.1	1,011,699	25.1
Northwestern	51,461	14.9	602,095	14.9
Southern	No baseline production data			
Western	46,754	13.6	547,019	13.6
Total	**345,007**		**4,036,584**	

PROJECTED EFFECT OF CLIMATE CHANGE ON DISTRIBUTION OF SUITABILITY FOR CASSAVA IN ZAMBIA



The effect of climate change on the future 'Mid-Century' suitability for establishment of cassava indicates a consistent positive change across the summer months. The total spatial extent of suitable areas for production of cassava is projected to undergo large increases in the period between the 'Historical' baseline and 'Mid-Century' future timepoints, particularly in the east and northeast of the country (Luapula, Northern, Muchinga and Eastern provinces), including some areas of good or excellent suitability (particularly in areas corresponding to AEZ III). Climate change may also result in the emergence of newly suitable production areas in Western province, although these areas are anticipated to be only marginally suitable. Cumulatively, these results suggest that the net effect of climate change on Zambia's cassava production will be to increase the total production area and productivity.

13 Including all farm types, ranging from smallholder subsistence farms up to largescale commercial farms, derived from the Post-Harvest Survey (2017) published by the Central Statistical Office (CFO) https://www.zamstats.gov.zm/index.php/publications/category/12-agriculture?download=720:phs-report-2014-2015-final-pdf

POTENTIAL CLIMATE CHANGE IMPACTS

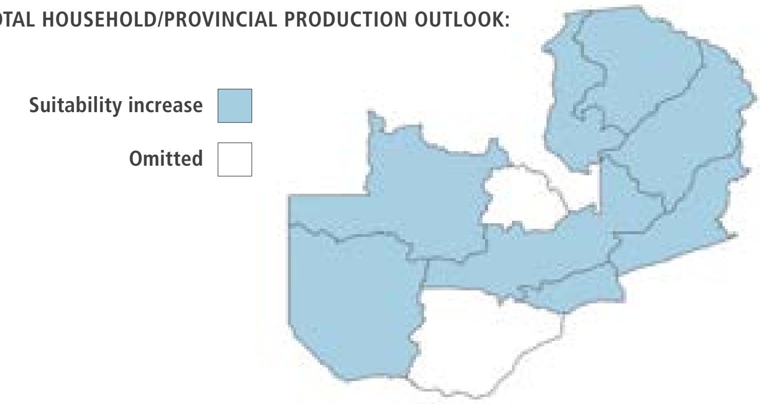
Results indicate that most provinces will experience positive changes to potential production of cassava. This can largely be attributed to an increase in total suitable area, despite the possibility of decreased average suitability index scores. **The only province which is clearly projected to experience negative changes to production of cassava is Southern province. However, as the latter province does not contribute any significant baseline cassava production, the effect of these changes on total production cannot be calculated and it is unlikely that climate changes in Southern province will influence the national production of cassava.**

The anticipated increase in suitable areas in the remaining nine provinces **must not be interpreted as a strong prediction that annual production will increase as a result of climate change**. Rather, these results suggest that those provinces which benefit from increased suitable area are unlikely to be impacted severely by the effects of climate change, but may not necessarily be able to benefit fully from the predicted increase in suitability.

Further, these results cannot consider other impacts of predicted climate changes on cassava production, such as increased toxicity resulting from increased cyagenic glucoside levels in response to heat stress, effects on post-harvest shelf-life and storage, and vectors for common cassava pests and diseases.

MOST VULNERABLE REGIONS, BASED ON CHANGES TO:

TOTAL HOUSEHOLD/PROVINCIAL PRODUCTION OUTLOOK:



KEY FINDINGS AND RECOMMENDATIONS

Zambia may benefit from increased production area for cassava.

The only exception to this is Southern province, which is not considered to be an important area for production of cassava.

Cassava's relative resilience and flexible growth habit (which allows for planting/establishment and harvesting across a wide range of seasonal conditions) suggests that cassava is likely to be a useful option for climate-resilient farming systems in the future, particularly in comparison with annual cereal and legume crops which are poorly adapted to erratic or irregular rainfall.

Recommended actions: increased access to quality, virus-free planting material of improved varieties; increased access to facilities and equipment for processing fresh cassava; improved capacity of farmers to monitor and respond to common pests and diseases.

CLIMATE CHANGE AND ITS EFFECT ON GROUNDNUT

BROAD CONTEXT

Groundnuts are grown as a subsistence crop across all of Zambia's provinces, with widespread areas of excellent suitability. The only provinces which appear to be less well-suited to groundnut production are the relatively arid southern areas corresponding to Agro-Ecological Zone I (particularly the southern extents of Western and Southern provinces). In the month of December, moderately suitable areas are confined to the northern extent of the country corresponding with AEZ III, including the Northwestern, Copperbelt, Luapula, Northern and Muchinga provinces.

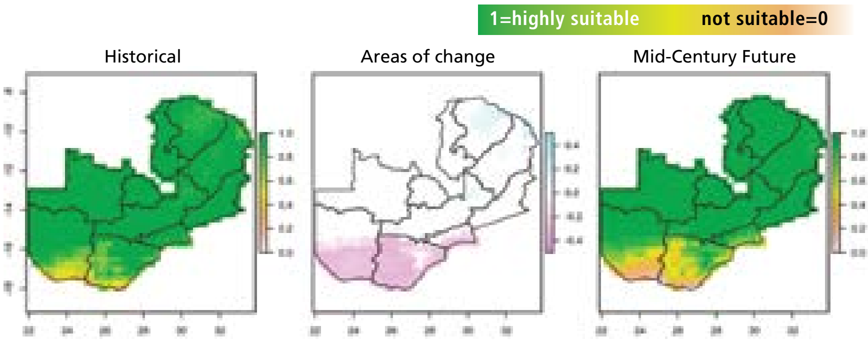
Climate change will likely result in relatively minor decreases to the total spatial extent of suitable areas for groundnut, as well as minor or moderate decreases to suitability index scores. These decreases are primarily associated with the southern provinces associated with AEZ I.

The effect of climate change will be to reduce production by 0.1 – 0.2% (Eastern and Central provinces) up to 5 – 15% (Lusaka, Western and Southern provinces). The Copperbelt, Luapula and Northern provinces are predicted to remain unchanged between the baseline and future scenarios – the entire extent of these provinces is predicted to remain characterised by excellent suitability for groundnuts. Very minor increases to suitability index scores are predicted for the north of the country, mainly in Northern and Muchinga provinces. Overall, the majority of Zambia is expected to maintain widespread suitability for groundnuts, including extensive areas of good or excellent suitability.

PRODUCTION OF GROUNDNUTS IN ZAMBIA[14].

