CLIMATE VARIABILTY AND TRENDS IN METEOROLOGICAL TIME SERIES IN SEMI ARID BOTSWANA

PRESENTED BY

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OUTLINE

1. General Background
2. Problem
3. Objectives
4. Methods
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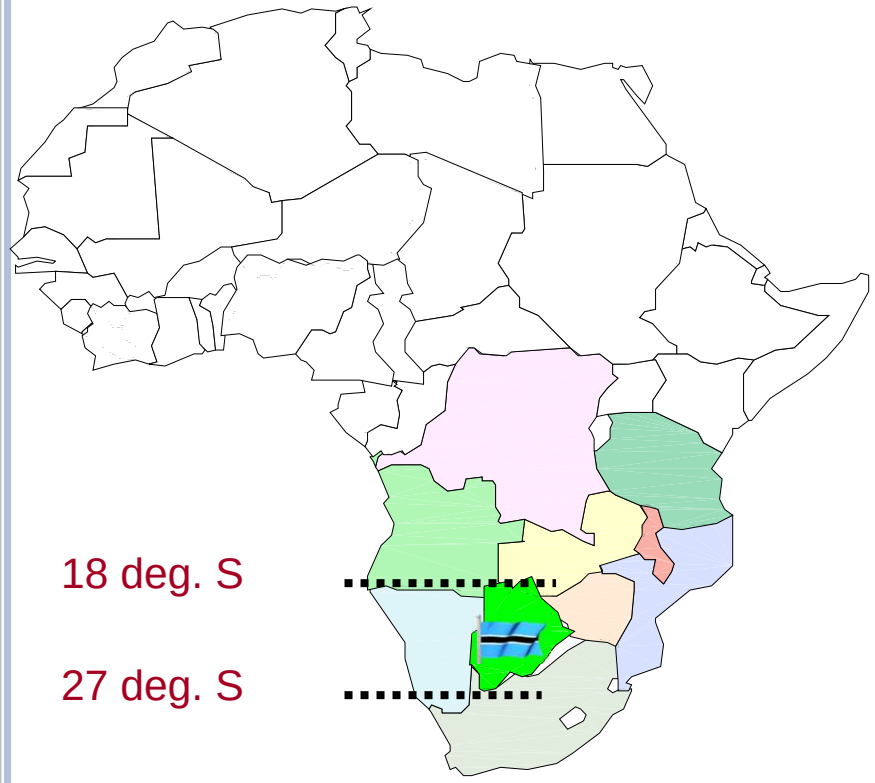
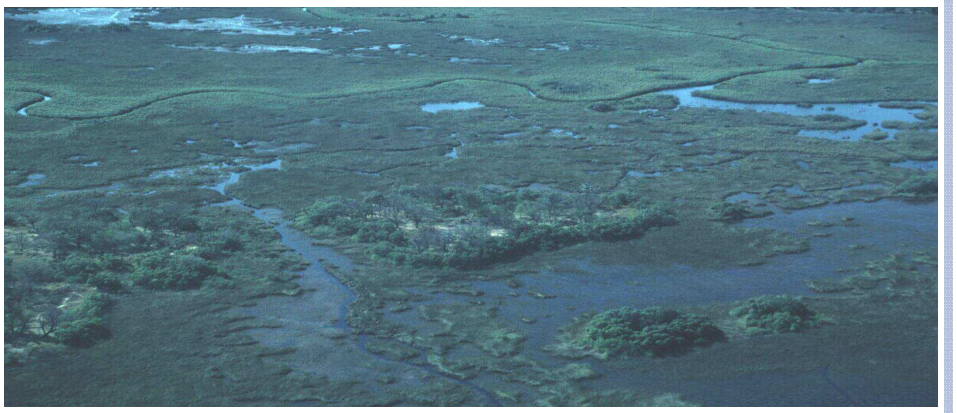
6. Discussions and conclusion

