RESEARCH HIGHLIGHTS

CLIMATE CHANGE AND FUTURE CROP SUITABILITY IN ZIMBABWE

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Research Highlights – Climate Change and Future Crop Suitability in Zimbabwe

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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 Zimbabwe.

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 Zimbabwe; 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 Zimbabwe, 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 ZIMBABWE

Zimbabwe is geographically divided into six distinct Agro-Ecological regions across a total of 10 provinces. A map of Zimbabwe's provinces and distribution of agro-ecological regions is provided in the Appendix section (Figure 1).

Zimbabwe's agricultural production is mainly characterised by relatively low productivity of a small selection of staple cereal and legume crops (including maize, sorghum, millet, beans, groundnuts and soyabeans). Rainfed agriculture, practiced by smallholder farmers, accounts for the vast majority of the planted area. In addition to rainfed production of staple crops, cash crops such as tobacco and to a lesser degree cotton are widely grown. In certain areas, horticultural vegetable crops are an important contributor to agricultural households, while relatively small areas of higher rainfall such as in the Eastern Highlands supports various high-value sub-tropical plantation crops such as citrus, avocado, tea and coffee.

1 https://www.ifad.org/en/web/operations/country/id/Zimbabwe

SUMMARY RESULTS

The likely effects of climate change are not fully consistent between each of Zimbabwe's ten provinces or the crops assessed, however, several general observations can be made. 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 620 mm to 526 mm, representing a decrease of 95 mm or 15% - the predicted decrease of rainfall across the country's provinces and Natural Regions ranges from 14-19%.

The full study includes analyses of the predicted effect of climate change on various crops, including inter alia cereals such as maize, sorghum and pearl millet, and legumes such as common beans and groundnuts in each of Zimbabwe's ten Provinces. The combined effects of reduced precipitation and increased temperatures are likely to result in negative impacts on all of the crops assessed. The annual production of beans, groundnut, maize and sorghum 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. Pearl millet is likely to be comparatively less affected by the predicted climate changes, and may serve as an appropriate alternative staple to be promoted in areas where maize production is expected to become marginal or unsustainable, or in cases where other traditional staples such as sorghum and groundnuts are increasingly unsuitable.

Production of maize, one of the most climate-vulnerable of Zimbabwe's staples, is predicted to undergo a range of negative changes, ranging from minor or moderate decreases across the provinces and Natural Regions. At the provincial level, the cumulative deficit in production of maize ranges from 4211 tonnes in Manicaland up to 91 676 tonnes in Mashonaland West. The production of maize is the most vulnerable to climate change in Matabeleland North, Midlands, Mashonaland West and Mashonaland East. This decrease in maize production will result in considerably increased costs for households to replace the lost production of staple food, as well as an increase in the demand for imported maize. The total replacement costs incurred as a result of lost production is estimated to be USD 88.8 million per year.

In the case of other staple crops such as beans and groundnuts, it is predicted that households will experience a minor or moderate decrease in annual production. Mashonaland Central and Mashonaland West are likely to be particularly vulnerable to the predicted changes on production of beans, as a result of the combined effect of their large exposure to climate related impacts as well as their relatively low adaptive capacities. However, all provinces are expected to experience negative impacts. In total, it is estimated that the annual production of beans across all provinces will be reduced by 3,300 tonnes, and the resultant annual cost of climate-related impacts is estimated to be USD 3 million per year. The total reduction in annual production of groundnuts is projected to range from 39 tonnes in Manicaland to 2156 tonnes in Masvingo - the greatest costs for purchase of replacement food will include Mashonaland East (USD 1.5 million), Midlands (USD 1.8 million) and Masvingo (USD 2 million). In total, it is estimated that the annual production of groundnuts across all provinces will be reduced by 8500 tonnes, equivalent to an annual replacement cost of USD 8.5 million per year.

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. 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. Matabeleland North is consistently among the provinces predicted to experience the largest crop production impacts for all five crops assessed. These crop production impacts are of particular concern given that Matabeleland North was also identified as the province with the second lowest adaptive capacity score out of eight provinces (excluding Harare and Bulawayo), based on a number of socio-economic and agronomic characteristics, and is therefore anticipated to be one of the least able to respond to climate change-related impacts. As a result, Matabeleland North is particularly vulnerable and should be prioritised for adaptation interventions.

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 Zimbabwe's ten provinces. For each of the crops considered in this study (including maize, sorghum, millet, beans, groundnuts and soyabeans) 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 Zimbabwe'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 Zimbabwe's climate, and then analysing the effects of those projected climate changes on economically important crops. Firstly, the potential future changes to Zimbabwe's climate were calculated 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 Zimbabwe, 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.

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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 Zimbabwe'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.

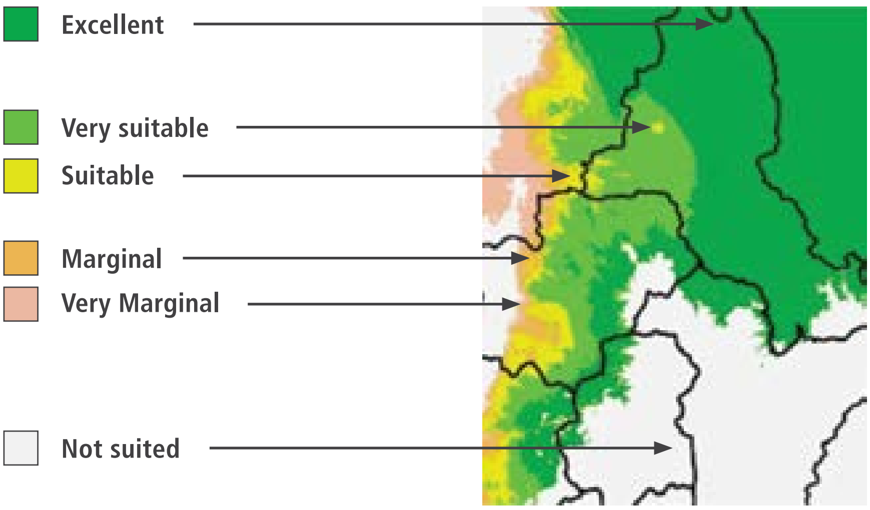
The comparison of maps of 'Historical' and 'Future' distribution of crop suitability can be used to estimate the potential changes to the size and relative productivity of crop-suitable areas. In addition, this approach allows for the identification of specific areas which are likely to undergo positive 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] Statistics were derived from 2015 data on the Zimstat website (http://www.zimstat.co.zw/agriculture-statistics), and summed for the following farm types: A1, A2, Communal Land and Old Resettlement Schemes. Figures exclude statistics from Harare and Bulawayo, which contribute a negligible amount to national crop totals.

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 Zimbabwe Data Portal [7]. In the case of Zimbabwe, the indicators used to estimate AC in each Province included

- **Access to Education** (% literacy rate);
- **Access to agricultural information:** (households with mobile telephone);
- **Adoption of improved agricultural practices:** (investment in irrigation, land improvement and conservation, loans, agricultural inputs).

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 Mashonaland West, Midlands and Mashonaland Central have the highest overall capacities to respond to climate change's impacts (ranking 1st, 2nd, and 3rd, respectively). Masvingo, Matabeleland North and South have the lowest overall **AC** scores (ranking 6th, 7th and 8th, respectively) and therefore are anticipated to be least able to respond or adapt to climate change-related impacts.

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

	Adaptive capacity Indicator category				
	Adoption of improved agricultural practices	Access to agricultural information	Education	**Adaptive capacity score**	**Adaptive capacity rank**
Adaptive capacity Indicator category	50%	25%	25%		
Manicaland	0.41	1	0.99	0.76	**5**
Mashonaland Central	0.72	0.6	0.96	0.81	**3**
Mashonaland East	0.54	0.76	0.99	0.76	**4**
Mashonaland West	1	0.73	0.98	1	**1**
Masvingo	0.5	0.81	0.98	0.75	**6**
Matabeleland North	0.25	0.32	0.96	0.48	**7**
Matabeleland South	0.09	0.36	1	0.42	**8**
Midlands	0.66	0.77	1	0.83	**2**

7 Derived from 2015 figures reported by Zimbabwe National Statistics Agency, www.zimstat.co.zw

CLIMATE PROJECTIONS

PROJECTED CHANGES TO TEMPERATURE IN ZIMBABWE 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 Zimbabwe. 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 October, November and December are predicted to increase by 2–2.7°C, relative to a Historical average of 24.8–25.5°C. Similar increases of 1.8–2.2°C are predicted for all other months of the year, including the peak summer months that support the rainfed agricultural season (December-March) as well as the colder winter months of April–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 (2–2.7°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 ZIMBABWE 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	24.8	24.4	23.9	22.3	19.8	17.3	17.0	19.3	22.8	25.0	25.5	24.8
Future	26.6	26.3	25.8	24.4	21.9	19.3	19.2	21.2	24.9	27.8	28.1	26.8
Anomaly	**1.9**	**1.8**	**1.9**	**2.1**	**2.2**	**2.1**	**2.2**	**1.8**	**2.1**	**2.7**	**2.6**	**2.0**