REGION	PRODUCTION AREA		ANNUAL PRODUCTION	
	TOTAL (HA)	% NATIONAL TOTAL	TOTAL (TONNES)	% NATIONAL TOTAL
Central	35,560	12.9	17,769	13.8
Copperbelt	11,305	4.1	10,575	8.2
Eastern	87,750	31.9	40,488	31.3
Luapula	19,364	7.0	12,657	9.8
Lusaka	4,347	1.6	597	0.5
Muchinga	14,502	5.3	9,869	7.6
Northern	27,891	10.1	17,490	13.5
Northwestern	16,725	6.1	11,030	8.5
Southern	46,150	16.8	6,876	5.3
Western	11,280	4.1	1,817	1.4
Total	**274,874**		**129,168**	

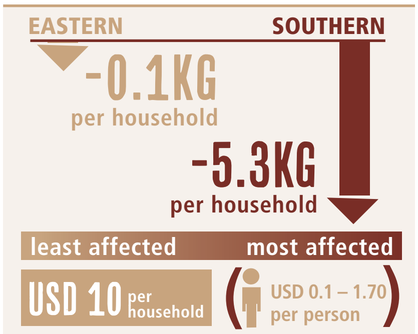
PROJECTED EFFECT OF CLIMATE CHANGE ON DISTRIBUTION OF SUITABILITY FOR GROUNDNUTS IN ZAMBIA



HOUSEHOLD LEVEL IMPACTS

In terms of the total change to annual production per household, the decrease in production is equivalent to a loss of 0.1 kg per household in Eastern province, and up to 5.3 kg per household in Southern province. The costs of reduced production of groundnut are estimated to range from USD 0.1 (Eastern) to USD 1.7 (Southern) per person, or, up to USD 10 per household [15].

The Copperbelt, Luapula and Northern provinces are predicted to remain unchanged and characterised by excellent suitability. In addition, the Muchinga and Northwestern provinces are predicted to benefit from very small increases to the average suitability index score and resultant productivity. These results must not be interpreted as a strong prediction that annual production will increase as a result of climate change. Rather, these results suggest that those provinces which benefit from increased suitable area are unlikely to be impacted severely by negative effects of climate change, but may not necessarily be able to benefit fully from the predicted increase of suitability.



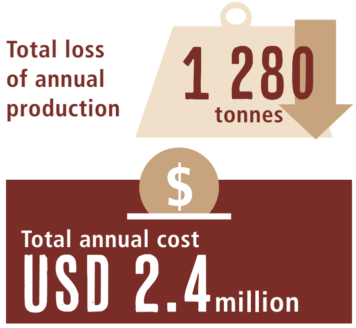
[14] Including all farm types, ranging from smallholder subsistence farms up to largescale commercial farms, derived from the Post-Harvest Survey (2017) published by the Central Statistical Office (CFO) https://www.zamstats.gov.zm/index.php/publications/category/12-agriculture?download=720:phs-report-2014-2015-final-pdf

[15] Market prices for groundnuts were derived from district-level statistics provided by the Central Statistics Organisation. Central Statistical Office - https://www.zamstats.gov.zm. US Dollar:Kwacha exchange rate was estimated as 0.084. Market prices for beans varies between provinces – average price across all provinces was approximately USD 1.87 per kg.

PROVINCE AND NATIONAL-LEVEL IMPACTS

In terms of the potential impact on total provincial production, the projected decreases to production are equivalent to 30 – 41 tonnes per year (in Central, Eastern and Lusaka provinces), 127 tonnes per year in Western province, and 1,050 tonnes per year in Southern province. In total, the cumulative loss of production of groundnut across all provinces is equivalent to 1,280 tonnes.

At the provincial scale, it is anticipated that the greatest costs for purchase of replacement food will be incurred in the Southern (USD 2 million), Western (USD 223,000) and Eastern (USD 88,000) provinces. At a national scale, the total annual cost of climate-related impacts on groundnuts is estimated to be USD 2.4 million per year, the large majority of which is expected to affect households in Southern province.

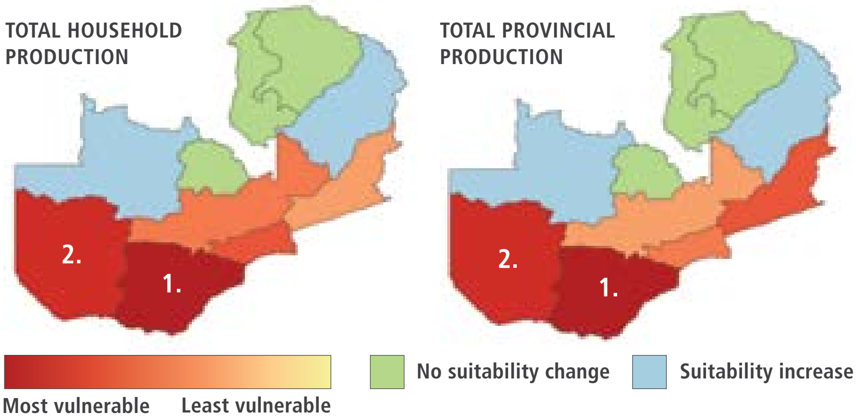


CLIMATE VULNERABLE PROVINCES AND HOUSEHOLDS

At the household level, the provinces which will experience the most severe negative impacts on %change to production per capita (i.e. decreased production relative to average historical production) are the Southern, Western and Lusaka provinces.

At the provincial level, the most severe negative impacts on total production per province are expected to be incurred in the Southern, Western and Eastern provinces.

MOST VULNERABLE REGIONS, BASED ON CHANGES TO:



KEY FINDINGS AND RECOMMENDATIONS

Zambia will likely experience minor decreases in production of groundnut in Southern, Western, Eastern and Lusaka provinces.

The loss of household production of groundnuts is likely to be relatively minor in comparison to other staple crops, but will result in increased costs for households to replace lost production of food.

The total loss of national production resulting from climate change is estimated to be 1,280 tonnes per annum, equivalent to a replacement cost of USD 2.4 million per year.

Despite the predicted negative impacts, the continued extensive distribution of suitable areas for groundnut production (particularly in the Central and Northern provinces) suggests that this crop is likely to remain a useful option for climate-resilient farming systems.

Recommended actions: promote within diversified, multi-crop and intercrop combinations; research, develop and promote locally-adapted and drought resilient varieties; invest in post-harvest processing facilities.

CLIMATE CHANGE AND ITS EFFECT ON MAIZE

BROAD CONTEXT

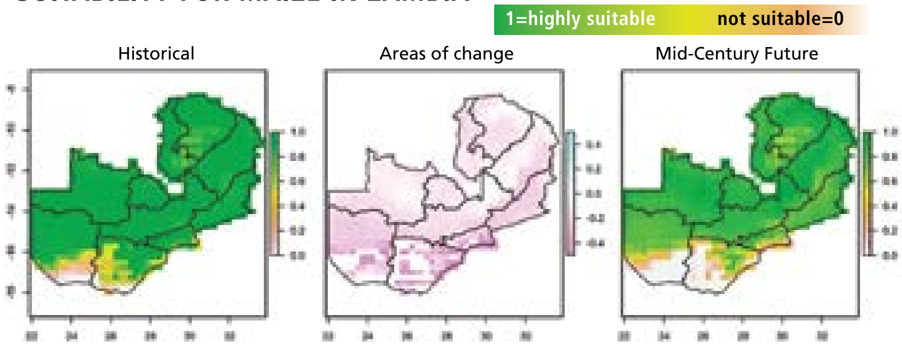
Maize is grown as a subsistence crop across all of Zambia's provinces. Long-maturing varieties have moderate to marginal suitability (mainly confined to the central and northern regions), while short-maturing varieties have widespread areas of good and excellent suitability.