GENERAL BACKGROUND-STUDY AREA



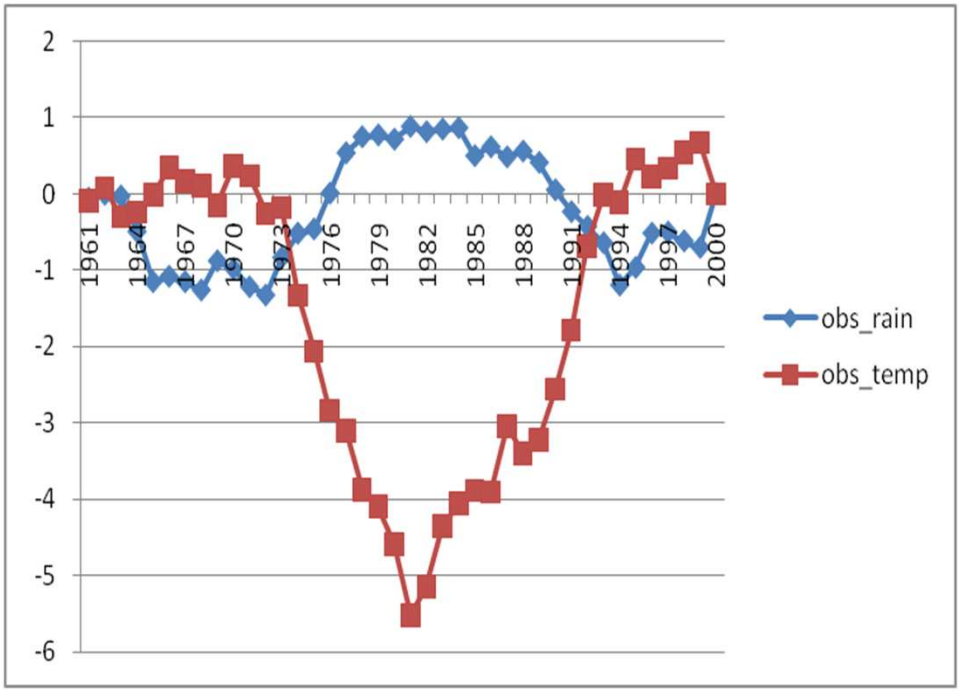
Limited Fresh Water Availability, Depletion of Aquifers,
Drying up of wetlands,
Overgrazing , Desertification, Low crop productivity.

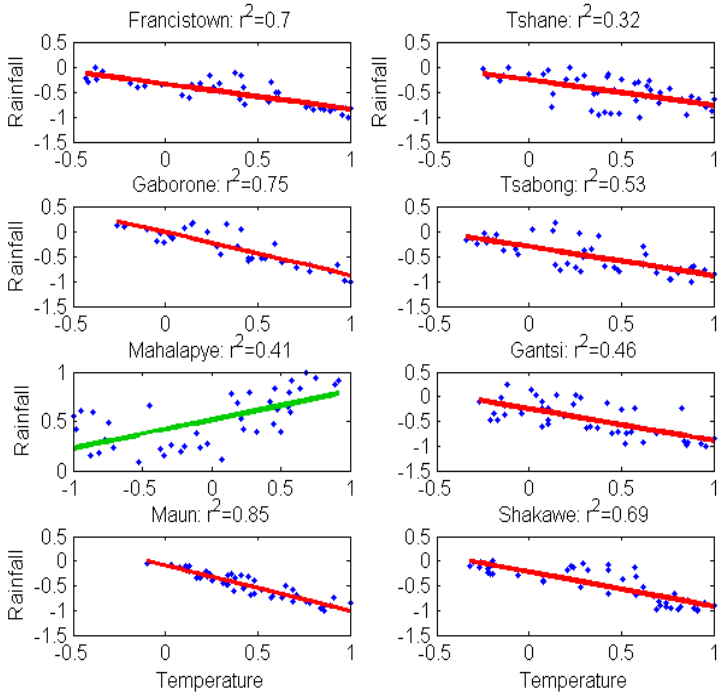


Climate change and Variability associated with disaster risk that leads to challenges towards
Food Security – sustainable development