[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 ZIMBABWE 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 and November is predicted to be reduced from 24.4 to 10.6 mm/month and 73.9 to 54 mm/month (total reduction of rainfall of 14 mm and 20 mm, respectively). Further reductions in monthly precipitation are predicted for the mid-summer months at the peak of the rainy season from December–March ranging from 10 to 12 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–March by 14%, from 572 mm/season to 494 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 months of October and November is likely to vary between provinces and Zimbabwe's agro-ecological zones but in some cases may result in inadequate rainfall to support effective establishment of crops during the period 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 ZIMBABWE 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	144.8	125.9	75.3	26.2	6.9	3.8	3.0	2.4	6.5	24.4	73.9	127.8	620.9
Future	133.1	115.3	63.5	18.8	4.3	2.4	2.2	1.8	2.9	10.6	54.0	117.4	526.3
Anomaly	**-11.7**	**-10.6**	**-11.8**	**-7.4**	**-2.5**	**-1.4**	**-0.8**	**-0.6**	**-3.6**	**-13.8**	**-19.9**	**-10.3**	**-94.6**

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

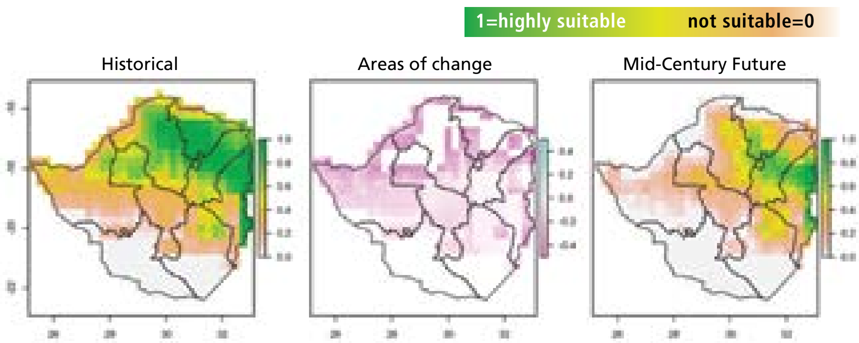
Beans are widely grown as a staple subsistence crop across most of Zimbabwe's provinces, where the majority of the country is considered to be suitable to some degree for bean production. The suitable range of beans is limited by the arid limits of the southern regions, particularly Natural Region V, and becomes increasingly marginal across all provinces in the later months of summer (November-December onwards).

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 Zimbabwe. The crop suitability analyses indicate that all provinces are expected to experience negative changes to suitability for cultivation of beans. All provinces are projected to experience decreases to average suitability index score. The provinces worst affected are likely to include the Midlands (54%), Mashonaland Central (37%) and Mashonaland West (34%), where the future suitability scores are projected to be reduced to moderate or very marginal. Furthermore, all provinces except for Mashonaland East are anticipated to undergo decreases to the overall suitable area and will therefore be affected both by a decrease in production area as well as a decrease in the productivity of those remaining suitable areas.

PRODUCTION OF BEANS IN ZIMBABWE[10].

PROVINCE	PRODUCTION AREA		ANNUAL PRODUCTION	
	TOTAL (HA)	% NATIONAL TOTAL	TOTAL (TONNES)	% NATIONAL TOTAL
Manicaland	1666	6.7	840	9.1
Mashonaland Central	3773	15.1	2500	27.1
Mashonaland East	4054	16.2	1937	21.0
Mashonaland West	6463	25.8	1960	21.3
Masvingo	1827	7.3	548	5.9
Matabeleland North	1634	6.5	237	2.6
Matabeleland South	2592	10.3	526	5.7
Midlands	3036	12.1	674	7.3
Total	**25045**		**9222**	

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



HOUSEHOLD LEVEL IMPACTS

It is predicted that households will experience a decrease in annual production ranging from 12% in Manicaland, up to 70% in Matabeleland South. In addition to the latter province, it is projected that Mashonaland West, Matabeleland North and Mashonaland Central will experience the greatest negative changes (reductions of 49%, 47% and 45%, respectively) to %production at the household level. In terms of the total impact of climate change on the annual production of agricultural households, the predicted decrease in annual production may range from 0.3 kg up to 3.6 kg per household. The Provinces anticipated to be most negatively impacted by total reduced production at the household level include Matabeleland south, Mashonaland West and Mashonaland Central (2, 3.3, 3.6 kg per household per annum). The costs of reduced production of beans are estimated to range from USD 0.1 to 0.8 per person, or, up to USD 3.2 per household[11].

[10] Statistics were derived from 2015 data on the Zimstat website (http://www.zimstat.co.zw/agriculture-statistics), and summed for the following farm types: A1, A2, Communal Land and Old Resettlement Schemes. Figures exclude statistics from Harare and Bulawayo, which contribute a negligible amount to national crop totals.

[11] Average market price was approximately USD 0.9 per kg

PROVINCE AND NATIONAL-LEVEL IMPACTS

The total reduction in annual production of beans is projected to range from 102 tonnes in Manicaland to 1113 tonnes in Mashonaland Central. In total, it is estimated that the annual production of beans across all provinces will be reduced by 3300 tonnes. It is anticipated that Mashonaland Central (USD 1 million), Mashonaland West (USD 856 000) and Mashonaland East (USD 340 000) will incur the greatest costs for purchase of replacement food. At a national scale, the total annual cost of climate-related impacts on beans is estimated to be USD 3 million per year.

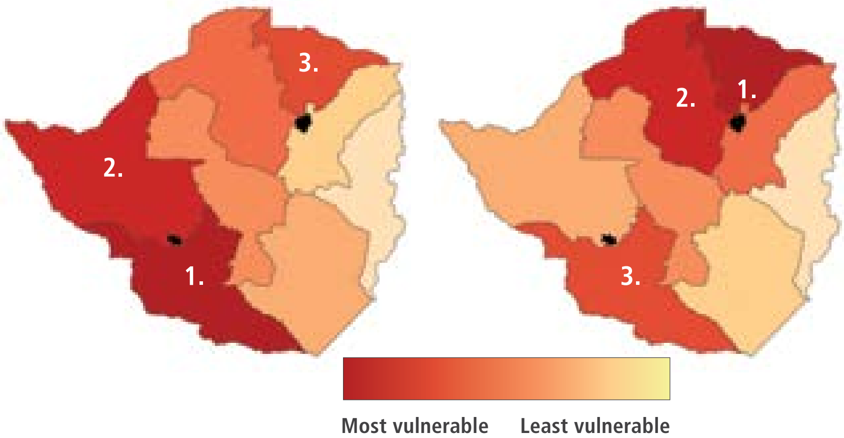
CLIMATE VULNERABLE PROVINCES AND HOUSEHOLDS

At the household level, the provinces that will experience the most severe negative impacts on %change to production per capita (i.e. decreased production relative to average historical production) are Matabeleland South (1), Matabeleland North (2) and Mashonaland Central(3). At the province-level, the most severe negative impacts on total production per province are Mashonaland Central (1), Mashonaland West (2) and Matabeleland South (3).

MOST VULNERABLE REGIONS, BASED ON CHANGES TO:

TOTAL HOUSEHOLD PRODUCTION

TOTAL PROVINCIAL PRODUCTION



KEY FINDINGS AND RECOMMENDATIONS

All provinces expected to experience negative impacts on beans.

Mashonaland Central and Mashonaland West are likely to be particularly vulnerable to the predicted impacts on beans.

Estimated decrease in annual production of 3,000 tonnes, total replacement costs incurred by households up to USD 3 million per year.

Recommended actions: 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.

CLIMATE CHANGE AND ITS EFFECT ON GROUNDNUT

BROAD CONTEXT

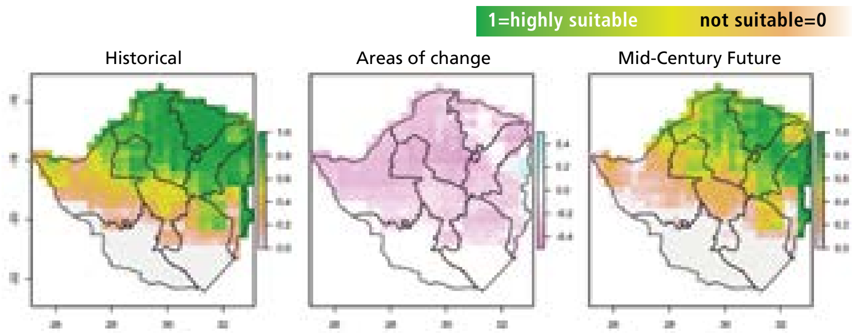
Groundnuts are grown as a subsistence crop across all of Zimbabwe's provinces, with widespread areas of good or excellent suitability. The only provinces which appear to be less well-suited to groundnut production are the relatively arid southern areas corresponding to NR V.

