

Climate Change and Variability in Southeast Zimbabwe: Scenarios and Societal Opportunities

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ABSTRACT

A lot of researches have been done on the negative impacts and challenges caused by extreme weather conditions due to climate change and variability. Not many researches have been focused on the positive side in form of opportunities presented due to climate change. The study aimed to show the climate change scenarios and explore possible opportunities that could be derived from such scenarios in the southeastern region of Zimbabwe. The research used climate data records from three Zimbabwe Meteorological Services Department run weather stations in the region. The time series data were analyzed to show trends of rainfall and temperature over time. A questionnaire survey was also carried out to enquire from the farmers if they perceived climate change to have any opportunities. The rainfall trend analysis showed that rainfall amounts have declined at two of the three stations used. Rainfall total was also shown to be variable from year to year at all the stations. Ambient temperatures at all the stations were shown to have increased for both winter and summer. Opportunities that could be derived from climate change in the region were identified as the hydrological, agricultural and industrial. The research concludes that taking advantages of opportunities offered by climate change and variability provides the quickest way of embracing climate change adaptation.

Keywords: Opportunities; Climate Change; Climate Variability; Adaptation; Rainfall; Temperature; Southeast Zimbabwe and Masvingo Region

1. Introduction

The occurrence of climate change in Zimbabwe and all over the world is no longer debatable [1,2]. Recent reports produced by the Intergovernmental Panel on Climate Change (IPCC) conclude not only that green-house gas emissions are already beginning to change the global climate, but also that Africa will experience increased water stress, decreased yields from rain-fed agriculture, increased food insecurity and malnutrition, sea level rise, and an increase in arid and semi-arid land as a result of this process [3]. Extreme weather events, notably floods, droughts and tropical storms are also expected to increase in frequency and intensity across the continent. These projections are consistent with recent climatic trends in southern Africa, including Zimbabwe. The effects of this exposure to changes in climate are exacerbated by the high levels of sensitivity of the social and ecological systems in the region, and the limited capacity of civil society, private sector and government actors to respond appropriately to these threats [2].

Zimbabwe is particularly vulnerable to climate change

due to its heavy dependence on rain-fed agriculture and climate sensitive resources [4]. Agriculture's sensitivity to climate induced water stress is likely to intensify the existing problems of declining agricultural outputs, declining economic productivity, poverty and food insecurity, with smallholder farmers particularly affected. Extreme weather events, notably drought, flood and tropical storms, are also likely to threaten development gains across a variety of sectors and intensify existing natural hazard burdens for the vulnerable populations in both rural and urban areas [5]. Consequently, climate change presents risks to lives and livelihoods at the individual level and to the economy and infrastructure at the regional and national levels and impacts on the ability to achieve sustainable development [6]. Climate change adaptation is therefore a principal development challenge in Zimbabwe.

The potential societal consequences of climate change over time in Zimbabwe are clearly game-changing. Adapting to a changing climate ought to be viewed as a business and development opportunity. While the threat posed

by climate change through droughts, cyclones, heat waves and other severe weather events seem overwhelming, it presents unique opportunities for innovation, development and employment creation. To reduce the economic and social impact of climate change in Zimbabwe the focus has to be on adaptation to the changes that are necessary to thrive in changing climatic conditions. Adaptation to climate resilient smart initiatives such as reforestation, renewable energy use, recycled water for agriculture, rainwater harvesting, water use efficiency, and improved environmental planning and enforcement requires funding and implementation and should be promoted to provide opportunities to market innovations, generate employment and build climate resilient communities [4, 6].

Investment in alternative environmental practices that are resilient to climate change, will not only address the challenges presented by the climate change crisis, will but also help the economy, which is currently beset by high rates of unemployment and a growing debt to GDP ratio [6].

It is against this background that there is now a realisation that climate change opportunities to affected communities can be exploited to help adaptation [7]. Research has shifted to concentrating on the opportunities and potentialities that could be derived from extreme weather events [8]. What is now important is to focus on how people can sustain their livelihoods in the face of climate change and variability [9].

The major objective of this study is therefore to focus on the positives that can be exploited by farmers as a result of climate change. Specifically, the study analyses the climate change scenarios for south eastern Zimbabwe. Secondly the opportunities offered by these climate change scenarios to local farmers will also be explored.

1.1. Study Area

The area of study comprises the whole southeastern parts of Zimbabwe were mainly Masvingo province is located. The region is found in the south-eastern parts of Zimbabwe comprising of seven districts Bikita, Chiredzi, Chivi, Gutu, Masvingo, Mwenezi and Zaka. The region is 56,566 km² in area with a total population of 1,318,705 of which 616,243 are male and 702,462 are female [10-12]. The main economic activities in the region include farming of mainly maize, groundnuts, roundnuts and small grains, commercial sugar plantation agriculture at Hippo Valley and Triangle Estates, cattle ranching and animal, tourism and a bit of mining [11]. The drainage of the region is dominated by the Save, Runde, Mwenezi, Mutirikwi, Tokwe and Limpopo Rivers [12]. The region has a number of dammed rivers which pass through it as it straddles the Save-Limpopo Catchment. The countryside is dotted by kopjes, hills and mountain ranges. The area is

dominated mostly by sandy soils and the rich basaltic soils of the South Eastern Lowveld. Miombo woodlands dominate the wetter parts while Mopani trees, which are drought tolerant and sturdy, are found throughout the region. **Figure 1** shows the study area of the research.