BOTSWANA CLIMATIC STUDIES (Rainfall Simulations)

- **Rainfall is major source of inland fresh water supply**
- **A strong relationship between rainfall and temperature has been established**





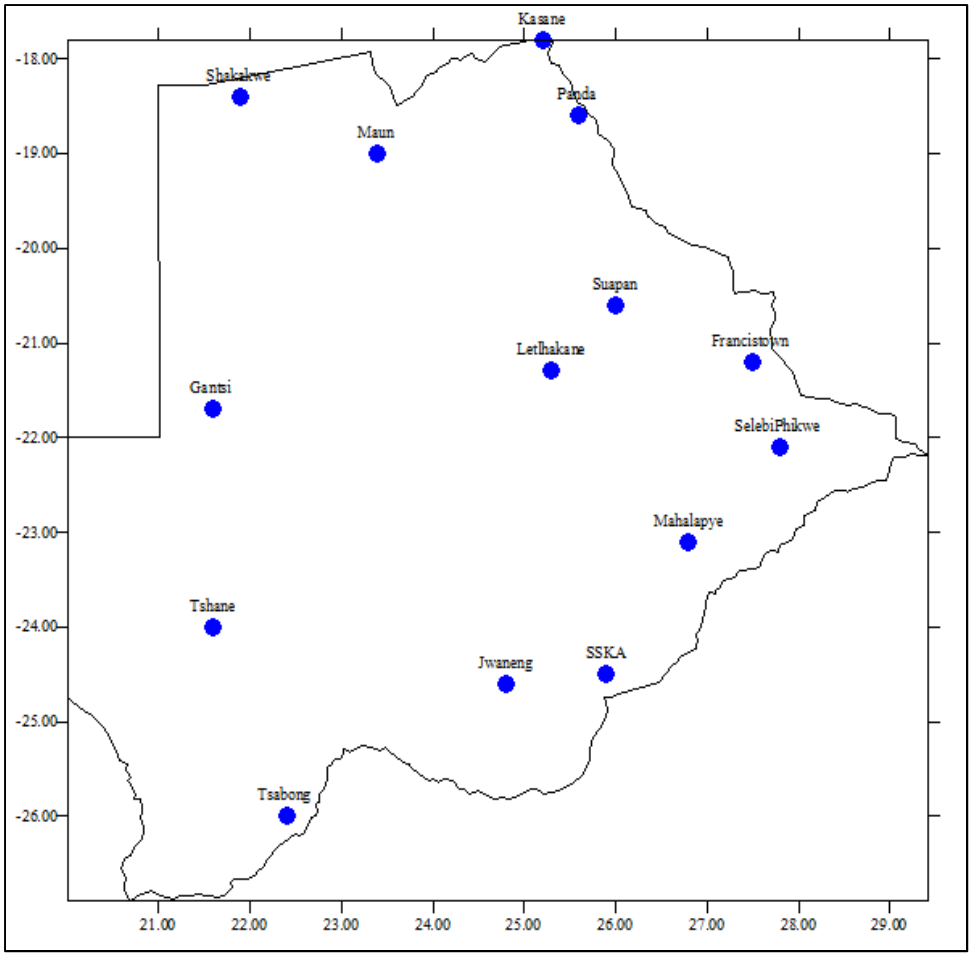
Kenabatho et al, 2012

EXTEND OF CLIMATIC CLIMATE CHANGE STUDIES OVER BOTSWANA

Some recent studies

- Climate model forecasts indicate a general decrease in rainfall and increasing temp with high variability over the Southern Africa (Tsheko, 2004; Parida et al, 2008, Kenabatho et al, 2012)
- Impact of climatic variability in Botswana has been studied by Parida and Moalafhi (2008) using rainfall time series at 11 synoptic stations
- Batisani and Yarnal (2010) studied rainfall variability at 8 meteorological stations using descriptive statistics