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 Natural Regions IIa, IIb, III and IV. These decreases in suitability will have minor to moderate impacts on annual production ranging from 7% in Mashonaland Central, up to 74% in Matabeleland South. In addition to the latter province, it is projected that Masvingo and Matabeleland North will experience the greatest negative changes (reductions of 34% and 30%, respectively).

PRODUCTION OF GROUNDNUTS IN ZIMBABWE[12].

PROVINCE	PRODUCTION AREA		ANNUAL PRODUCTION	
	TOTAL (HA)	% NATIONAL TOTAL	TOTAL (TONNES)	% NATIONAL TOTAL
Manicaland	1,312	1.0	352	0.7
Mashonaland Central	18,722	14.1	11,032	23.2
Mashonaland East	27,078	20.4	13,062	27.5
Mashonaland West	14,414	10.9	6,843	14.4
Masvingo	34,409	25.9	6,381	13.4
Matabeleland North	4,772	3.6	1,074	2.3
Matabeleland South	8,931	6.7	1,267	2.7
Midlands	23,055	17.4	7,473	15.7
Total	**132,693**		**47,484**	

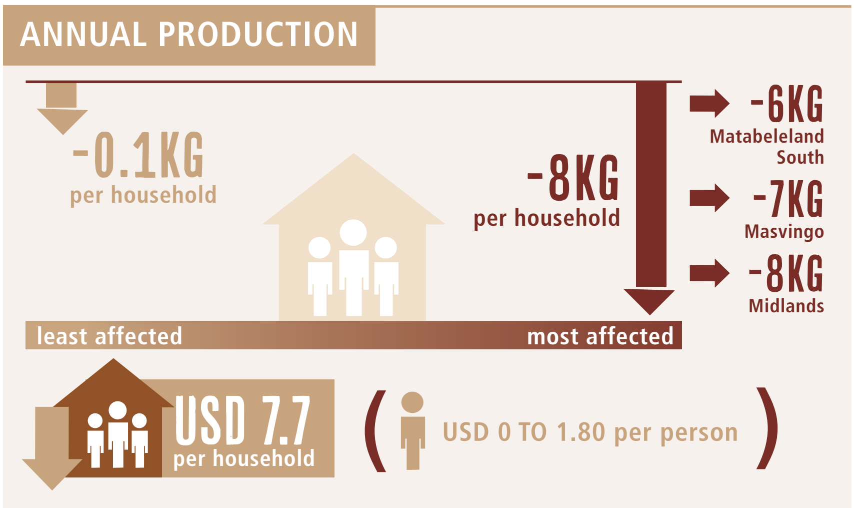
PROJECTED EFFECT OF CLIMATE CHANGE ON DISTRIBUTION OF SUITABILITY FOR GROUNDNUTS IN ZIMBABWE



Overall, the majority of Zimbabwe is expected to maintain widespread suitability for groundnuts, including extensive areas of good suitability.

HOUSEHOLD LEVEL IMPACTS

In terms of the total change to annual production per household, the decrease in production is equivalent to a loss of may range from 0.1 kg up to 8 kg per household. The provinces anticipated to be most negatively impacted by total reduced production at the household level include Matabeleland South, Masvingo and the Midlands (6, 7, 8 kg per household per annum). The costs of reduced production of groundnut are estimated to range from USD 0 to 1.8 per person, or, up to USD 7.7 per household[13].



[12] Statistics were derived from 2015 data on the Zimstat website (http://www.zimstat.co.zw/agriculture-statistics), and summed for the following farm types: A1, A2, Communal Land and Old Resettlement Schemes. Figures exclude statistics from Harare and Bulawayo, which contribute a negligible amount to national crop totals.

[13] Market prices for groundnuts in the period October 2018 – February 2019 were derived from statistics reported on the Agri Universe website. Average market price was approximately USD 1 per kg

PROVINCE AND NATIONAL-LEVEL IMPACTS

In terms of the potential impact on total provincial production, estimated impacts range from 39 tonnes in Manicaland to 2,156 tonnes in Masvingo. The greatest costs for purchase of replacement food will include Mashonaland East (USD 1.5 million), Midlands (USD 1.8 million) and Masvingo (USD 2 million). At a national scale, the annual production of groundnuts across all provinces will be reduced by 8,500 tonnes, resulting in estimated replacement costs for climate-related impacts on groundnuts of USD 8.5 million per year.

Total loss of annual production

8 500 tonnes

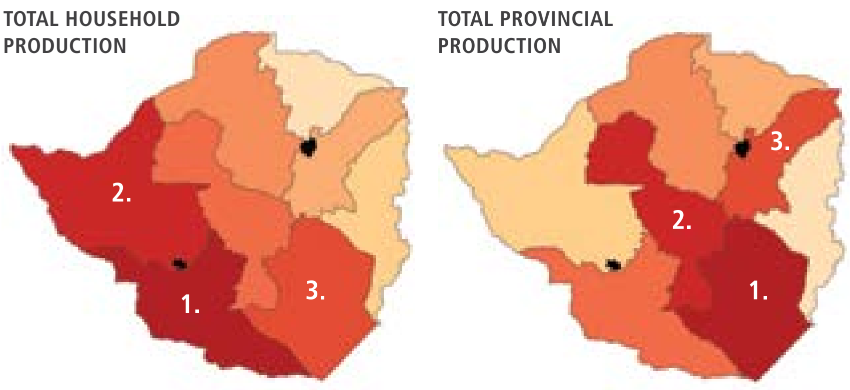
Total annual cost

USD 8.5 million

CLIMATE VULNERABLE PROVINCES AND HOUSEHOLDS

At the household level, the provinces that will experience the most severe negative impacts on %change to production per capita (i.e. decreased production relative to average historical production) are Matabeleland South (1), Matabeleland North (2) and Masvingo (3). At the province level, the most severe negative impacts on total production are Masvingo (1), Midlands (2) and Mashonaland East (3).

MOST VULNERABLE REGIONS, BASED ON CHANGES TO:



Most vulnerable   Least vulnerable

KEY FINDINGS AND RECOMMENDATIONS

Zimbabwe will likely experience minor or moderate decreases in production of groundnut, particularly in Matabeleland South, Matabeleland North, Masvingo, Mashonaland East and the Midlands 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 8,500 tonnes per annum, equivalent to a replacement cost of USD 8.5 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 Zimbabwe's provinces. Areas of very good or excellent suitability are widespread across Natural Regions I-III, whereas Natural Regions IV and V are largely considered to be marginal or totally unsuitable for maize.

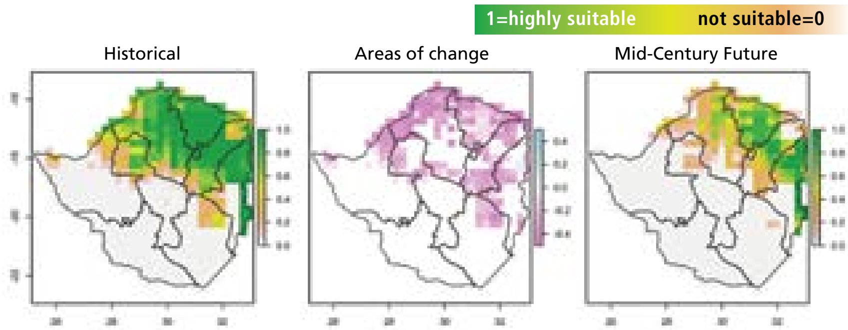
Climate change is predicted to result in negative changes to suitability across most of the current growing areas, and by Mid-Century, the area considered to be of good-to-excellent suitability will be considerably reduced and confined to Agroecological Zones I, IIA and II B.

All provinces are predicted to undergo decreases to average suitability index score and resultant negative changes to productivity, ranging from 5% to 59%. The Midlands, Matabeleland North and Mashonaland West are expected to experience the greatest decreases in productivity. Furthermore, all provinces are likely to experience decreases to the overall suitable area – Matabeleland North and the Midlands are likely to be particularly negatively affected by declines in productivity and losses of between 60 and 79% of the current suitable area. Matabeleland South was not included in the analysis as the current and future suitability for maize is too low.

PRODUCTION OF MAIZE IN ZIMBABWE[14].