1.2. Climate of Southeastern Zimbabwe

The region is located in the south-east low veld of the country where rainfall is minimal and uncertain. The southern parts of the region are drought prone and occur in agro-ecological region 5 of Zimbabwe’s climatic regions. The area receives an average of 620 mm of rainfall per annum and average potential evapo-transpiration between 600 - 1000mm which by far exceeds the available water supply. The area has got an aridity index of between 0.2 - 0.5 and means that the region is semi-arid. **Figure 2** shows the average temperature of the region [11,13].

The average temperature of southeastern Zimbabwe is 19.4°C. The range of average monthly temperatures is 9.5°C. The warmest average max temperature is 34°C in October. The coolest average min temperature is 5°C in July. Temperatures in parts of southeastern Zimbabwe, especially Chiredzi have risen by 0.6°C since 1966 [9, 14]. Both the maximum and the minimum temperatures

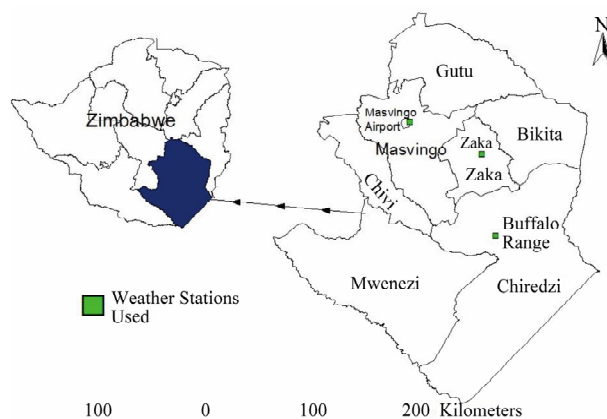


Figure 1. Southeastern Zimbabwe showing the surface water characteristics within the districts of the region.

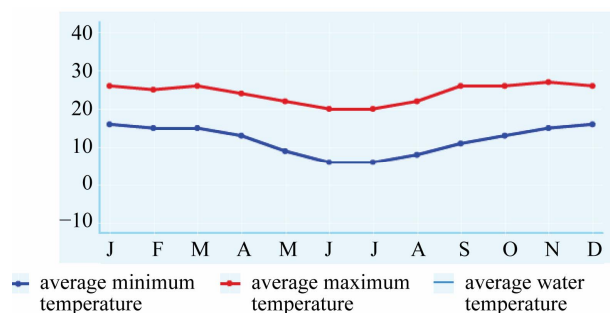


Figure 2. Average temperatures of southeastern Zimbabwe.

have increased. In some instances the temperature increase has surpassed the average global temperature increase of 0.4°C [6,15]. Tentatively while the summer temperatures have become warmer the winters have also become warmer. **Table 1** shows the relative humidity, hours of sunshine and precipitation of southeastern Zimbabwe.

Southeastern Zimbabwe receives on average 622 mm of precipitation annually or 52 mm each month. On average there are 75 days annually on which greater than 0.1 mm of precipitation occurs or 6.3 days on an average month. The month with the driest weather is July when on balance 1 mm of rain, drizzle and hail falls across 2 days. The month with the wettest weather is December when on balance 153 mm of rain, sleet and hail falls across 13 days [11].

Rainfall variability has become markedly wide in the country. The onset of the rains has been changing with the rains coming in late most of the times [2]. The dry spells are also increasing and this is having profound impact on the crop production rhythm of the area [10]. The cessation of rainfall is also unpredictable with rainfall periods extending into June and July and sometimes ending much earlier in March. The frequency and magnitude of flooding has also increased perhaps due to increasing frequency of land falling tropical cyclones within the Save-Limpopo Basin [11,14]. Even though these floods might appear to be far apart water logging conditions have tended to reduce the harvest in the area [14,15]. Despite, the seasonal variability in rainfall in southeastern Zimbabwe, it was realised that the average rainfall amount for the area has not changed significantly [15].

Mean relative humidity for an average year is recorded as 41.7% and on a monthly basis it ranges from 27% in September to 55% in February. Hours of sunshine range between 6.7 hours per day in January and 9.1 hours per day in September. On balance there are 2991 sunshine hours annually and approximately 8.2 sunlight hours for each day [11-12].

2. Research Materials and Methods

2.1. Materials Used

- 1) Daily climatic data for Masvingo Airport; Zaka and Buffalo Range stations.
- 2) Questionnaires.

- 3) GPS Handsets.
- 4) Statistical Package for Social Scientists (SPSS).
- 5) Arcview GIS.

2.2. Methods

This study is a result of a combination of data collection procedures and analysis. Data on the climate change scenarios in southeastern Zimbabwe was mainly obtained from daily climatic records of the Zimbabwe Meteorological Services Department (ZMSD). Daily rainfall and temperature data were obtained for three principal weather stations in southeastern Zimbabwe which are: Buffalo Range, Masvingo Airport and Zaka.

The weather stations provided weather data between 1900 to 2011. The data needed to be extended for a period of more than 30 years in order to be usable. This was meant to enable the determination of climatic variability and change in terms of rainfall and temperature. Similarly, climate change data need to cover a long period of time so that weather extremes can be determined for a number of stations. The climatic scenarios for each individual station were then derived and analysed as time series trend analysis.

A questionnaire survey was carried out in southeastern Zimbabwe to capture the views and perceptions of regions households on issues of climate change and variability. Households selected to take part in the survey were randomly chosen using the Arcview GIS random points generator points. A total of 200 points were generated and questionnaires administered. Global Positioning Systems (GPS) receivers were then used to navigate to the selected points.