Synoptic Stations used



- Analysis of air temperature data at global scales with respect to climate change indicates a 0.4 °C to 0.8 °C rise since 1860 (Pachauri and Reisinger, 2007; Tabari et al., 2011a)

- Climatic changes and their impacts are experienced through variability in temperature and precipitation (Heim Jr, 2002). Consequently, the analysis of changes in these meteorological variables represents an important task in climate change detection

- Change detection and trends analysis of long time series of meteorological data aids understanding climatic variability

- Studying climatic variability facilitaes water resource planning

To understand the variability and trend in max, min air temperatures and precipitation time series in Botswana for a period of 1960 to 2013

Specific objectives

1. To determine variability in max, min air temp and precipitation time series
2. To carry out intervention and step change analysis
3. Perform homogeneity test on the meteorological data series
4. To determine the magnitude and statistical significance of changes
5. To assess serial correlation effect on the Mann-Kendall (MK) test statistic

METHODS

1. Coefficient of variation (CV)
2. Intervention analysis using CUSUM technique
3. Step change analysis using split sample t-tests
4. Homogeneity tests using cumulative residuals
5. Monotonic trend tests using MK and Sen slope estimator
6. Serial correlation test and effective sample size

METHODS

Intervention analysis-CUSUMS

- $Y_i = x_i + x_{i-1} + x_{i-2} + \cdots + x_1 - i.\frac{\sum_i^n x_i}{n}$

Split sample t-tests

- $t_t = \frac{|\bar{X}_1 - \bar{X}_2|}{\sqrt{\frac{(n_1-1)s_1^2+(n_2-1)s_2^2}{(n_1+n_2-2)}\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}}$
- $\begin{cases} |\bar{X}_1 = \bar{X}_2|, & H_0 \\ |\bar{X}_1 \neq \bar{X}_2|, & H_1 \end{cases}$

Monotonic trend-MK test

- $S = \sum_i^{n-1} \sum_{j=i+1}^{n} \mathrm{sgn}(x_j - x_k)$
- $\mathrm{sgn}(x_j - x_i) = \begin{cases} +1 & \text{if } (x_j - x_k) > 0 \\ 0 & \text{if } (x_j - x_k) = 0 \\ -1 & \text{if } (x_j - x_k) < 0 \end{cases}$
- $Z_s = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & \text{if } S > 0 \\ 0 \text{ if } S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & \text{if } S < 0 \end{cases}$
- $Var(S) = \frac{n(n-1)(2n+5)-\sum_i^m t_i(t_i-1)(2t_i+5)}{18}$

METHODS

Sen Slope estimator

- $Q_i = \frac{x_j - x_k}{j-k}$ for $i = 1,2,\ldots\ldots,N$
- $Q_{med} = \begin{cases} Q_{\frac{(N+1)}{2}} \text{ if N is odd} \\ \frac{Q_{\left(\frac{N}{2}\right)} + Q_{\left[\frac{(N+2)}{2}\right/_2\right]}}{2} \text{ if N is even} \end{cases}$