Climate change is predicted to result in negative impacts on maize in all provinces. In the case of long-maturing varieties, all provinces are predicted to undergo significant decreases to total suitable area (ranging from ~20% in Northwestern province, up to ~77-82% in Copperbelt and Muchinga provinces). In the case of short-maturing varieties (which will be the main focus of this analysis), climate change is likely to result in a decrease in suitability from 'very good' and 'excellent' areas in the baseline, to 'moderate' and 'good' areas in the future scenario.

PRODUCTION OF MAIZE IN ZAMBIA[16].

REGION	PRODUCTION AREA		ANNUAL PRODUCTION	
	TOTAL (HA)	% NATIONAL TOTAL	TOTAL (TONNES)	% NATIONAL TOTAL
Central	267,993	17.2	460,509	18.9
Copperbelt	88,997	5.7	201,571	8.3
Eastern	325,348	20.8	555,972	22.9
Luapula	52,120	3.3	131,023	5.4
Lusaka	49,191	3.2	71,727	3.0
Muchinga	85,671	5.5	243,654	10.0
Northern	110,324	7.1	266,244	11.0
Northwestern	79,832	5.1	143,304	5.9
Southern	386,361	24.7	311,626	12.8
Western	115,359	7.4	45,241	1.9
Total	**1,561,196**		**2,430,871**	

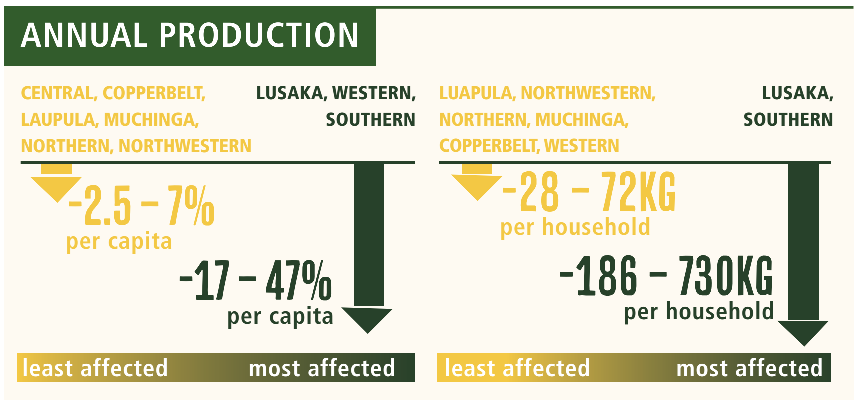
PROJECTED EFFECT OF CLIMATE CHANGE ON DISTRIBUTION OF SUITABILITY FOR MAIZE IN ZAMBIA



Decreases to the average suitability index score and resultant changes to productivity range from ~2-3%, up to ~17-20% (in Lusaka and Southern provinces, respectively). In addition, Western and Southern provinces may experience further decreases in the extent of suitable production area.

HOUSEHOLD- AND NATIONAL- LEVEL IMPACTS

In terms of potential change in production of short-maturing maize varieties per capita, it is predicted that climate change will only result in minor impacts on annual production of maize per capita, equivalent to a decrease of 2.5 – 7% per capita, in Central, Copperbelt, Luapula, Muchinga, Northern and Northwestern provinces. However, the effects are likely to be comparatively larger in Lusaka, Western and Southern provinces, where the predicted decrease in production per capita is equivalent to a loss of 17 – 47% per capita.



At the household level, the effect of climate change on annual maize production may result in decreased production of 28 – 72 kg per household (Luapula, Northwestern, Northern, Muchinga, Copperbelt and Western), up to 186 kg per household in Lusaka, and up to 730 kg per household in Southern province. The costs of reduced production of maize are estimated to range from USD 1.5 to USD 28 per person, or, up to USD 169 per household in Southern province.

[16] Including all farm types, ranging from smallholder subsistence farms up to largescale commercial farms, derived from the Post-Harvest Survey (2017) published by the Central Statistical Office (CFO) https://www.zamstats.gov.zm/index.php/publications/category/12-agriculture?download=720:phs-report-2014-2015-final-pdf

PROVINCE AND NATIONAL-LEVEL IMPACTS

At the province level, the largest decreases in annual production of maize (assuming short-maturing varieties are grown) are predicted for Southern, Eastern and Central provinces (cumulative losses of 145,000, 38,000 and 20,000 tonnes per annum, respectively). The replacement costs for lost production in these provinces are estimated to be USD 33.7 million, USD 8 million and USD 4.9 million in Southern, Eastern and Central provinces, respectively. In total, the cumulative loss of production of maize (short-maturing varieties) across all provinces is equivalent to 252,000 tonnes and a total annual replacement cost of USD 58.9 million per year. By comparison, it is estimated that the climate impacts on long-maturing maize varieties would be equivalent to lost annual production of 590,000 tonnes per annum, with potential replacement costs of lost production of up to USD 101 million per year.

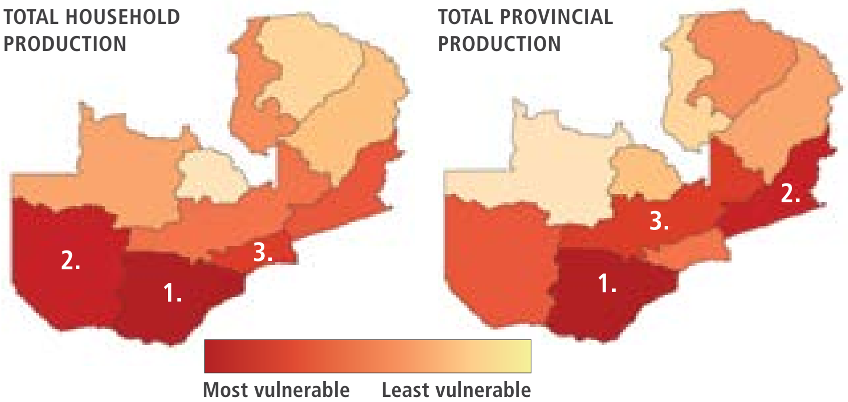
Total loss of annual production **590 000** tonnes

Total annual cost **USD 101** million

CLIMATE VULNERABLE PROVINCES AND HOUSEHOLDS

At the household level, the households which will experience the most severe negative impacts on per capita production are in the Southern (1), Western (2) and Lusaka (3) provinces. At the province level, the provinces that will experience the most severe negative impacts on total production are Southern (1), Eastern (2) and Central (3) provinces.