Purposive sampling targeting the elderly of about 60 years and above was also used. The elderly were targeted because they would be in a position to make significantly reliable comparisons with past climate swings [16,17]. The questionnaire was targeting the household head. In the absence such persons the second influential person in the household was considered. However, in some cases informed males and females of twenty years and above in age were also considered suitable. The questionnaire dealt with the views and perceptions of households on environmental and climate change issues. Further, respondents were probed whether climate change has led to changes in livelihood systems for better or for worse.

Focus group discussions (FGD) were held to obtain

Table 1. Shows the relative humidity, hours of sunshine and precipitation of southeastern Zimbabwe.

	J	F	M	A	M	J	J	A	S	O	N	D
Relative humidity	75	87	83	76	71	69	68	56	49	50	63	74
Rainfall sum	143	136	78	23	8	3	3	3	8	28	101	160
Rainfall days	14	22	16	6	5	3	4	2	4	5	13	16

more information on the views of men and women on climate change and variability and possible adaptation measures. The first FGD was held at Chief Nemamwa’s Homestead in Masvingo Rural District. The focus group consisted of eight men and eight women. The second FGD was held in Matibi 2 Area close to Gonarezhou National Park. In Matibi 2 Area the focus group consisted of the male chief, village headman, eight men and seven women. The age groups of the focus group participants were varied to capture the interests of everyone in the communities. The FDGs were used to identify the opportunities offered by climate change in southeastern Zimbabwe. In addition the exercise presented an opportunity to identify adaptation measures related to opportunities in the region.

Key informants at institutions with specialised knowledge on climate change were used in the study. These included chief researchers at Research Stations in, Agricultural Research and Extension (AREX) officers, community development officers from non-governmental organisations working on climate change issues in southeastern Zimbabwe were also interviewed. ZMSD officers also had an input into the study. Key informants helped in the provision of informed assessment of the role that could be played by exploitation of climate change opportunities and food availability in the region.

The questionnaires were then checked for completeness and other data quality related issues before being coded and entered in SPSS for further statistics exploration and analysis.

3. Results

3.1. Climate Scenarios for Southeastern Zimbabwe

The long-term climate scenarios for southeastern Zimbabwe show declining rainfall amounts and increasing temperatures. The rainfall amounts received in the region over time as compared to the national average rainfalls received over time are shown on **Figure 3**. **Figure 3** shows that there is decline in both the National and southeastern Zimbabwe rainfall totals over time, however the annual rate of rainfall decline for region is lower than the national decline figure.

Figure 3 shows that starting from the 1960s to the 2010s there were marked variations in the precipitation pattern southeastern Zimbabwe. The years with extreme above normal rainfall were 1973/74, 1977/78 and 1999/2000 and this were replicated country wide. Years with extreme below normal rainfall were numerous and dominant in 1963/64, 1967/68, 1972/73, 1982/83, 1986/87 and 1991/92. There is a noticeable increase in departure from normal between 1960 and 1990 and the 1991/92 was the season of extreme drought for southeastern Zimbabwe and the southern African region.

Figure 4(a) shows the time series of rainfall at Zaka station in southeastern Zimbabwe. Rainfall over Zaka shows a fluctuating trend about the mean from year to year, however there is a marked increase in the magnitude of years of below average rainfall since 1980. Year of above normal rainfall have also declined but occa-