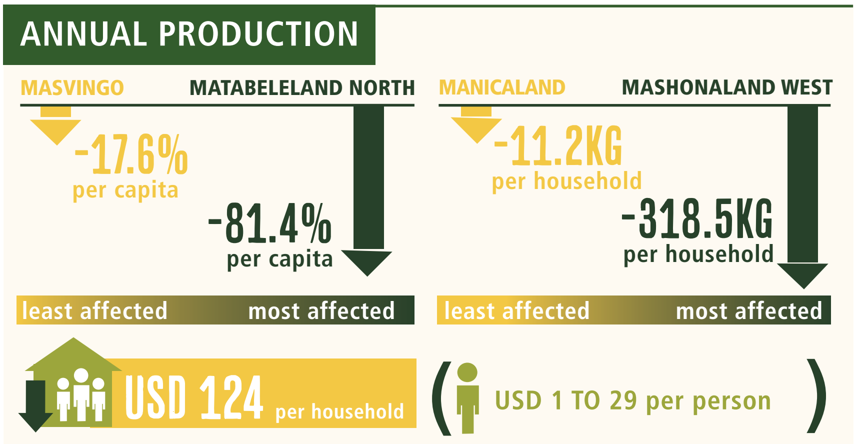
PROVINCE	PRODUCTION AREA		ANNUAL PRODUCTION	
	TOTAL (HA)	% NATIONAL TOTAL	TOTAL (TONNES)	% NATIONAL TOTAL
Manicaland	22,758	2.3	17,839	3.1
Mashonaland Central	112,419	11.5	138,174	23.7
Mashonaland East	136,153	14.0	104,726	18.0
Mashonaland West	182,347	18.7	191,672	32.9
Masvingo	180,677	18.5	37,366	6.4
Matabeleland North	79,816	8.2	16,783	2.9
Matabeleland South	76,332	7.8	10,815	1.9
Midlands	183,854	18.9	64,512	11.1
Total	**974,356**		**581,887**	

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



HOUSEHOLD- AND NATIONAL- LEVEL IMPACTS

The total % change of annual production of maize per capita is predicted to range from a loss of 17.6% in Masvingo up to 81.4% in Matabeleland North. At the household level, the projected decrease in production ranges from 11.2kg in Manicaland up to 318.5kg in Mashonaland West. The costs of reduced production of maize are estimated to range from USD 1 to USD 29 per person, or, up to USD 124 per household [15].



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[14] Statistics were derived from 2015 data on the Zimstat website (http://www.zimstat.co.zw/agriculture-statistics), and summed for the following farm types: A1, A2, Communal Land and Old Resettlement Schemes. Figures exclude statistics from Harare and Bulawayo, which contribute a negligible amount to national crop totals.

[15] Market prices for maize in the period October 2018 – February 2019 were derived from statistics reported on the Agri Universe website. Average market price was approximately USD 0.39 per kg

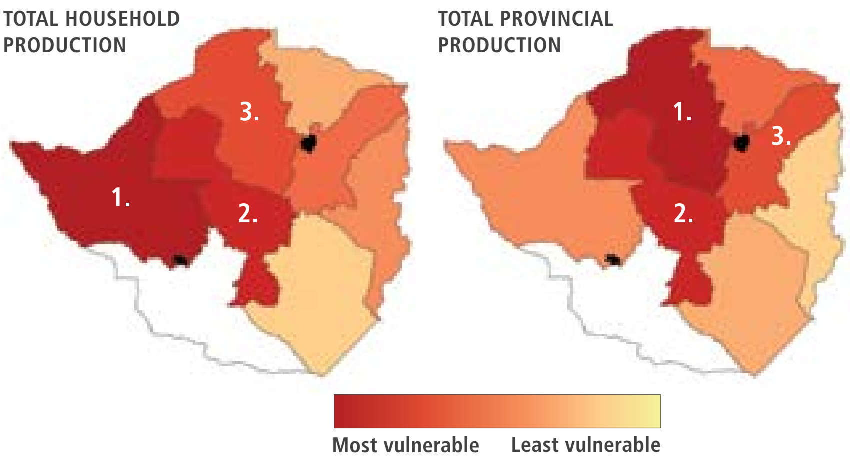
PROVINCE AND NATIONAL-LEVEL IMPACTS

At the provincial level, the deficit in production of maize ranges from 4,211 tonnes in Manicaland up to 91,676 tonnes in Mashonaland West. At the provincial scale, it is anticipated that the greatest costs for purchase of replacement food will be experienced in Mashonaland West (USD 35.7 million), Midlands (USD 17.8 million) and Mashonaland East (USD15 million). At the national level, the total decrease in maize production is equivalent to 230,000 tonnes, resulting in estimated annual cost of climate-related impacts on maize of approximately USD 88.8 million per year.

CLIMATE VULNERABLE PROVINCES AND HOUSEHOLDS

At the household level, the provinces that will experience the most severe negative impacts on %change to production per capita (i.e. decreased production relative to average historical production) are Matabeleland North (1), Midlands (2) and Mashonaland West (3). At the provincial scale, the most severe negative impacts on total production per province are Mashonaland West (1), Midlands (2) and Mashonaland East (3).

MOST VULNERABLE REGIONS, BASED ON CHANGES TO:



KEY FINDINGS AND RECOMMENDATIONS

Zimbabwe will experience a moderate to severe decrease in the production potential for maize.

The impacts of climate change on maize production are equivalent to a loss of 230,000 tonnes per annum and a total annual replacement cost of USD 89 million per year.

Recommended actions include: i) identify and increase access to the most locally appropriate cultivars to be promoted, notably including fast-maturing varieties; ii) increase technical support and assistance for farmers to adopt new practices for climate resilience and management of climate risks; and iii) promote the adoption of alternative, climate-resilient crops such as millet.

CLIMATE CHANGE AND ITS EFFECT ON MILLET

BROAD CONTEXT

Various races of millet are widely grown as an alternative to other staple cereals, with wide areas of moderate or good suitability across Zimbabwe. The southern areas, corresponding to NR V, are marginally or moderately suitable for millet production.

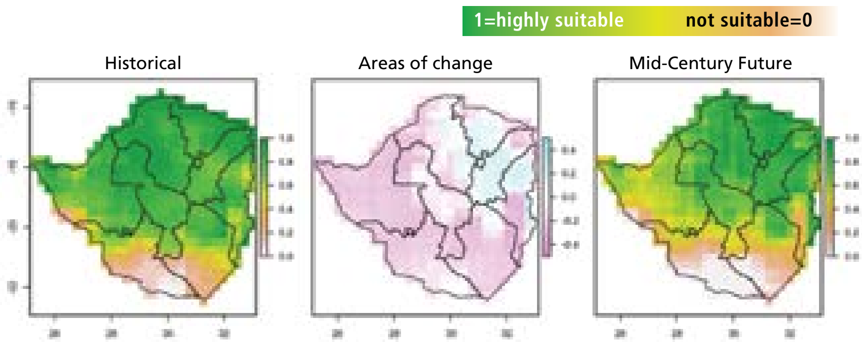
Climate change will likely result in decreases in suitability across most of the current growing areas, and slight increases across NRs I, IIA and IIB. Most provinces are expected to experience decreased suitability (ranging from -3% to -20%), except for Mashonaland East and Central, which may experience minor increases (3.4 and 1.7% respectively) in productivity. The total suitable area is expected to remain unchanged in most provinces, except for Masvingo and Matabeleland South, which are expected to undergo decreases of 6% and 23.5%, respectively. Manicaland, the Midlands and Mashonaland Central, East and West will likely remain highly suitable for pearl millet.

In the case of Mashonaland East and Central Provinces, the anticipated increase in suitable areas 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 are unlikely to be impacted severely by the effects of climate change on millet, but may not necessarily be able to benefit fully from the predicted increase in suitability.

PRODUCTION OF MILLET IN ZIMBABWE[16].