MOST VULNERABLE REGIONS, BASED ON CHANGES TO:



KEY FINDINGS AND RECOMMENDATIONS

Zambia will experience a moderate decrease in the production potential for short-maturing maize varieties as a result of climate change.

Despite the predicted negative changes, wide expanses of the country are likely to be characterised by moderate/good suitability for short-maturing maize varieties.

The impacts of climate change on maize production are estimated to be at least a loss of 252,000 tonnes and a total replacement cost of USD 58 million per year, while the projected impacts for long-maturing maize varieties are twice as severe.

Recommended actions: identify and increase access to locally-adapted cultivars; support farmers to adopt climate-resilient practices; promote the adoption of alternative, climate-resilient crops such as sorghum, beans, cowpeas, groundnuts and pigeonpeas.

CLIMATE CHANGE AND ITS EFFECT ON MILLET

BROAD CONTEXT

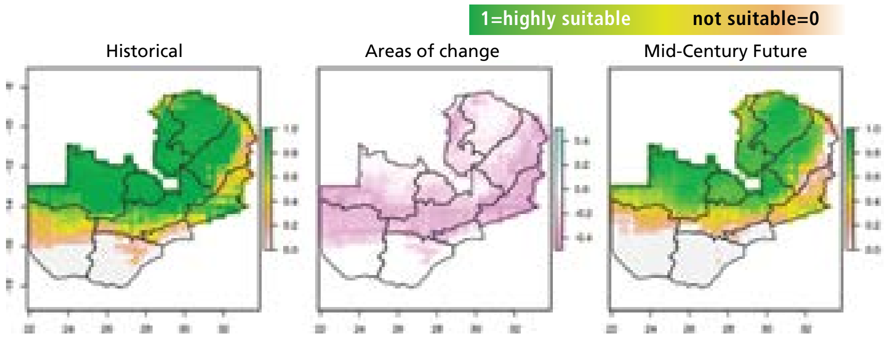
Finger and pearl millet is widely grown as a complement or alternative to other cereals. Agro-Ecological Zones II.a, II.b and III are widely suitable for production of finger millet, including areas of very good or excellent suitability in the north (corresponding to AEZ III). The southern extent of Western and Southern provinces (corresponding to AEZ I), are only marginally suitable for millet production.

Climate change will likely result in negative impacts on millet across all provinces. Most provinces are expected to undergo minor (1.2–7.2% in Northern, Southern, Northwestern and Luapula provinces) or moderate (20-32 % in Lusaka, Muchinga, Western, Central and Eastern provinces) negative changes to suitability for cultivation of millet. Several provinces are expected to remain unchanged in terms of total suitable area (e.g. Copperbelt, Luapula, Lusaka). Of the remaining provinces, the loss of total suitable area ranges from <10% in Southern and Western provinces, 10-20% in Northern, Central, Eastern and Muchinga provinces, and up to 67% in Northwestern province.

PRODUCTION OF MILLET IN ZAMBIA[17].

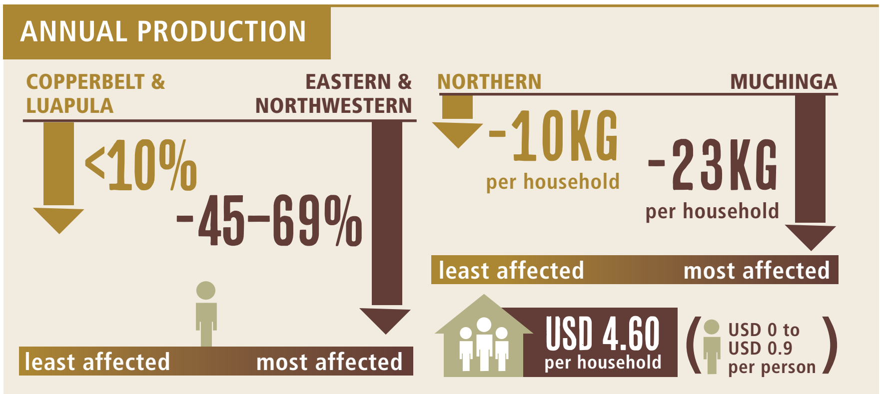
REGION	PRODUCTION AREA		ANNUAL PRODUCTION	
	TOTAL (HA)	% NATIONAL TOTAL	TOTAL (TONNES)	% NATIONAL TOTAL
Central	1,800	4.0	1,347	5.4
Copperbelt	76	0.2	36	0.1
Eastern	19	0.0	5	0.0
Luapula	1,605	3.6	1,743	7.0
Lusaka	12	0.0	9	0.0
Muchinga	7,459	16.5	7,011	28.3
Northern	13,471	29.8	12,378	50.0
Northwestern	213	0.5	101	0.4
Southern	4,418	9.8	203	0.8
Western	16,064	35.6	1,911	7.7
Total	**45,137**		**24,744**	

PROJECTED EFFECT OF CLIMATE CHANGE ON DISTRIBUTION OF SUITABILITY FOR MILLET IN ZAMBIA



HOUSEHOLD LEVEL IMPACTS

In terms of the potential change in production per capita, it is predicted that households will experience a decrease in annual production ranging from <10% in Copperbelt and Luapula, 15-20% in Northern, Southern and Lusaka, up to 45-69% in Eastern and Northwestern provinces.



In terms of the potential change in annual household production, Northern and Muchinga provinces are expected to experience the most significant decreases to household-level production, where losses are estimated to be equivalent to 10 kg and 23 kg per household per year. In terms of replacement costs for lost production, households are anticipated to experience a loss ranging from less than USD 0 to 0.9 per person, or, up to USD 4.6 per household[18]. Copperbelt, Eastern, Luapula, Lusaka, Northwestern and Southern provinces are expected to experience negligible negative effects, equivalent to a loss of less than 1 kg per household per annum.

17 including all farm types, ranging from smallholder subsistence farms up to largescale commercial farms, derived from the Post-Harvest Survey (2017) published by the Central Statistical Office (CFO) https://www.zamstats.gov.zm/index.php/publications/category/12-agriculture?download=720:phs-report-2014-2015-final-pdf

18 Market prices for millet were derived from district-level statistics provided by the Central Statistics Organisation. Central Statistical Office - https://www.zamstats.gov.zm. US Dollar:Kwacha exchange rate was estimated as 0.084. Market prices for millet varies between provinces – average price across all provinces was approximately USD 0.3 per kg.

PROVINCE AND NATIONAL-LEVEL IMPACTS

At the province level, the reduction in total annual production of millet ranges from 2 – 4 tonnes per year (Lusaka, Eastern and Copperbelt), up to 1,800 tonnes and 2,700 tonnes in Northwestern and Muchinga provinces. In total, the cumulative loss of production of finger millet across all provinces is equivalent to 5,247 tonnes, equivalent to an annual replacement cost of USD 1.24 million per year. At the provincial scale, it is anticipated that the greatest costs for purchase of replacement millet will be incurred in Muchinga (USD 540,000), Northern (USD 334,000) and Western (USD 165,000) provinces.