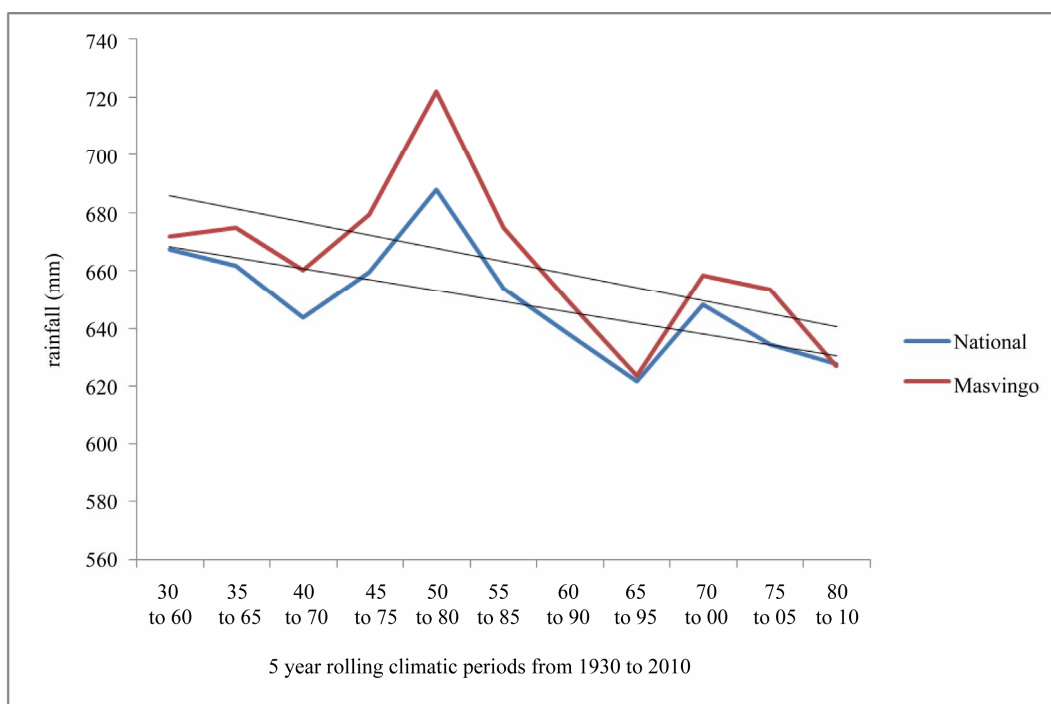
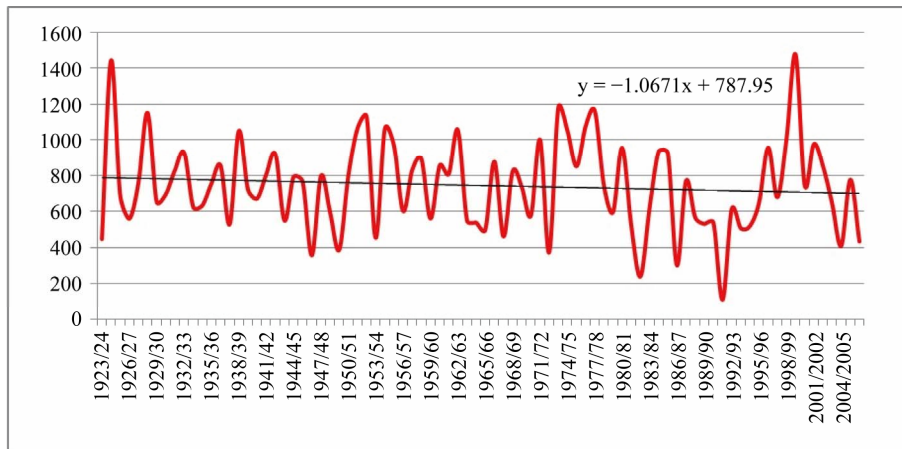
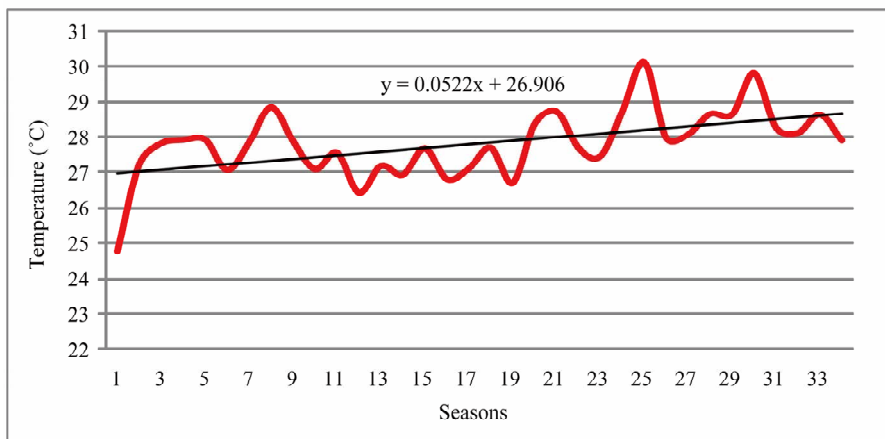


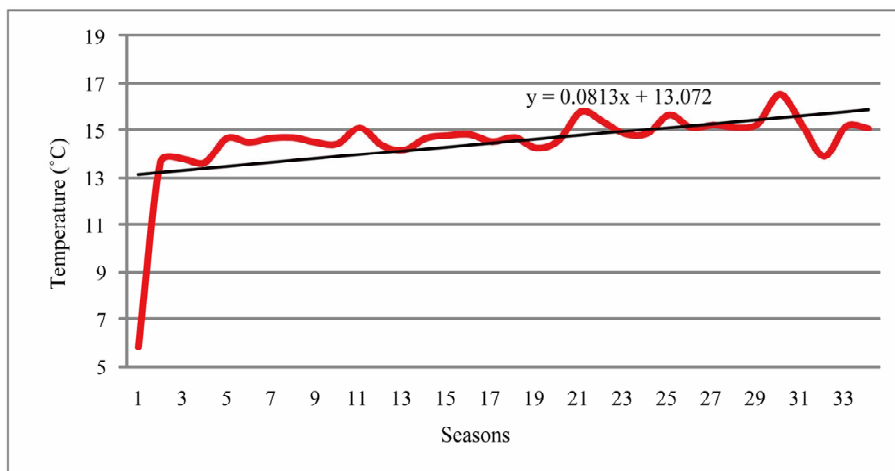
Figure 3. The national and southeastern Zimbabwe average rainfall for 30 years climatic periods from 1930-2010.



(a)



(b)



(c)

Figure 4. (a) Longterm rainfall trend scenerio for Zaka station; (b) Longterm maximum temperatures for Zaka; (c) Longterm minimum temperatures for Zaka.

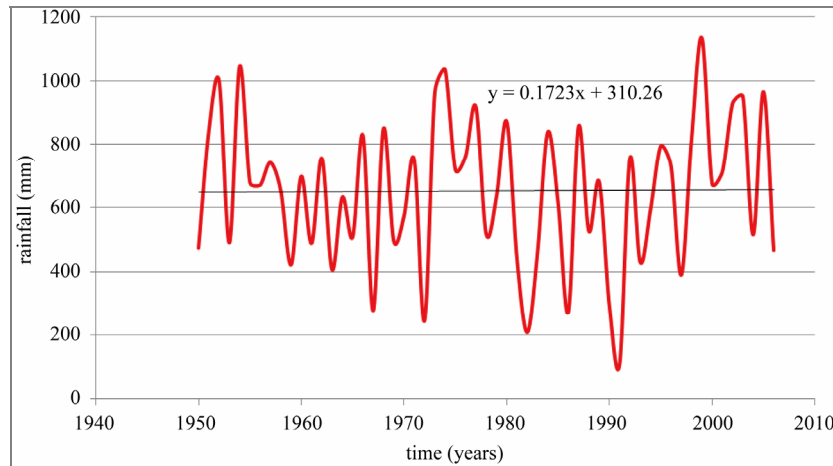
sional occurrence of extreme rainfall events above 1400 mm is also shown on the rainfall trend (**Figure 4(a)**). On average rainfall shows a declining trend at Zaka station as shown by the negative trend line equation on **Figure**

4(a).