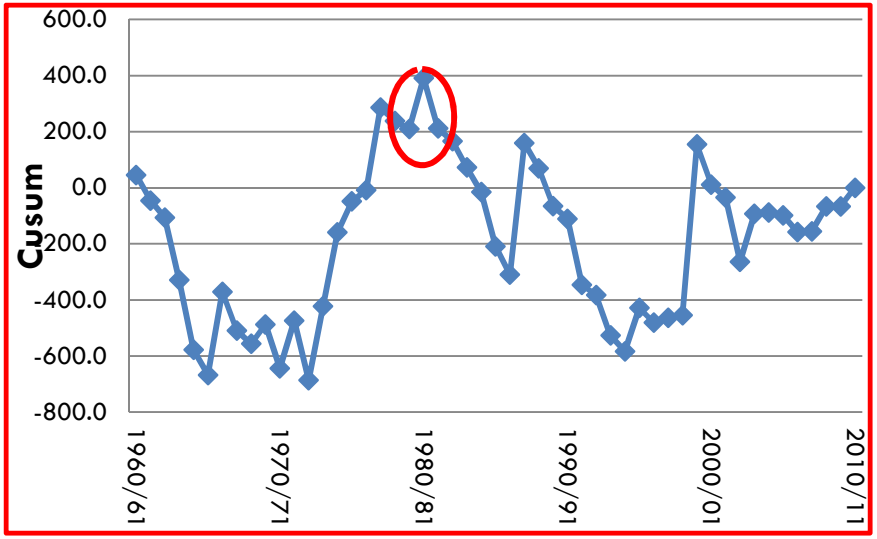
Serial correlation effect

- $r_1 = \frac{\frac{1}{n-1}\sum_{i=1}^{n-1}(X_i - \bar{X}).(x_{i+1} - \bar{X})}{\frac{1}{n}\sum_{i=1}^{n}(X_i - \bar{X})^2}$

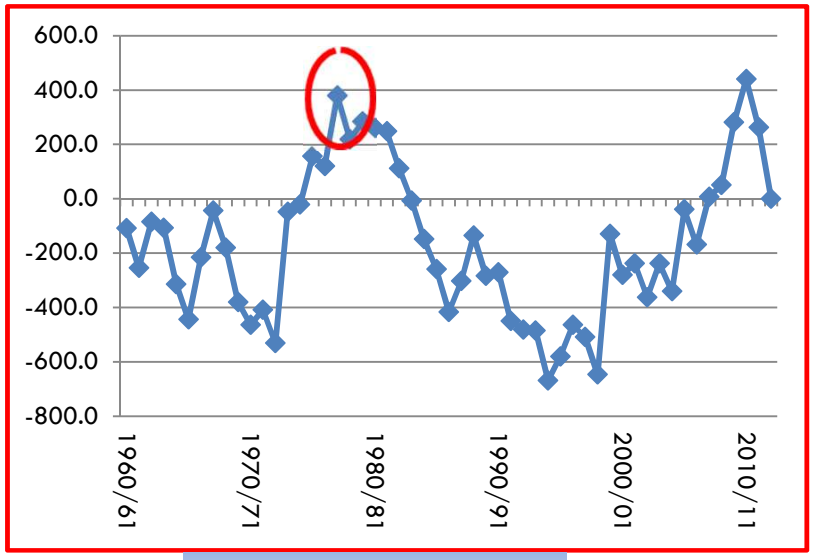
Effective sample size

- $Var^*(s) = var(s).\frac{n}{n^*}$
- $n^* = \frac{n}{1+2.\frac{r_1 n+1 - n{r_1}^2 + (n-1)r_1}{n(r_1-1)^2}}$