Total loss of annual production

5 247 tonnes

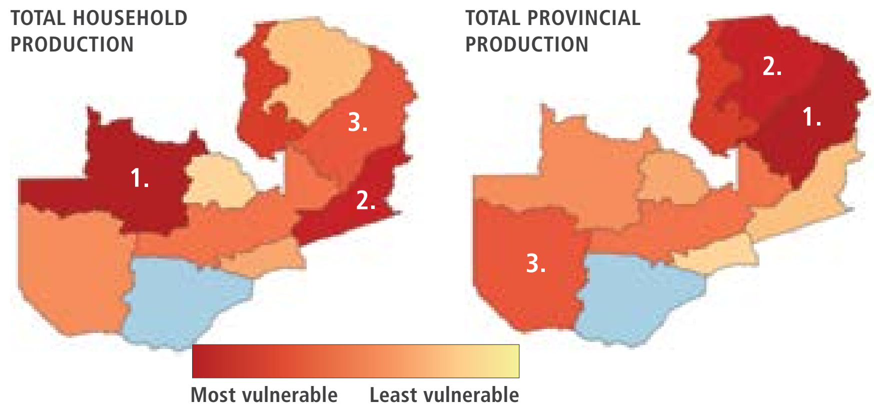
Total annual cost

USD 1.24 million

CLIMATE VULNERABLE PROVINCES AND HOUSEHOLDS

At the household level, the provinces which will experience the most severe negative impacts on per capita production are Northwestern (1), Eastern (2) and Muchinga (3). At the province level, the two regions that will experience the most severe negative impacts on total production are Muchinga (1), Northern (2) and Western (3).

MOST VULNERABLE REGIONS, BASED ON CHANGES TO:



KEY FINDINGS AND RECOMMENDATIONS

Zambia will likely experience minor to moderate decreases in production of millet as a result of climate change-related declines in productivity.

Substantial areas of moderate to good suitability are likely to remain.

Millet will not be impacted as negatively as the main cereal crop, maize,- and may be an appropriate option for further promotion and development as a climate-resilient alternative in combination with other staple cereal and legume crops.

Recommended actions: sustained efforts to promote inclusion of novel cereals in households and markets, improve farmers’ perceptions of the crop, research and increase availability of high-quality seeds; promote as a diverse feedstock for livestock and human consumption.

CLIMATE CHANGE AND ITS EFFECT ON SORGHUM

BROAD CONTEXT

Sorghum is grown as a subsistence crop across most of Zambia's provinces. Much of central and northern Zambia (including the areas corresponding to Agro-Ecological Zones II.a, II.b and III) is to some degree suitable for production of sorghum, including areas of excellent suitability in the north, corresponding to AEZ III. The southern areas corresponding to AEZ I (particularly the southern extent of Western and Southern provinces) are found to be mostly unsuitable for production of sorghum.

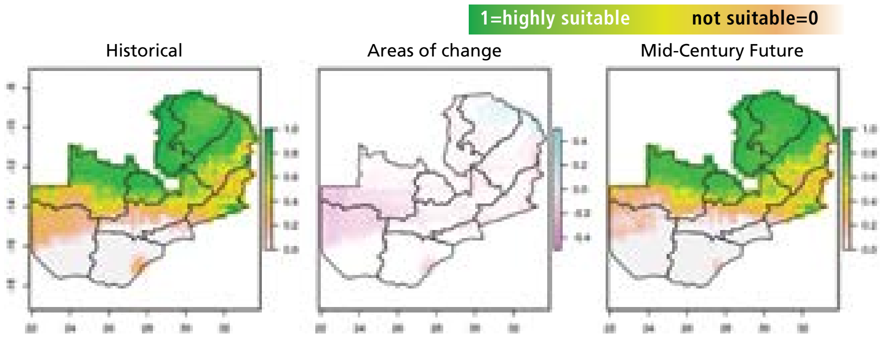
Climate change will likely result in a minor decrease in the total spatial extent of suitable production areas for sorghum. The effect of climate change on sorghum production is likely to be relatively minor in AEZs II and III, while provinces associated with AEZ I are expected to experience more negative impacts. Results also indicate minor decreases at the southern extent of existing suitable areas, suggesting a northward shift in the distribution of areas suitable for sorghum.

The Lusaka, Western and Southern provinces are predicted to experience the greatest decrease in sorghum production, equivalent to a decrease of 47%, 74% and 92% production per capita, respectively. The Eastern, Northern and Central provinces may experience moderate decreases in production, equivalent to 8 – 14% decrease in production per capita. Of the remaining provinces – Muchinga, Luapula and Copperbelt – the estimated impact on annual production per capita is <2%. Northwestern province is the only area which is predicted to experience a minor (0.9%) increase in productivity.

PRODUCTION OF SORGHUM IN ZAMBIA[19].

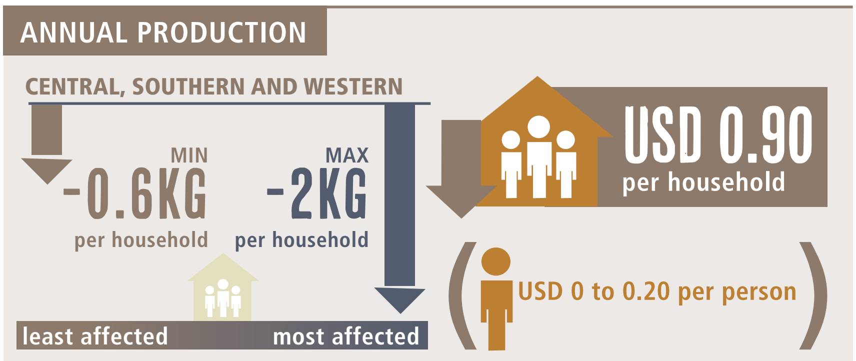
REGION	PRODUCTION AREA		ANNUAL PRODUCTION	
	TOTAL (HA)	% NATIONAL TOTAL	TOTAL (TONNES)	% NATIONAL TOTAL
Central	1,331	3.6	927	15.4
Copperbelt	284	0.8	172	2.9
Eastern	226	0.6	143	2.4
Luapula	60	0.2	107	1.8
Lusaka	73	0.2	12	0.2
Muchinga	2,938	7.8	2,504	41.5
Northern	581	1.6	313	5.2
Northwestern	1,615	4.3	1,306	21.7
Southern	20,845	55.7	126	2.1
Western	9,496	25.4	419	6.9
Total	**37,449**		**6,029**	

PROJECTED EFFECT OF CLIMATE CHANGE ON DISTRIBUTION OF SUITABILITY FOR SORGHUM IN ZAMBIA



HOUSEHOLD LEVEL IMPACTS

In terms of negative impacts at the household level, households in the Central, Southern and Western provinces are predicted to experience a deficit in annual production ranging from 0.6 – 2 kg of sorghum per household. In several provinces, the baseline production of sorghum per household is so low such that the predicted decreases to productivity do not result in a measurable change at the household level – for example, the loss of production in Copperbelt, Eastern and Luapula provinces is small enough to be considered negligible. The costs of reduced production of sorghum are estimated to range from USD 0 to 0.2 per person, or, up to USD 0.9 per household in Western Province[20].