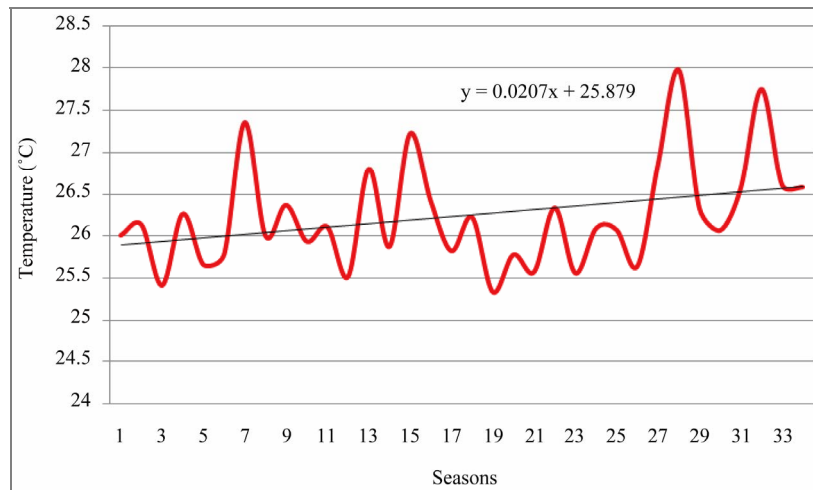
Figures 4(b) and **(c)** show that both mean summer and mean winter temperatures have increased over the past 33 seasons at Zaka stations. It is mainly the summer

temperatures that have increased by an average of almost 2°C. Winter temperatures have increased steadily by almost 1.5°C over the past 33 years.

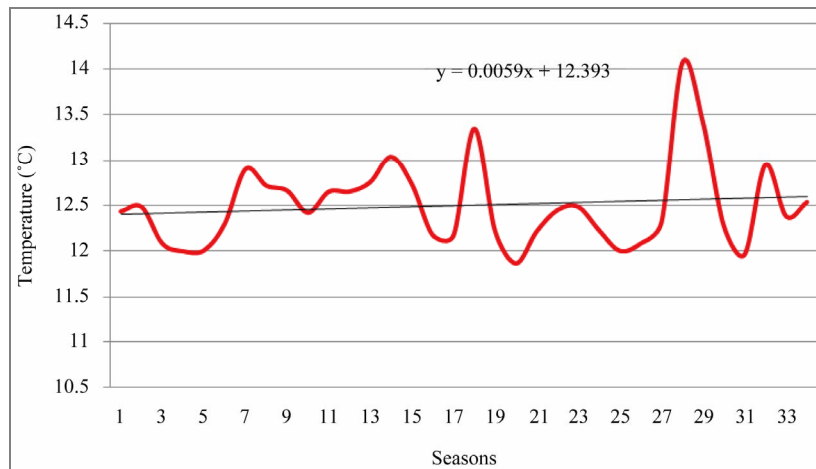
Figure 5(a) shows the rainfall trend of Masvingo Airport station from 1950-1980. The rainfall pattern shows a fluctuating pattern from year to year but with more inci-



(a)



(b)



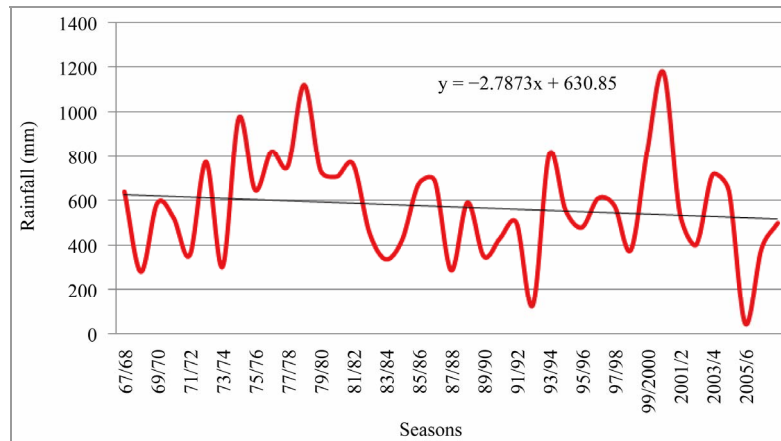
(c)

Figure 5. (a) Longterm rainfall trend scenerio for Masvingo station; (b) Longterm maximum temperatures for Masvingo; (c) Longterm minimum temperatures for Masvingo.

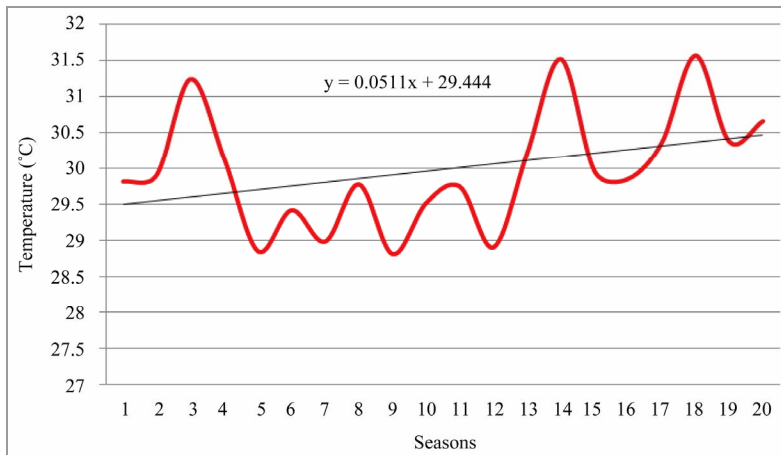
dents of below normal rainfall than above normal. The trend also shows that seasons of extreme sudden peak of above normal rainfall occur occasionally. On average, the rainfall pattern of Masvingo Airport station has remained more or less constant with just a marginal increase as shown by the positive trend line on **Figure 5(a)**.