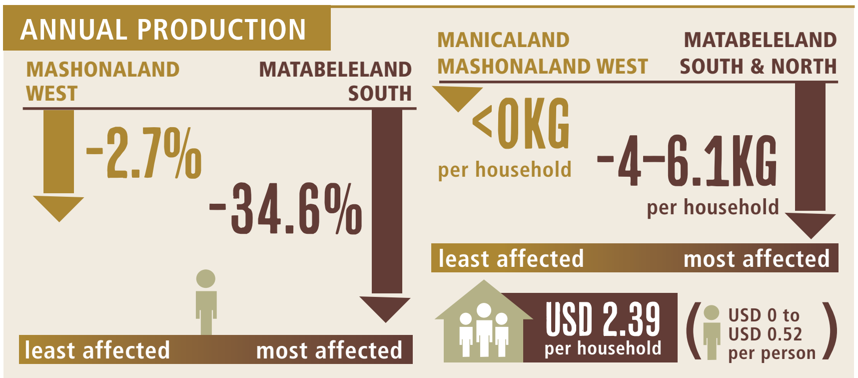
REGION	PRODUCTION AREA		ANNUAL PRODUCTION	
	TOTAL (HA)	% NATIONAL TOTAL	TOTAL (TONNES)	% NATIONAL TOTAL
Manicaland	322	0.3	16	0.1
Mashonaland Central	1,294	1.2	257	2.1
Mashonaland East	3,408	3.3	893	7.3
Mashonaland West	69	0.1	26	0.2
Masvingo	25,316	24.2	2,508	20.5
Matabeleland North	42,453	40.5	6,477	53.1
Matabeleland South	29,311	28.0	1,748	14.3
Midlands	2,623	2.5	284	2.3
Total	**104,796**		**12,209**	

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



HOUSEHOLD LEVEL IMPACTS

In terms of the potential change in production per capita, climate change will production from 2.7% in Mashonaland West up to 34.6% in Matabeleland South. At the household level, predicted losses of annual production of pearl millet range from negligible in Manicaland and Mashonaland West, up to 4–6.1 kg per household in Matabeleland South and North, respectively. In terms of replacement costs for lost production, the costs of reduced production of pearl millet are estimated to range from USD 0 to USD 0.52 per person, or, up to USD 2.39 per household[17].



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[16] Statistics were derived from 2015 data on the Zimstat website (http://www.zimstat.co.zw/agriculture-statistics), and summed for the following farm types: A1, A2, Communal Land and Old Resettlement Schemes. Figures exclude statistics from Harare and Bulawayo, which contribute a negligible amount to national crop totals.

[17] Market prices for pearl millet in the period October 2018 – February 2019 were derived from statistics reported on the Agri Universe website . Average market price was approximately USD 0.39 per kg

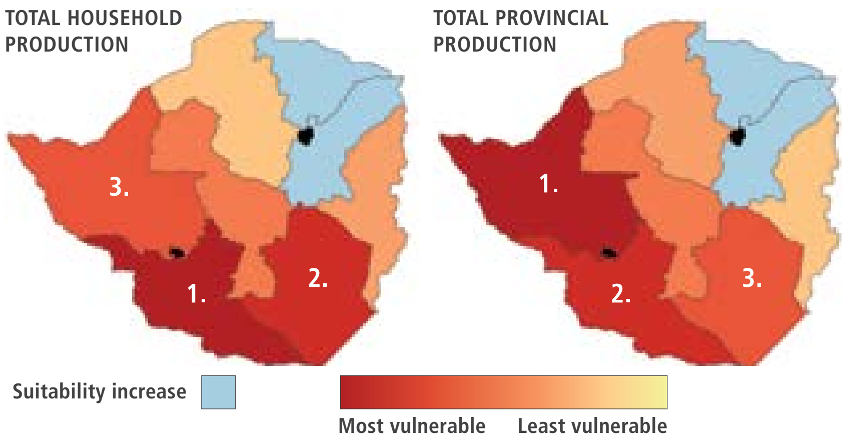
PROVINCE AND NATIONAL-LEVEL IMPACTS

At the province level, the predicted decreases in total annual production are lowest in Manicaland (negligible losses) and Mashonaland West (loss of 1 tonne per annum). The worst affected province of Matabeleland North is predicted to experience a decrease of 937 tonnes per annum. In total, the predicted decrease in production of pearl millet across all provinces is approximately 2,097 tonnes per annum, equivalent to an annual replacement cost of USD 818,000 per year. At the provincial scale, it is anticipated that the greatest costs for purchase of replacement millet will be incurred in Matabeleland North (USD 366,000), Matabeleland South (USD 236,000) and Masvingo (USD 206,000).

CLIMATE VULNERABLE PROVINCES AND HOUSEHOLDS

At the household level, the provinces that will experience the most severe negative impacts on %change to production per capita (i.e. decreased production relative to average historical production) are Matabeleland South (1), Masvingo (2) and Matabeleland North (3). At the provincial level, the most severe negative impacts on total production per Province are Matabeleland North (1), Matabeleland South (2) and Masvingo (3).

MOST VULNERABLE REGIONS, BASED ON CHANGES TO:



KEY FINDINGS AND RECOMMENDATIONS

Zimbabwe will likely experience minor negative impacts of climate change on millet.

The provinces of Matabeleland North, Matabeleland South and Masvingo are considered to be the most vulnerable to reduced millet production.

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

Millet 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: efforts to increase the demand and average prices paid for pearl millet and similar cereals, thereby improving 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

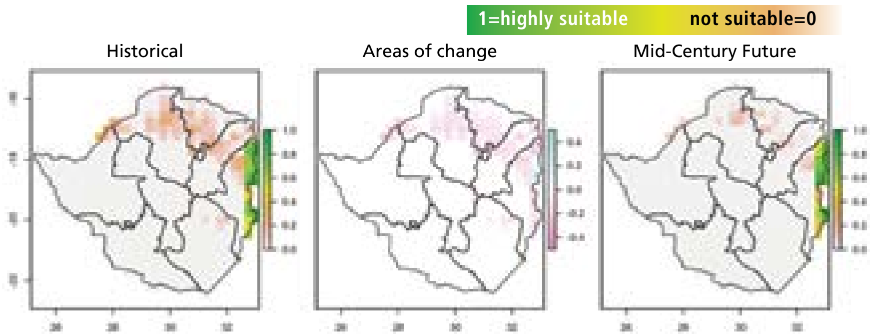
Sorghum is grown as a subsistence crop across most of Zimbabwe's provinces. It should be noted that EcoCrop analyses indicate that the baseline 'Historic' suitability of Zimbabwe for sorghum production appears to be very marginal or entirely unsuitable except for a narrow range coinciding with NR I, indicating that additional calibration of models are needed.

Analyses indicate that most provinces are projected to experience moderate to severe declines in total area suitable for sorghum production, ranging from -31.6 to -80%. Further, most provinces are predicted to undergo minor negative changes to the suitability index score, resulting in a decrease to productivity of -2.0 – 5%.

PRODUCTION OF SORGHUM IN ZIMBABWE[18].

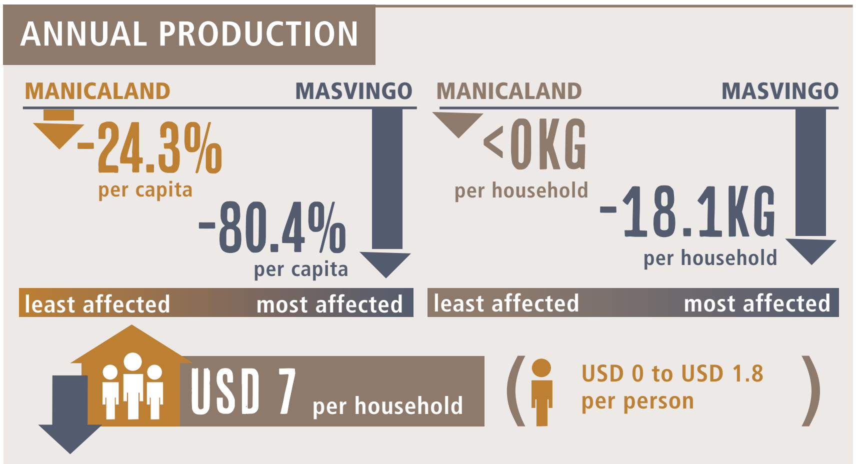
PROVINCE	PRODUCTION AREA		ANNUAL PRODUCTION	
	TOTAL (HA)	% NATIONAL TOTAL	TOTAL (TONNES)	% NATIONAL TOTAL
Manicaland	294	0.2	53	0.2
Mashonaland Central	21,472	17.4	8,779	27.6
Mashonaland East	18,849	15.3	8,196	25.7
Mashonaland West	3,076	2.5	1,204	3.8
Masvingo	32,582	26.5	2,563	8.0
Matabeleland North	14,199	11.5	2,448	7.7
Matabeleland South	18,711	15.2	4,079	12.8
Midlands	13,919	11.3	4,541	14.3
Total	**123,102**		**31,863**	

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



HOUSEHOLD LEVEL IMPACTS

In terms of negative impacts at the household level, the effect of climate change will be to reduce production from 24.3% in Manicaland up to 80.4% in Masvingo. At the household level, losses to annual production of sorghum are predicted to range from less than 0 to 18.1 kg per household. The costs of reduced production of sorghum are estimated to range from USD 0 to USD 1.8 per person, or, up to USD 7 per household[19].



[18] Statistics were derived from 2015 data on the Zimstat website (http://www.zimstat.co.zw/agriculture-statistics), and summed for the following farm types: A1, A2, Communal Land and Old Resettlement Schemes. Figures exclude statistics from Harare and Bulawayo, which contribute a negligible amount to national crop totals.