[19] including all farm types, ranging from smallholder subsistence farms up to largescale commercial farms, derived from the Post-Harvest Survey (2017) published by the Central Statistical Office (CFO) https://www.zamstats.gov.zm/index.php/publications/category/12-agriculture?download=720:phs-report-2014-2015-final-pdf

[20] Market prices for sorghum were derived from district-level statistics provided by the Central Statistics Organisation. Central Statistical Office - https://www.zamstats.gov.zm. US Dollar:Kwacha exchange rate was estimated as 0.084. Market prices for sorghum varies between provinces – average price across all provinces was approximately USD 0.5 per kg.

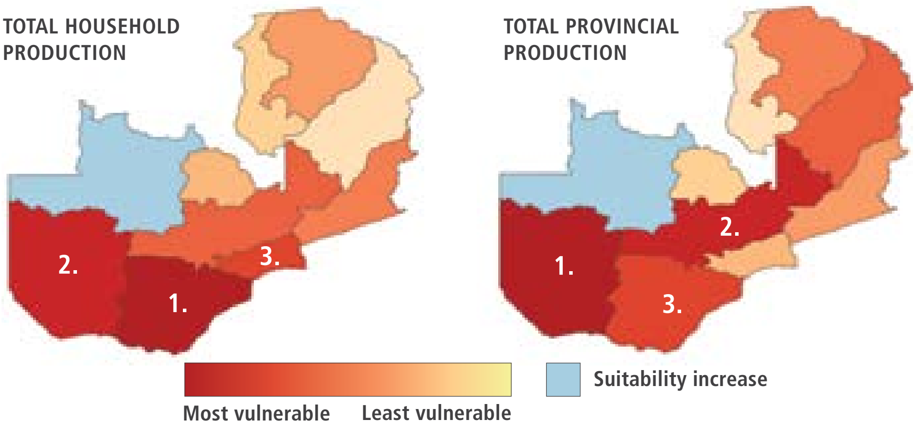
PROVINCE AND NATIONAL-LEVEL IMPACTS

At the provincial level, the effect of climate change on annual sorghum production may result in a shortfall of production ranging from 3 – 5 tonnes per annum (in Luapula, Copperbelt and Lusaka provinces), up to 116 tonnes per annum in Southern Province, 131 tonnes per annum in Central province and 308 tonnes per annum in Western province. In total, the cumulative loss of production of sorghum across all Provinces is equivalent to 488 tonnes. At a national scale, the total annual cost of climate-related impacts on sorghum is estimated to be USD 282,000 per year.

CLIMATE VULNERABLE PROVINCES AND HOUSEHOLDS

At the household level, the provinces which will experience the most severe negative impacts on per capita production are Southern (1), Western (2) and Lusaka (3). At the province level, regions that will experience the most severe negative impacts on total production are Western (1), Central (2) and Southern (3).

MOST VULNERABLE REGIONS, BASED ON CHANGES TO:



KEY FINDINGS AND RECOMMENDATIONS

Zambia will likely experience minor decreases in production of sorghum as a result of climate change-related declines in total production area and productivity.

Southern, Western, Central and Lusaka provinces are most vulnerable to changes in production of sorghum.

The total lost production of sorghum as a result of climate change is estimated to be 488 tonnes per annum.

Despite these negative trends, this cereal crop is predicted to be considerably more resilient to the impacts of climate change than other staples such as maize and beans.

Recommended actions: research and development required to identify the most locally appropriate cultivars to be promoted as a climate-resilient cereal alternative to maize; and promote a change in dietary preferences, and farmers' perceptions of the crop.

SUMMARY OF FINDINGS, RECOMMENDATIONS, ADAPTATION STRATEGIES AND CLIMATE-RESILIENT ALTERNATIVES FOR SMALLHOLDER FARMERS

The summarised findings above indicate that several important staple crops ,notably beans, groundnuts and maize, are predicted to experience significant decreases in production. Consequently, it is strongly recommended that initiatives related to climate change adaptation, food security and enhanced agricultural production include careful consideration of strategies to increase the resilience of these three crops. Sorghum and millet are predicted to experience negative, but comparatively minor impacts, and therefore are suggested to be suitable alternative or complementary cereal crops to be promoted. Despite the negative impacts predicted on these cereal and legume staples, most provinces may have the opportunity to benefit from increased suitability for cassava production.

In the case of maize, the results strongly support the case for development and promotion of fast-growing, early-maturing varieties to be disseminated as widely as possible. Despite the prediction of negative impacts on the early-maturing varieties, these are predicted to be considerably less severe and costly than the negative impacts incurred by households growing late-maturing maize varieties. Analyses indicate that potential losses to annual production, assuming long-maturing varieties are grown, may be 300,000 tonnes greater and result in additional replacement costs of up to USD 40 million compared to short-maturing varieties. In addition to strategies based on selection of locally-adapted and climate-resilient cultivars, the risk of reduced production of all maize varieties can be partly offset by continued promotion of crop diversification, including intercropping and multi-crop approaches that include diverse legumes and alternative cereals such as sorghum and millet. Finally, farmers will benefit from capacity-building and training on techniques to manage the challenge of delayed or unreliable rainfall at the onset of the rainy season – for example, strategies to stagger planting times over an extended period, techniques such as conservation agriculture to improve the water-holding capacity of soils, and increased access and ability to use seasonal weather forecasts.

In the case of beans, a moderate or severe reduction of production is expected between the current baseline period and the mid-century future. Despite this predicted negative trend, beans and other leguminous crops are still expected to be a useful component of future strategies to adapt smallholder agriculture to climate change in Zambia. The crop is already widely grown and eaten, can be incorporated into diverse inter-cropping and crop rotation strategies with other staple crops, and contributes positively to soil fertility. The potential risk of negative impacts of climate change on beans can be partly offset by promoting the adoption of a diversity of bean cultivars as well as additional legume species which are relatively resilient to the changing climate – this may include groundnuts (particularly in AEZ II and AEZ III), cowpea and pigeonpea.

In the case of groundnuts, several provinces may experience minor or moderate negative impacts on annual production, particularly in the southern extents of AEZ I. However, the crop appears to be well-suited to the northern regions of AEZ III, which are not predicted to experience any negative impacts. Consequently, groundnut appears to be an appropriate crop to promote as a means of safeguarding food security at the household level and potential source of cash income. Furthermore, groundnuts and other legumes are likely to be appropriate in various inter- and multi-cropping approaches.