Figures 5(b) and **(c)** show that both summer and winter temperatures have been on the increase especially the summer temperatures that have gone up by an average of 0.5°C over the past 33 seasons. Winter temperatures have only marginally increased by less than 0.01°C .

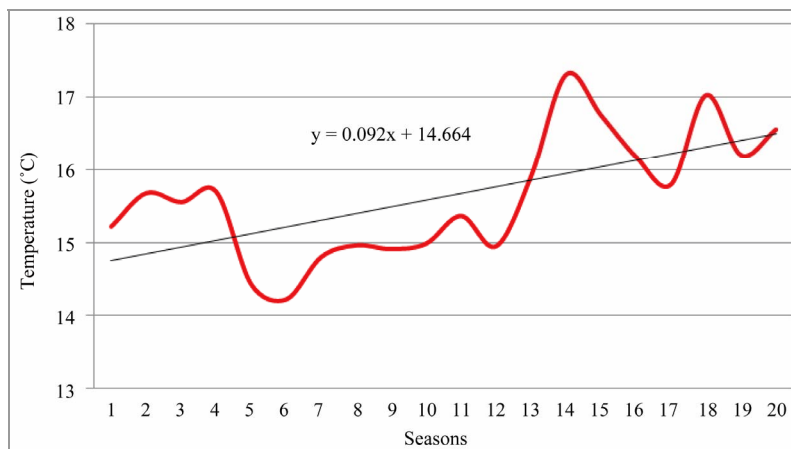
Figure 6(a) shows the rainfall trend for Buffalo Range



(a)



(b)



(c)

Figure 6. (a) Longterm rainfall trend scenerio for Buffalo Range station; (b) Longterm maximum temperatures Buffalo Range; (c) Longterm minimum temperatures for Buffalo Range.

Airport in Chiredzi District. The trend shows declining rainfall totals for the station over time as shown by the negative trend line and a tendency to have occasional high peak rainfall events. The station trend also shows that the years of below normal rainfall are now frequently occurring more than those of above normal.

Figures 6(b) and (c) show the long-term trends of minimum and maximum temperature for Buffalo Range station. The figure shows that both summer and winter temperatures are on the increase. Maximum temperatures have gone up by an average of 1°C from an average of about 29.5°C to an average of 30.5°C. Figure 6(b) also shows that winter temperatures have increased by about 1.5°C from an average close to 15°C to about 16.5°C.

Table 2 shows aspects of seasonal rainfall change and variability as perceived by farmers in southeastern Zimbabwe.

The major area of concern for southeastern Zimbabwe is the occurrence of drought at seasonal level. About 32% of the respondents were worried about the end of season drought which would normally wipe away their produce when they would be expectant of a better yield at the same time the season would have looked promising. About 26% of the responses were worried about the mid season drought which would normally occur at the middle of the growing season. Twenty (20%) of the respondents singled out beginning of season drought as having devastating effects on their yields as some crops and farming activities have strict schedules. About 16% of the respondents singled out terminal drought as a threat to their activities and also affects the hydrological set up of an area. Nearly 6% of the respondents singled out a whole range of other seasonal rainfall anomalies within the rainy season especially inadequate rainfall during rainy periods.

3.2. Climate Change Opportunities

Table 3 shows the climate change opportunities that can be derived from climate change as perceived by the local farmers.

Table 2. Aspects of seasonal variations used in the study.

Aspect	Number of respondents	Percentage of respondents
End of season drought	64	32
Mid season drought	51	25.5
Beginning of season drought	40	20
Terminal drought	33	16.5
Other	12	6
Total	200	100

Table 3. Opportunities presented by climate change.

Activity and opportunity	Number of respondents	Percentage of respondents
Irrigation and related activities	58	29
Short/medium term growing crops	41	20.5
Introduction of new agricultural practices	38	19
Energy production	23	11.5
Mineral exploitation	16	8
Agribusiness	13	6.5
Other	11	5.5
Total	200	100

About 29% of the respondents saw climate change potential and opportunities for southeastern Zimbabwe emanating from development of irrigation practices. Adoption of short-medium season crop varieties was singled out by 20.5% of the respondents. Because of the seasonal variability experienced in the region farmers saw it prudent to the grow small grains and short to medium term growing crops which are early maturing and drought resistant. About 19% of the respondents indicated that the opportunities can arise from the introduction of new agricultural practices. In as much as crop production is vulnerable to climate change farmers saw it prudent practice agricultural activities which are more favorable to the prevailing dry conditions.

About 11.5% indicated that the existence of large water bodies in the area generates large interest in energy production. The major inland lake of Mutirikwi has potential to generate hydro-electricity power. About 6.5% indicated that the region has potential to develop agribusiness ventures. These can use agricultural products as raw materials, sugar cane has already acted as a pointer towards this direction. About 8% of the respondents indicated that mineral exploitation in southeastern Zimbabwe can absorb people who are being pushed off their main activity of crop and livestock production. Other opportunities singled out by about 5% of the respondents include the introduction of new farming techniques that hinge other activities like agro-forestry, intercropping, indigenous tree plantations among others.