[19] Market prices for sorghum in the period October 2018 – February 2019 were derived from statistics reported on the Agri Universe website. Average market price was approximately USD 0.39 per kg

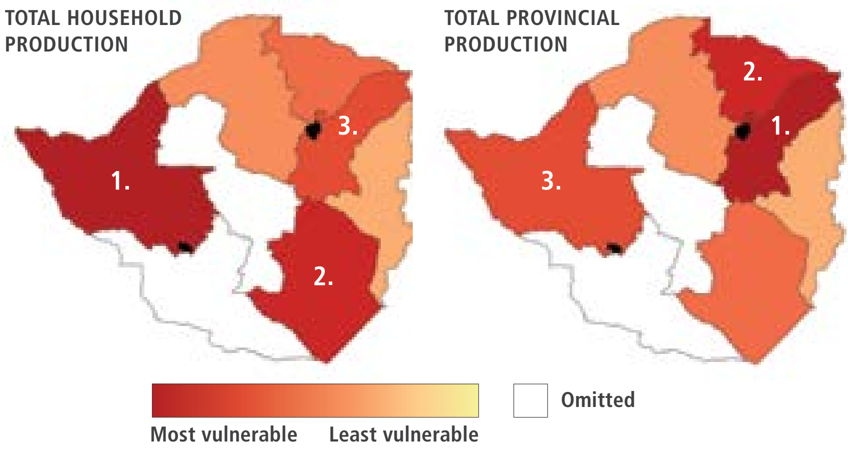
PROVINCE AND NATIONAL-LEVEL IMPACTS

At the provincial level, the predicted decreases in total annual production are lowest in Manicaland (annual loss of 13 tonnes). The worst affected provinces of Mashonaland Central and East are predicted to experience a decrease of 5,000 tonnes per annum each (equivalent to an annual replacement cost of USD 2.1 million per annum each). In total, the predicted decrease of production of sorghum across all provinces is approximately 15,000 tonnes per annum, resulting in total replacement costs of USD 6 million per year.

CLIMATE VULNERABLE PROVINCES AND HOUSEHOLDS

At the household level, the provinces that will experience the most severe negative impacts on %change to production per capita (i.e. decreased production relative to average historical production) are Matabeleland North (1), Masvingo (2) and Mashonaland East (3). At the provincial level, the most severe negative impacts on total production are Mashonaland East (1), Mashonaland Central(2) and Matabeleland North (3).

MOST VULNERABLE REGIONS, BASED ON CHANGES TO:



KEY FINDINGS AND RECOMMENDATIONS

Zimbabwe will likely experience minor to moderate decreases in production of sorghum as a result of climate change-related impacts on production.

The total lost production of sorghum as a result of climate change is estimated to be 15 000 tonnes per annum and is likely to result in increased costs for households to replace the lost production of staple food, estimated to be USD 6 million per year.

In some regions, sorghum is likely to become increasingly marginal or wholly unsuitable.

Recommended actions: investigate multiple cultivars as well as additional alternative cereals such as millet in order to identify the most locally appropriate combination of cereals for local climate conditions and farmer preferences.

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

The summarised findings above indicate that several important staple crops – notably maize, sorghum, groundnut and beans – 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. This may include specific strategies to safeguard the production of traditional staples and other crops, as well as broader measures to diversify agricultural income and food production in general (including development of water resources and irrigation infrastructure, strengthening of value chains and facilities for agro-processing, and increasing the resilience of the livestock production sector).

IRRIGATION AND WATER

One of the primary constraints to Zimbabwe's future food security is likely to be the reliability and volume of seasonal rainfall, particularly in the semi-arid Natural Regions 4 and 5. The erratic rainfall and droughts experienced in these provinces mean that access to irrigation is considered one of the few strategies to maintain the food security of subsistence farming households, in which crop production is already marginal and entirely reliant on rainfed production of a limited number of drought-tolerant staples. Irrespective of priorities related to promotion of irrigation, many districts are in urgent need of investments in infrastructure for management and supply of water resources for use by households, productive industry and agriculture, as well as to prevent or mitigate the impacts of flooding during heavy rainfall events.

A number of ongoing and planned initiatives intend to promote and expand the use of irrigation across the country. However, while the plans for irrigation expansion are developed at various scales (ranging from large-scale irrigation blocks, to establishment of village-level boreholes), there is an urgent need for continuous research and monitoring of surface- and ground-water sources to safeguard against unsustainable use. The projected long-term trends for rainfall predict a decrease of average annual rainfall of ~14-20% across all provinces and Natural Regions by mid-Century, which is likely to result in increasingly unpredictable inter-annual rainfall and reduced flow into surface rivers and storage dams. Consequently, the development and expansion of irrigation should be promoted with careful management of increasingly scarce water resources, with a strong emphasis on efficient irrigation techniques and rigorous measures to monitor surface waters and the volumes extracted for irrigation. The devolution of irrigation schemes to community- or farmer-based management structures requires sustained support and capacity-building to ensure that correct operation and maintenance of infrastructure can be financed and sustained. In consideration of the increasing likelihood that emerging or proposed irrigation schemes will face periodic disruptions or constraints as a result of droughts and reduced rainfall, the promotion of irrigation as a means of developing Zimbabwe's agricultural economy must always simultaneously include de-risking measures to diversify and strengthen other agricultural activities and livelihoods, including inter alia unirrigated crop production, small and large livestock production, value addition and processing etc.

LIVESTOCK PRODUCTION

Production of various species of livestock for meat, milk and eggs is widely practiced across the country as a supplementary or main source of income, most particularly in the arid Natural Regions 3, 4 and 5 where crop production is comparatively unreliable and marginal. Management of small numbers of livestock, including cattle for meat and dairy production, various goat species and poultry chickens, were noted as important contributors to income and food security within the mixed farming systems practiced in various districts. In semi-arid zones where rainfall is too low or erratic to reliably support productive subsistence farming, grazing of locally-adapted cattle is a comparatively resilient source of food and income. However, a factor which challenges the climate-resilience of livestock production is the widespread degradation of grazing resources, as a result of persistent overgrazing and the impact of droughts. An additional challenge is the likelihood of increased bush encroachment and a decline of preferred grazing species in favour of less palatable species, driven both by climate change as well as overgrazing and degradation of grazing lands. The limited availability of forage will reduce the overall health of the national herd, thereby increasing susceptibility to diseases and climate-related stresses.

The results of this study indicate that production of most cereal and pulses/legumes is likely to undergo minor or moderate decreases. This includes maize, beans and to a lesser degree other staples such groundnuts, cowpeas and pigeonpeas. The shortfall in national production of these crops will most likely be met by increased imports and rising prices, and consequently a shortage of affordable supplementary feed for livestock. Therefore, there is a need for supporting measures to increase the sustainability and climate-resilience of the livestock sector, particularly to safeguard against loss of animals during periods of drought or erratic rainfall. Indigenous pastures have a relatively low holding capacity, and most farmers are unfamiliar with, or unwilling to invest in, approaches to supplement free grazing with additional fodder (e.g. through purchase of supplementary feed or through establishment of fodder banks). The demonstration of supplementary fodder banks and other similar approaches to supplementing livestock feed during drought periods could be considered in appropriate livestock production areas. However, such approaches are only likely to succeed if supported by sensitisation training and farmer field days to encourage farmers to supplement livestock grazing with fodder banks, which are not widely recognised or practiced at present.

Farmers and extension workers are increasingly interested in the promotion of small livestock species as an alternative to cattle herding, as a result of the adaptable diets, small space requirements, and rapid return of income of small livestock. However, as a result of the continued degradation of grazing resources through sustained drought and intense grazing pressure, as well as the limited availability of drinking water, the promotion of small livestock (e.g. sheep, goats and pigs) and poultry may provide climate-resilient alternatives to production of cattle.

MAIZE

In the case of maize, analyses indicate that potential losses to annual production may be up to 227,000 tonnes, equivalent to a replacement cost to households of up to USD 89 million relative to current production levels and market prices.

The results strongly support the case for development and promotion of fast-growing, early-maturing varieties, allowing farmers to manage risks related to the timing of the onset and end of the rainy season (particularly by increasing the likelihood that a mature crop can be harvested in the event of a shorted or delayed rainy season). Access to certified, high-quality seeds is unreliable and variable between districts, particularly since local production of seeds has declined and access to imported seed is generally too expensive for smallscale subsistence farmers. The experiences of farmer managed seed production cooperatives such as Zimbabwe Super Seed may provide insights and lessons into the potential opportunities for production of high-quality seed as a means of increasing the income and climate-resilience of farming households.