Cassava is the only crop which is predicted to experience positive impacts, in virtually all regions. Cassava is likely to be an increasingly important contributor towards Zambia's future food security and climate change resilience. The crop is quite resilient to drought and variable rainfall, and offers farmers the option to harvest tubers throughout the year according to market demand or household food security needs. To fully realise the opportunities presented by Zambia's apparent potential for cassava production, it is recommended that future initiatives should include a focus on development of facilities and a supporting value chain for post-harvest processing and value addition of cassava. The ability to process fresh cassava roots into chips, flour, starch or other shelf-stable products will reduce the loss of fresh cassava to waste and spoilage, thereby contributing to food security and providing farmers with a potential source of income. Furthermore, the production of cassava in Zambia can be further strengthened by initiatives that promote access to good-quality plant materials, focusing on virus-free clones of high-yielding and locally-adapted varieties. In addition, it is recommended that farmers are provided with capacity building and training to control pests and diseases, particularly the insect vectors of cassava mosaic virus, as well as to identify and remove infected plants.

APPENDIX TABLES

APPENDIX TABLE A.1.

SUMMARISED ADAPTIVE CAPACITY (AC) INDICATORS COLLECTED FOR ALL PROVINCES OF ZAMBIA[21]

Indicator category	Adaptive capacity indicators	Central	Copperbelt	Eastern	Luapula	Lusaka	Muchinga	Northern	North-Western	Southern	Western
Adoption of improved agricultural practices	% Fertilizer use among smallholder farmers	75.0	68.0	54.0	53.0	74.0	71.0	64.0	57.0	59.0	14.0
	% Manure use	3.1	4.4	5.6	1.1	14.2	1.5	2.0	1.6	14.9	9.8
	% Herbicide use	18.4	26.6	4.6	7.1	15.5	17.6	25.3	15.9	4.0	5.9
	% Households using improved maize seed	87.0	71.0	42.0	68.0	77.0	72.0	82.0	67.0	69.0	38.0
	% Adoption of intercropping	0.8	2.8	1.3	13.9	1.9	5.1	12.3	5.2	1.6	8.7
Access to alternative income	% Employment rate	87.3	77.9	91.2	92.3	80.0	93.6	93.7	89.7	87.9	92.3
Education	% Literacy rate (15+)	85.4	93.5	66.5	77.9	93.5	78.3	75.8	76.3	85.4	72.5

21 CSO (2018) Zambia In Figures http://www.zamstats.gov.zm/phocadownload/Dissemination/Zambia%20in%20Figure%202018.pdf ; IAPRI (2015) Rural Agricultural Livelihoods Survey https://agriprofocus.com/upload/post/RALS_2015_Survey_Report__Finalv-_edited1456827249.pdf; IAPRI (2017) Zambia Agriculture Status Report https://www.researchgate.net/publication/322676437_Zambia_Agriculture_Status_Report_2017

APPENDIX TABLE A.2.

PROJECTED INFLUENCE OF CLIMATE CHANGE ON MEAN MONTHLY PRECIPITATION (MM/MONTH) IN THE PROVINCES OF ZAMBIA AT HISTORICAL AND MID-CENTURY PERIODS, AND MONTHLY ANOMALIES BETWEEN THE TWO TIME PERIODS

mm/month		MONTH												TOTAL
		J	F	M	A	M	J	J	A	S	O	N	D	
CENTRAL	Historical	239.9	204.0	123.2	27.0	3.5	1.1	0.2	0.4	2.4	19.8	93.3	211.6	**926.4**
	Future	229.2	196.8	113.2	20.6	1.9	0.7	0.2	0.4	1.2	9.3	73.0	195.8	**842.3**
	Anomaly	*-10.7*	*-7.2*	*-10.0*	*-6.4*	*-1.6*	*-0.4*	*0.0*	*-0.1*	*-1.3*	*-10.4*	*-20.3*	*-15.8*	***-84.1***
COPPER BELT	Historical	279.4	231.9	183.3	38.5	5.4	0.7	0.3	0.6	3.3	31.7	137.2	255.0	**1167.3**
	Future	276.5	232.9	167.4	32.3	3.1	0.6	0.2	0.4	1.5	18.0	115.0	244.7	**1092.6**
	Anomaly	*-2.9*	*1.0*	*-16.0*	*-6.2*	*-2.3*	*-0.2*	*0.0*	*-0.2*	*-1.8*	*-13.7*	*-22.2*	*-10.3*	***-74.7***
EASTERN	Historical	240.6	201.9	141.9	39.3	4.8	0.8	0.6	0.9	1.6	12.8	74.9	194.8	**914.9**
	Future	225.8	197.2	132.1	31.7	3.0	0.6	0.4	0.8	1.0	5.9	54.3	175.5	**828.3**
	Anomaly	*-14.9*	*-4.6*	*-9.8*	*-7.7*	*-1.8*	*-0.3*	*-0.2*	*-0.1*	*-0.6*	*-6.9*	*-20.6*	*-19.3*	***-86.6***
LUAPULA	Historical	244.8	213.8	220.3	81.6	7.8	0.8	0.3	0.4	5.7	40.1	139.6	248.6	**1203.8**
	Future	238.9	213.8	209.7	74.7	4.9	0.7	0.3	0.3	3.1	25.8	119.5	241.6	**1133.3**
	Anomaly	*-5.9*	*0.1*	*-10.6*	*-6.8*	*-2.8*	*-0.1*	*0.0*	*-0.1*	*-2.6*	*-14.2*	*-20.1*	*-6.9*	***-70.5***
LUSAKA	Historical	200.2	166.5	94.2	24.2	4.1	0.5	0.3	0.6	1.9	15.0	73.0	174.9	**755.4**
	Future	190.9	159.6	82.6	17.2	2.2	0.4	0.3	0.6	1.3	6.8	52.4	160.8	**675.1**
	Anomaly	*-9.3*	*-7.0*	*-11.6*	*-7.0*	*-1.8*	*-0.1*	*0.0*	*0.0*	*-0.6*	*-8.2*	*-20.6*	*-14.1*	***-80.3***
MUCHINGA	Historical	245.5	216.0	174.6	51.7	5.9	1.4	0.6	0.7	1.7	13.1	91.3	211.4	**1013.9**
	Future	234.0	207.8	164.9	44.1	4.0	0.9	0.4	0.5	0.9	6.4	66.1	191.3	**921.3**
	Anomaly	*-11.5*	*-8.2*	*-9.7*	*-7.5*	*-1.9*	*-0.5*	*-0.2*	*-0.1*	*-0.8*	*-6.6*	*-25.2*	*-20.1*	***-92.6***
NORTHERN	Historical	244.0	219.4	225.5	87.1	9.5	1.2	0.3	0.5	3.8	32.5	135.3	242.4	**1201.5**
	Future	237.0	216.1	214.4	77.6	6.1	1.0	0.2	0.4	2.2	19.7	110.8	232.5	**1118**
	Anomaly	*-6.9*	*-3.2*	*-11.1*	*-9.5*	*-3.3*	*-0.1*	*0.0*	*-0.1*	*-1.7*	*-12.8*	*-24.5*	*-9.8*	***-83.5***
N. WESTERN	Historical	242.0	201.9	174.7	43.9	4.9	1.1	0.3	1.0	9.7	55.0	149.9	229.8	**1114.2**
	Future	232.4	196.9	158.1	37.1	2.6	0.9	0.3	0.4	5.1	36.2	129.4	223.0	**1022.4**
	Anomaly	*-9.6*	*-5.1*	*-16.6*	*-6.7*	*-2.2*	*-0.3*	*0.0*	*-0.6*	*-4.6*	*-18.8*	*-20.5*	*-6.9*	***-91.8***
SOUTHERN	Historical	176.5	152.7	88.7	18.6	3.3	1.5	0.2	0.3	2.7	19.1	73.7	153.1	**690.4**
	Future	164.0	138.7	73.2	12.6	1.7	1.1	0.1	0.2	0.9	8.4	54.8	141.0	**596.7**
	Anomaly	*-12.5*	*-14.1*	*-15.5*	*-6.1*	*-1.6*	*-0.4*	*0.0*	*-0.1*	*-1.8*	*-10.8*	*-18.9*	*-12.1*	***-93.7***
WESTERN	Historical	188.9	161.9	110.2	26.4	2.8	1.3	0.3	0.3	3.7	26.2	88.5	157.7	**768.2**
	Future	172.8	147.0	93.6	20.9	1.3	1.1	0.3	0.2	1.4	15.2	70.9	147.5	**672.2**
	Anomaly	*-16.2*	*-14.9*	*-16.6*	*-5.5*	*-1.4*	*-0.2*	*0.0*	*-0.1*	*-2.3*	*-11.1*	*-17.5*	*-10.2*	***-96***