Opportunities that can be derived from the increasing temperatures as indicated by the people of southeastern Zimbabwe are shown on Table 4. The respondents say that if exploited well these can be used as the best alternatives that do not involve lots of capital and is adaptive to local communities in southeastern Zimbabwe.

Close to 31.5% of the respondents saw rising temperatures as increasing the potential for using organic material as a soil conditioner to improve its fertility and productiveness. Nearly 26.5% of the respondents indi-

Table 4. Opportunities derived from high temperatures.

Activity and opportunity	Number of respondents	Percentage of respondents
Use of organic manure	63	31.5
Extended cropping season	53	26.5
Crop diversification	33	16.5
Greenhouse farming	23	11.5
Energy exploitation	15	7.5
Other	13	6.5
Total	200	100

cated that they apply the spontaneous response technique of extending the cropping season. About 16.5% of the respondents indicated that crop diversification and intensification is of great potential in the face of climate change in the area. There is a possibility of maintaining the same crops as in the past as well as diversifying in terms of types of crops to be grown since adaptive crops can be cultivated.

About 11.5% of the respondents singled out greenhouse farming as a chance of creating real opportunities and investment in southeastern Zimbabwe especially in peri-urban environments. This will attract new farmers and increase land under intensive farming. Close to 7.5% of the respondents indicated that energy exploitation alternatives will also be beneficial to the populace. About 6.5% of the respondents were singling out other measures that would be used to take advantage of the vagaries of climate change.

4. Discussion

Rainfall at all stations in southeastern Zimbabwe has been declining except for Masvingo Airport while as temperatures have been on the increase. Temperature increases for both the mean annual maximum and minimum temperatures has shortened the winter period and extended the growing season for crops [2,10,14], hence temperature upswings have advantages which can be exploited for the development of the Region.

Southeastern Zimbabwe has the largest Dam capacity in Zimbabwe. This gives the region the best opportunity to harness these waters, develop low cost and water efficient irrigation systems that can practice crop farming throughout the year. Priority should therefore be allocated to water harnessing, harvesting and consumption [11,16,17]. The water from rivers should be captured, stored and used before leaving the catchment areas of the region.

During periods of floods and flooding that can occur in the region as periodic intense rainfall events, there is addition of fertility to the soil which can be used to enhance crop productivity on the croplands. Flooding is

also known for exposing new minerals to the surface [18]. Flooding also increases the levels of both surface and ground water reservoirs which can be used for a number of purposes that include irrigation, consumption by humans and animals, biodiversity support and energy generation [19].

Climate change as shown in the results section provides an opportunity for diversification from dryland agriculture in the region. Diversification includes cattle and wildlife ranching, fish and crocodile farming [20-23]. Researchers have indicated that crop production in the region will diminish and wild stock production will increase [22,23]. However, crop production in southeastern Zimbabwe remains a possibility as rainfall amount hovers around 600 mm mark annually. Small grains thrive in regions of low rainfall and high temperatures. Other crops with much resilience include cassava, yams, and sweet potatoes among others can be adopted at a large scale.

The presence of large and numerous water bodies in southeastern Zimbabwe like Lake Mutirikwi, Bangala, Siya, MacDougall, Mushandike, Ruti and the giant Tokwe-Mukorsi Dam can make the region potentially self sufficient in energy production from small scale hydro-electric plants and bio-fuels. The irrigated sugar cane plantations of Hippo Valley, Mkwesine, Mwenezi and Triangle have potential to generate electricity from bagasse and produce ethanol which can be used to blend fuel used by motor vehicles. All these energy sources could be used to drive the regions general development [23].

Apart from hydro-electricity, high temperatures resulting from incident solar radiation from the sun to the atmosphere and on the surface of the earth would result in increased solar energy which can be harnessed and help the region to produce affordable and sustainable clean energy [24,25]. Wind energy can also be exploited. High temperatures have an effect on increasing high wind speeds and an investment in wind energy can be worthwhile and sustainable in the near future [24].

Industrial development in the region is possible when irrigation related potential is exploited. Diversified irrigation farming will include cotton production as is at Chisumbanje and Mkwesine Estates as well as for other crops which will act as raw materials for these industries. Livestock and wilds tock can be used to create industries related to these products like tourism development, tanneries, abattoirs, meat processing among other factories. These factories will generate employment for the local community and also provide market for the products they produce.

Increasing temperatures observed at all the weather stations in the region can increase the rate of organic matter decay rates and provide a conducive environment for micro-organism activity in the breakdown of the

matter. This provides an opportunity use of compost manure in conservation agriculture first at small scale, then transformed to large scale and latter mechanized to improve the practicality of the processes. In rural south-eastern Zimbabwe, the use of organic manure is more practical in the sense it increases the fertility of the soil for a longer period than artificial fertilizers [10, 21].

5. Conclusions

From the study, it can be realized that not all impacts of climate change are bad. Climate change can be used in southeastern Zimbabwe as catalyst to reorient the development goals and targets of the region to those that are climate change resistant. In the process of trying to overcome the new threats, the region also creates opportunities for new development [10].

Adaptation in its many forms can be enhanced by many opportunities that are derived in climate change and variability. There is a need for capacity and intellect for full realisation of the advantages and merits that extreme weather events avail. Most communal farmers do not either have one or both, a situation that compromises their adaptive capacity. Stake holders and government intervention in tapping into the resources availed by these conditions can go a long way in changing livelihoods in the region for the better.