The risk of reduced production of maize 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 millet and sorghum. 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. Multiple other barriers to agricultural production should be considered in the design of initiatives focused on production of maize and other subsistence crops, irrespective of climate change – for example, generic constraints such as limited access to inputs, insecurity of tenure and lack of access to finance.

BEANS

In the case of beans, the results indicate a moderate or severe reduction of production between the current baseline period and the mid-century future. At the province-level, the total reduction in annual production of beans is projected to range from 102 tonnes in Manicaland to 1113 tonnes in Mashonaland Central - the Provinces anticipated to be most negatively impacted by total reduced production at the household level include Matabeleland South, Mashonaland West and Mashonaland Central. In total, it is estimated that the annual production of beans across all provinces will be reduced by ~3300 tonnes. 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. 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.

GROUNDNUTS

In the case of groundnuts, climate change is predicted to result in mildly negative effects on production in the relatively high rainfall regions (e.g. Manicaland, Mashonland C, E & W), and relatively more severe impacts in the central and southern provinces (e.g. Matabeleland S and Masvingo). At the province-level, the total reduction in annual production of groundnuts is projected to range from 39 tonnes in Manicaland to 2156 tonnes in Masvingo. In total, it is estimated that the annual production of groundnuts across all provinces will be reduced by ~8500 tonnes.Despite this negative prediction, nevertheless it is anticipated that large expanses of Zimbabwe are likely to remain moderately suitable for groundnuts. The crop is nutritious, widely grown and eaten, and is compatible with a range of intercropping and mixed cropping systems – the beneficial impacts of legumes on soil fertility are widely appreciated by farmers and AGRITEX extension workers.

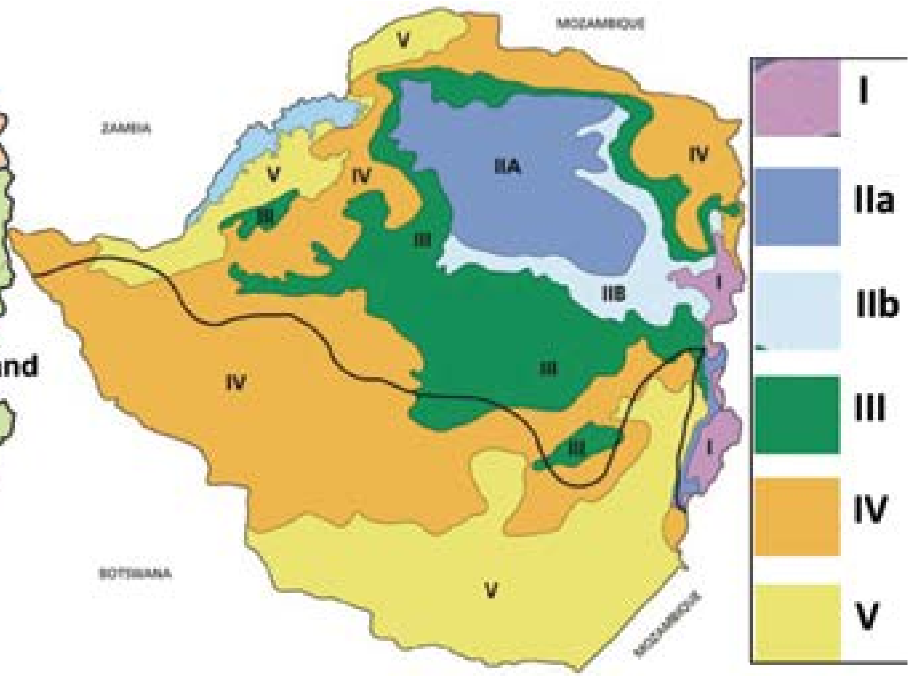
One of the main barriers to the increased production of groundnuts by farmers is reportedly the limited availability of good-quality, certified seeds. In addition, the limited access to adequate facilities for processing and drying results in challenges related to management of aflatoxin – contamination by the latter fungus not only results in spoilage of a proportion of annual production but also is a barrier to accessing formal commodity and export markets.

It is recommended that future initiatives aiming to increase the climate change resilience and food security of Zimbabwe's farmers should consider the feasibility of establishing modern facilities and a supporting value chain for post-harvest processing and value addition of groundnuts. This may include the feasibility of processing groundnuts into a shelf-stable cooking oil as means of reducing waste and spoilage, in addition to providing farmers with potential sources of income. Finally, farmers will benefit from continued capacity building and training to control pests and diseases of groundnuts such as the groundnut leafminer, as well as post-harvest management and processing of groundnuts.

APPENDIX SECTION

APPENDIX FIGURE 1

MAP OF ZIMBABWE'S PROVINCES AND AGRO-ECOLOGICAL REGIONS



APPENDIX TABLE A.1.

SUMMARISED ADAPTIVE CAPACITY (AC) INDICATORS COLLECTED FOR ALL PROVINCES OF ZIMBABWE[20]

Indicator category	Adaptive capacity indicators	Manicaland	Mashonaland Central	Mashonaland East	Mashonaland West	Masvingo	Matabeleland North	Matabeleland South	Midlands
Adoption of improved agricultural practices	Investment in irrigation works (USD per farming household member)	1.48	0.62	1.31	16.47	0.66	0.04	0.42	0.44
	Land improvement and conservation (USD per farming household member)	0.63	0.55	0.8	0.39	0.93	1.07	0.33	1.04
	Value of agricultural inputs (USD per farming household member)	10.84	20.11	17.32	31.76	2.54	0.57	1.11	4.36
	Farms receiving loans	2092	6694	1428	4088	3046	481	121	6344
Access to agricultural information	Households with a mobile telephone (%)	13.9	8.3	10.5	10.2	11.3	4.5	5	10.7
Education	% Literacy rate (15+)	94	91	94	93	93	91	95	95

[20] Derived from 2015 figures reported by Zimbabwe National Statistics Agency, www.zimstat.co.zw

APPENDIX TABLE A.2. A

PROJECTED INFLUENCE OF CLIMATE CHANGE ON MEAN MONTHLY PRECIPITATION (MM/MONTH) IN THE PROVINCES OF ZIMBABWE (A. BULAWAYO-MASHONALAND EAST; B. MASHONALAND WEST -MIDLANDS) 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	
BULAWAYO	Historical	117.4	100.3	62.5	30.6	5.5	3.0	1.8	1.0	6.0	32.1	91.1	106.8	**558.1**
	Future	103.0	85.7	49.4	21.1	3.2	1.6	1.1	0.6	2.1	16.2	65.9	97.9	**447.8**
	Anomaly	*-14.4*	*-14.6*	*-13.0*	*-9.5*	*-2.3*	*-1.4*	*-0.7*	*-0.4*	*-3.9*	*-15.9*	*-25.1*	*-8.9*	***-110.1***
HARARE	Historical	183.0	145.9	101.8	32.9	7.6	2.7	1.8	2.9	6.2	33.1	78.7	164.1	**760.7**
	Future	170.3	138.7	91.0	22.9	4.8	1.8	1.2	1.9	2.5	11.8	54.1	149.4	**650.4**
	Anomaly	*-12.6*	*-7.2*	*-10.8*	*-10.1*	*-2.7*	*-0.9*	*-0.6*	*-1.0*	*-3.7*	*-21.3*	*-24.7*	*-14.8*	***-110.4***
MANICALAND	Historical	176.7	157.6	93.6	35.9	12.6	7.9	9.6	6.3	12.3	35.4	85.1	159.4	**792.4**
	Future	162.5	147.8	83.3	27.4	8.8	5.4	7.3	4.9	6.1	14.9	61.3	144.7	**674.4**
	Anomaly	*-14.2*	*-9.8*	*-10.3*	*-8.5*	*-3.8*	*-2.4*	*-2.2*	*-1.4*	*-6.1*	*-20.4*	*-23.8*	*-14.7*	***-117.6***
MASHONALAND CENTRAL	Historical	198.0	165.4	102.1	25.4	6.1	1.7	1.2	1.4	2.9	18.0	66.1	166.5	**754.8**
	Future	184.1	159.3	90.9	17.6	3.9	1.2	0.9	1.1	1.4	6.8	45.3	153.2	**665.7**
	Anomaly	*-13.9*	*-6.1*	*-11.2*	*-7.8*	*-2.3*	*-0.5*	*-0.3*	*-0.3*	*-1.5*	*-11.2*	*-20.8*	*-13.3*	***-89.2***
MASHONALAND EAST	Historical	179.3	146.6	87.2	28.6	7.6	4.6	4.1	4.0	6.8	29.3	77.8	160.1	**736**
	Future	166.1	137.2	77.1	20.7	4.9	3.1	2.9	2.9	2.8	11.1	55.1	146.9	**630.8**
	Anomaly	*-13.3*	*-9.4*	*-10.2*	*-7.9*	*-2.7*	*-1.5*	*-1.2*	*-1.1*	*-3.9*	*-18.1*	*-22.7*	*-13.1*	***-105.1***