APPENDIX TABLE A.3.

PROJECTED INFLUENCE OF CLIMATE CHANGE ON MEAN MONTHLY TEMPERATURE (°C) IN THE PROVINCES OF ZAMBIA AT HISTORICAL AND MID-CENTURY PERIODS, AND MONTHLY ANOMALIES BETWEEN THE TWO TIME PERIODS

		MONTH											
		J	F	M	A	M	J	J	A	S	O	N	D
CENTRAL	Historical (°C)	23.1	23.1	22.9	21.8	19.7	17.7	17.3	19.8	23.4	25.4	25.1	23.4
	Future (°C)	24.9	24.8	24.8	23.8	21.9	19.8	19.5	21.8	25.6	28.0	27.7	25.5
	Anomaly (°C)	*1.8*	*1.7*	*1.9*	*2.0*	*2.2*	*2.1*	*2.2*	*2.0*	*2.2*	*2.6*	*2.6*	*2.1*
COPPER BELT	Historical (°C)	22.5	22.5	22.5	21.3	19.4	17.4	17.1	19.6	22.9	24.8	24.5	22.9
	Future (°C)	24.3	24.3	24.4	23.3	21.5	19.5	19.4	21.7	25.2	27.4	27.0	24.9
	Anomaly (°C)	*1.8*	*1.8*	*1.9*	*2.0*	*2.2*	*2.1*	*2.3*	*2.0*	*2.3*	*2.7*	*2.5*	*2.0*
EASTERN	Historical (°C)	24.0	24.0	24.0	23.2	21.6	19.7	19.4	21.3	24.8	26.7	26.7	24.8
	Future (°C)	25.8	25.8	25.9	25.1	23.7	21.8	21.5	23.2	26.8	29.1	29.3	27.0
	Anomaly (°C)	*1.8*	*1.8*	*1.9*	*1.9*	*2.1*	*2.1*	*2.1*	*1.9*	*2.0*	*2.4*	*2.6*	*2.2*
LUAPULA	Historical (°C)	22.7	22.8	22.9	22.5	21.4	19.3	19.2	21.2	24.1	25.3	24.5	23.2
	Future (°C)	24.5	24.6	24.7	24.5	23.4	21.5	21.3	23.2	26.3	27.7	26.8	25.1
	Anomaly (°C)	*1.8*	*1.8*	*1.8*	*2.0*	*2.0*	*2.1*	*2.1*	*2.0*	*2.2*	*2.4*	*2.3*	*2.0*
LUSAKA	Historical (°C)	24.6	24.4	24.3	23.3	21.2	19.1	18.9	21.3	25.0	27.4	27.1	24.7
	Future (°C)	26.4	26.2	26.2	25.4	23.5	21.3	21.0	23.2	27.1	30.1	29.8	26.8
	Anomaly (°C)	*1.8*	*1.8*	*1.9*	*2.0*	*2.3*	*2.1*	*2.2*	*1.9*	*2.1*	*2.6*	*2.6*	*2.1*
MUCHINGA	Historical (°C)	22.4	22.6	22.6	21.9	20.4	18.4	18.1	19.9	22.8	24.8	24.8	23.3
	Future (°C)	24.3	24.4	24.5	23.8	22.4	20.6	20.2	21.8	25.0	27.0	27.3	25.4
	Anomaly (°C)	*1.8*	*1.8*	*1.8*	*1.9*	*2.0*	*2.2*	*2.1*	*1.9*	*2.1*	*2.2*	*2.5*	*2.1*
NORTHERN	Historical (°C)	21.8	22.0	22.2	22.1	21.0	19.0	18.8	20.7	23.4	24.6	23.8	22.4
	Future (°C)	23.7	23.8	24.0	24.0	23.0	21.2	20.9	22.6	25.5	26.9	26.1	24.4
	Anomaly (°C)	*1.9*	*1.8*	*1.8*	*1.9*	*2.0*	*2.2*	*2.1*	*1.9*	*2.1*	*2.3*	*2.3*	*2.0*
N. WESTERN	Historical (°C)	22.7	22.7	22.7	21.8	19.8	17.6	17.4	20.2	23.3	24.8	24.1	23.0
	Future (°C)	24.5	24.5	24.6	23.8	22.1	19.8	19.7	22.3	25.8	27.5	26.5	25.0
	Anomaly (°C)	*1.8*	*1.8*	*1.9*	*2.1*	*2.2*	*2.1*	*2.2*	*2.1*	*2.5*	*2.7*	*2.4*	*2.0*
SOUTHERN	Historical (°C)	24.5	24.3	24.2	23.1	20.4	17.8	17.5	20.6	24.5	26.9	26.6	25.0
	Future (°C)	26.3	26.2	26.1	25.3	22.7	20.0	19.7	22.5	26.7	29.7	29.4	27.2
	Anomaly (°C)	*1.8*	*1.9*	*1.9*	*2.2*	*2.4*	*2.2*	*2.2*	*1.9*	*2.2*	*2.8*	*2.8*	*2.1*
WESTERN	Historical (°C)	24.5	24.4	24.4	23.4	21.1	18.6	18.2	21.6	25.1	26.9	26.0	24.8
	Future (°C)	26.4	26.2	26.4	25.5	23.5	20.8	20.4	23.6	27.5	29.8	28.6	26.9
	Anomaly (°C)	*1.9*	*1.8*	*2.0*	*2.2*	*2.4*	*2.2*	*2.2*	*2.0*	*2.4*	*2.8*	*2.5*	*2.1*