REFERENCES

- [1] P. Z. Yanda, "Climate change impacts, vulnerability and adaptation in Southern Africa," *Sarua Leadership Dialogue Series*, Vol. 2, No. 4, 2010, pp. 11-30.
- [2] L. Unganai, A. Murwira, B. Nherera, J. Troni and D. Mukarakate, "Historic and Future Climate Change Implications for Crop and Livestock Production in Chiredzi District," National Climate Change Symposium, Rainbow Towers, Harare, 2010.
- [3] IPCC, "Climate Change 2007: the Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change".
- [4] T. Chagutah, "Climate Change Vulnerability and Preparedness in Southern Africa: Zimbabwe Country Report," Heinrich Boell Stiftung, Cape Town, 2010.
- [5] C. Mutasa, "Evidence of Climate Change in Zimbabwe. Paper Presented at the Climate Change Awareness and Dialogue Workshop for Mashonaland Central and Mashonaland West Regions," Kariba, 29-30 September, 2008.
- [6] M. E. Hellmuth, A. Moorhead, M. C. Thomson and J. Williams, "Climate Risk Management in Africa: Learning from Practice," International Research Institute for Climate and Society (IRI), Columbia University, New York, 2007.
- [7] B. Smit, D. McNabb and J. Smithers, "Agricultural Adaptation to Climatic Variation," *Climate Change*, Vol. 33, 1996, pp. 7-29. [doi:10.1007/BF00140511](https://doi.org/10.1007/BF00140511)
- [8] E. Sundbland, "People's Knowledge about Climate Change: Uncertainty as a Guide to Future Comments," University of Gothenburg, Gothenburg, 2008.
- [9] P. Kachere, "Zimbabwe Meteorological Services Department Blasted for Inaccurate Weather Reports," *The Sunday Mail*, 2011, p. 11.
- [10] F. Simba, T. Murwendo, D. Chikodzi, B. Mapurisa, A. Munthali and L. Seyitini, "Environmental Changes and Farm Productivity: An Assessment of Masvingo Region of the Zimbabwe," *SACHA Journal of Environmental Studies*, Vol. 2, No. 1, 2012, pp. 114-129.
- [11] J. Malherbe, F. A. Engelbrecht, W. A. Landman and C. J. Engelbrecht, "Tropical Systems from the Southwest Indian Ocean Making Landfall over the Limpopo River Basin, Southern Africa: A Historical Perspective," *International Journal of Climatology*, Vol. 32, No. 7, pp. 1018-1032. [doi:10.1002/joc.2320](https://doi.org/10.1002/joc.2320)
- [12] Central Statistics Office (CSO), "Zimbabwe Population Profile," 2002. <http://www.zimstat.co.zw/dmdocuments/Census/Census.pdf>
- [13] D. Chikodzi and G. Mutowo, "Agro-Ecological Zonation of Masvingo Region: Land Suitability Classification Factoring In Climate Change, Variability Swings and New Technology," 2012.
- [14] J. M. Makadho, "Potential Effects of Climate on Corn Production in Zimbabwe," *Climate Research*, Vol. 16, 1996, pp. 146-151.
- [15] D. Mazvimavi, "Investigating possible changes of extreme annual rainfall in Zimbabwe Hydrol," *Hydrology and Earth System Sciences*, Vol. 5, 2008, pp. 1765-1785. www.hydrol-earth-syst-sci-discuss.net/5/1765/2008/
- [16] F. T. Mugabe, M. G. Hodnet, A. Senzanje and T. Gonah, "Spatio-Temporal Rainfall and Runoff Variability of the Runde Catchment, Zimbabwe, and Implications on Surface Water Resources," *African Water Resources Journal*, Vol. 1, No. 1, 2010, pp. 66-79.
- [17] United Nations Convention to Combat Desertification, "Global Dry Lands," 2012. <http://www.unccd.int/Lists/SiteDocumentLibrary/Publications/Desertification-EN.pdf>
- [18] USGS, "Minerals and the Environment," 2013. <http://minerals.usgs.gov/granted.html>
- [19] A. E. De Jonge, "Farmers' perception on adaptation to climate change: A case study of irrigators in the Riverland, South Australia," Master Thesis, Wageningen University, 2010.
- [20] B. L. Dhaka, K. Chayal and M. K. Poonia, "Analysis of Farmers' Perception and Adaptation Strategies to Climate Change," *Libyan Agriculture Research Center Journal International*, Vol. 1, No. 6, 2010, 388-390.
- [21] FAO/WFP, "Crop and Food Security Assessment Mission to Zimbabwe," Special Report, FAO Global Information and Early Warning System on Food and Agriculture, 2010.
- [22] M. Parry, C. Rosenzweig, A. Iglesias, G. Fischer and M. Livermore, "Climate Change and World Food Security. A

- New Assessment,” *Global Environmental Change*, Vol. 9, Suppl. 1, 1999, pp. 51-67.
[doi:10.1016/S0959-3780\(99\)00018-7](https://doi.org/10.1016/S0959-3780(99)00018-7)
- [23] FAO, “Building Adaptive Capacity to Climate Change: Policies to Sustain Livelihoods and Fisheries. New Directions in Fisheries: A Series of Policy Briefs on Development Issues,” No. 08, Rome, 2007.
- [24] K. Voss, J. Herkel, G. Pfafferott, C. Lohnert and A. Wagner “Energy Efficient Office Buildings with Passive Cooling. Results and Experiences from a Research and Demonstration Programme,” *Solar Energy*, Vol. 81, No. 3, 2007, pp. 424-434. [doi:10.1016/j.solener.2006.04.008](https://doi.org/10.1016/j.solener.2006.04.008)
- [25] WEC, “New Energy Resources World Energy Resources,” WEC, London, 1994.