APPENDIX TABLE A.2. B

mm/month		MONTH												TOTAL
		J	F	M	A	M	J	J	A	S	O	N	D	
MASHONALAND WEST	Historical	178.3	152.2	96.8	26.8	5.9	1.8	1.2	1.5	3.5	21.6	74.1	149.9	**713.6**
	Future	166.3	143.3	83.1	18.1	3.1	1.1	0.8	1.1	1.4	8.0	51.6	136.9	**614.8**
	Anomaly	*-12.0*	*-8.9*	*-13.8*	*-8.7*	*-2.8*	*-0.6*	*-0.3*	*-0.4*	*-2.1*	*-13.7*	*-22.5*	*-13.0*	***-98.8***
MASVINGO	Historical	105.3	102.3	54.0	24.1	10.0	6.1	5.6	3.8	11.3	24.1	70.0	101.0	**517.6**
	Future	96.5	93.3	45.1	18.6	6.9	3.8	4.2	2.8	5.9	11.4	54.0	93.2	**435.7**
	Anomaly	*-8.9*	*-9.0*	*-8.9*	*-5.5*	*-3.1*	*-2.4*	*-1.5*	*-1.0*	*-5.4*	*-12.6*	*-16.0*	*-7.8*	***-82.1***
MATABELELAND NORTH	Historical	139.1	119.1	71.6	24.2	4.2	2.1	0.6	0.7	4.0	22.3	71.7	120.2	**579.8**
	Future	126.0	103.5	56.6	17.0	2.3	1.3	0.4	0.6	1.3	10.2	52.8	110.6	**482.6**
	Anomaly	*-13.1*	*-15.5*	*-14.9*	*-7.3*	*-1.9*	*-0.8*	*-0.2*	*-0.1*	*-2.7*	*-12.1*	*-18.9*	*-9.6*	***-97.1***
MATABELELAND SOUTH	Historical	88.2	77.9	48.1	22.0	5.3	3.8	2.0	1.2	6.5	23.7	71.9	81.9	**432.5**
	Future	79.0	67.9	38.3	15.6	3.4	2.2	1.4	0.8	2.9	11.9	53.7	75.7	**352.8**
	Anomaly	*-9.1*	*-10.0*	*-9.8*	*-6.4*	*-1.9*	*-1.6*	*-0.5*	*-0.4*	*-3.7*	*-11.8*	*-18.2*	*-6.2*	***-79.6***
MIDLANDS	Historical	140.9	123.1	70.2	27.3	5.9	3.5	2.1	1.9	6.1	25.2	80.0	129.2	**615.4**
	Future	130.1	110.9	57.5	19.1	3.4	2.1	1.4	1.3	2.5	10.3	59.8	119.8	**518.2**
	Anomaly	*-10.9*	*-12.2*	*-12.7*	*-8.2*	*-2.6*	*-1.4*	*-0.6*	*-0.6*	*-3.6*	*-14.9*	*-20.2*	*-9.4*	***-97.3***

APPENDIX TABLE A.3. A

PROJECTED INFLUENCE OF CLIMATE CHANGE ON MEAN MONTHLY TEMPERATURE (°C) IN THE PROVINCES OF ZIMBABWE (A. BULAWAYO-MASHONALAND EAST; B. MASHONALAND WEST -MIDLANDS) 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**
BULAWAYO	Historical (°C)	22.9	22.6	22.1	20.4	17.8	15.3	15.0	17.7	21.2	23.2	23.3	22.9
	Future (°C)	24.8	24.5	23.9	22.6	20.1	17.5	17.2	19.6	23.4	26.1	25.9	24.9
	Anomaly (°C)	*1.9*	*1.9*	*1.8*	*2.2*	*2.3*	*2.1*	*2.2*	*1.9*	*2.2*	*2.9*	*2.7*	*2.1*
HARARE	Historical (°C)	22.1	21.8	21.3	19.6	17.2	15.0	14.7	16.7	20.0	22.0	22.7	22.0
	Future (°C)	23.9	23.7	23.1	21.6	19.3	17.0	16.8	18.5	22.1	24.7	25.3	24.2
	Anomaly (°C)	*1.8*	*1.9*	*1.8*	*2*	*2.1*	*2*	*2.1*	*1.8*	*2.1*	*2.7*	*2.6*	*2.2*
MANICALAND	Historical (°C)	23.7	23.4	22.8	21.1	19.0	16.7	16.4	18.3	21.2	23.1	24.0	23.5
	Future (°C)	25.5	25.2	24.6	23.0	21.1	18.7	18.5	20.1	23.2	25.7	26.6	25.5
	Anomaly (°C)	*1.8*	*1.8*	*1.8*	*1.9*	*2.1*	*2.0*	*2.1*	*1.8*	*2.0*	*2.6*	*2.5*	*2.0*
MASHONALAND CENTRAL	Historical (°C)	24.3	24.1	23.8	22.3	20.1	17.9	17.6	19.6	22.9	25.3	25.8	24.4
	Future (°C)	26.2	25.9	25.6	24.3	22.3	19.9	19.8	21.4	24.9	27.9	28.4	26.5
	Anomaly (°C)	*1.8*	*1.8*	*1.9*	*2.0*	*2.2*	*2.0*	*2.1*	*1.8*	*2.0*	*2.6*	*2.6*	*2.1*
MASHONALAND EAST	Historical (°C)	23.2	23.0	22.4	20.9	18.6	16.4	16.0	18.0	21.1	23.2	23.8	23.1
	Future (°C)	25.0	24.8	24.2	22.8	20.7	18.4	18.2	19.8	23.1	25.8	26.4	25.2
	Anomaly (°C)	*1.8*	*1.8*	*1.8*	*2.0*	*2.1*	*2.0*	*2.1*	*1.8*	*2.0*	*2.7*	*2.6*	*2.1*

APPENDIX TABLE A.3. B

PROJECTED INFLUENCE OF CLIMATE CHANGE ON MEAN MONTHLY TEMPERATURE (°C) IN THE PROVINCES OF ZIMBABWE (A. BULAWAYO-MASHONALAND EAST; B. MASHONALAND WEST -MIDLANDS) 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
MASHONALAND WEST	Historical (°C)	24.6	24.3	24.0	22.8	20.5	18.2	18.0	20.3	24.1	26.3	26.4	24.8
	Future (°C)	26.4	26.1	25.9	24.9	22.7	20.2	20.2	22.2	26.1	29.0	29.1	26.9
	Anomaly (°C)	*1.8*	*1.8*	*1.9*	*2.1*	*2.2*	*2.0*	*2.2*	*1.9*	*2.1*	*2.7*	*2.7*	*2.1*
MASVINGO	Historical (°C)	25.8	25.4	24.5	22.6	19.9	17.3	17.0	19.1	22.2	24.3	25.4	25.6
	Future (°C)	27.7	27.2	26.3	24.7	21.9	19.4	19.2	20.9	24.2	27.1	27.9	27.5
	Anomaly (°C)	*1.9*	*1.8*	*1.8*	*2.0*	*2.1*	*2.1*	*2.2*	*1.8*	*2.1*	*2.8*	*2.5*	*1.9*
MATABELELAND NORTH	Historical (°C)	24.8	24.5	24.2	22.8	20.0	17.3	17.1	20.0	23.9	26.3	26.3	25.2
	Future (°C)	26.7	26.4	26.2	25.1	22.3	19.5	19.3	21.8	26.1	29.1	29.0	27.3
	Anomaly (°C)	*1.9*	*1.9*	*2.0*	*2.2*	*2.3*	*2.2*	*2.2*	*1.9*	*2.2*	*2.8*	*2.7*	*2.1*
MATABELELAND SOUTH	Historical (°C)	25.6	25.2	24.4	22.4	19.4	16.7	16.3	19.0	22.5	24.7	25.4	25.4
	Future (°C)	27.5	27.0	26.3	24.6	21.6	18.8	18.5	20.9	24.6	27.5	27.9	27.4
	Anomaly (°C)	*1.9*	*1.8*	*1.9*	*2.2*	*2.1*	*2.1*	*2.2*	*1.9*	*2.1*	*2.9*	*2.5*	*2.0*
MIDLANDS	Historical (°C)	24.2	23.8	23.3	21.8	19.2	16.7	16.5	19.0	22.5	24.7	25.0	24.3
	Future (°C)	26.1	25.7	25.1	23.9	21.4	18.8	18.7	20.8	24.7	27.5	27.7	26.3
	Anomaly (°C)	*1.9*	*1.9*	*1.8*	*2.1*	*2.2*	*2.1*	*2.2*	*1.8*	*2.1*	*2.8*	*2.7*	*2.0*