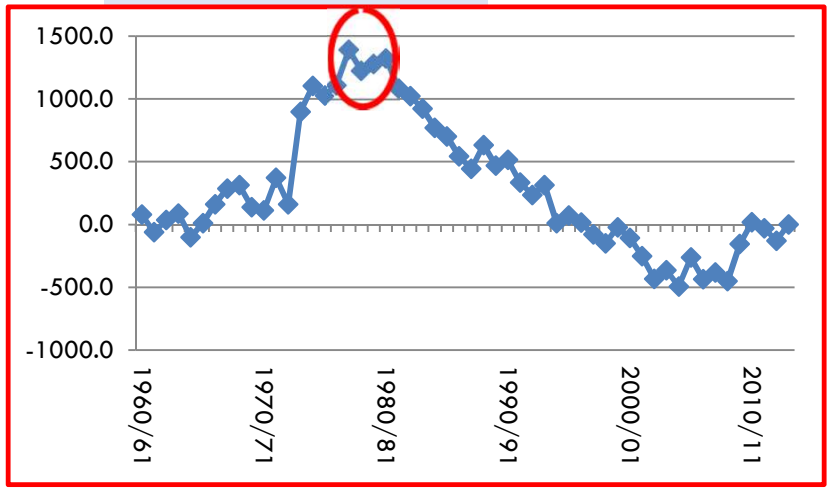
RAINFALL CUSUM PLOTS



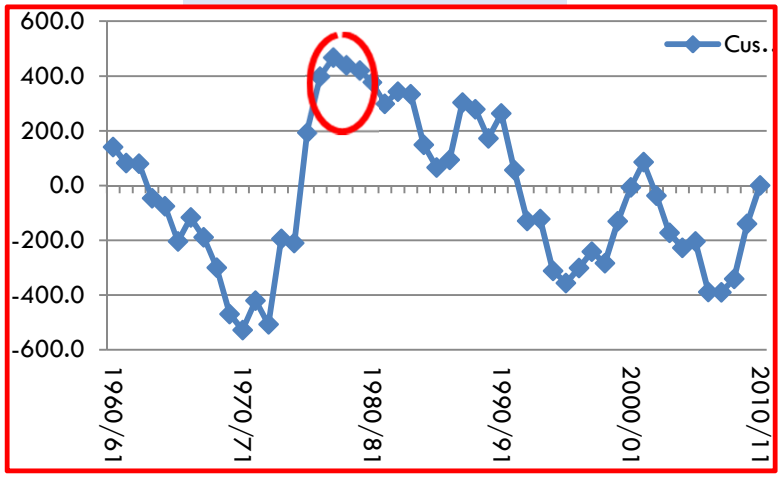
FRANCISTOWN



GANTSI



MAUN

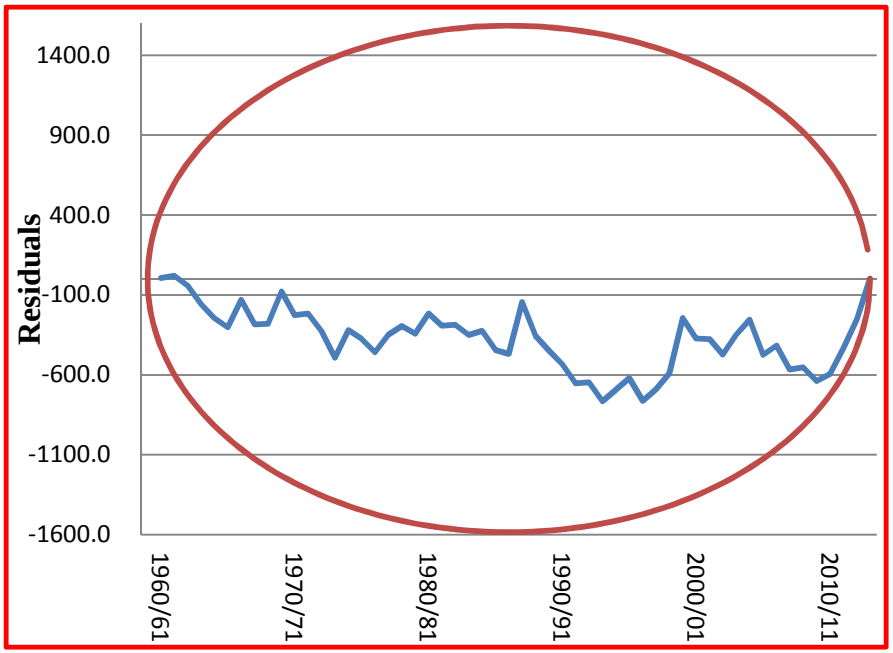


TSABONG

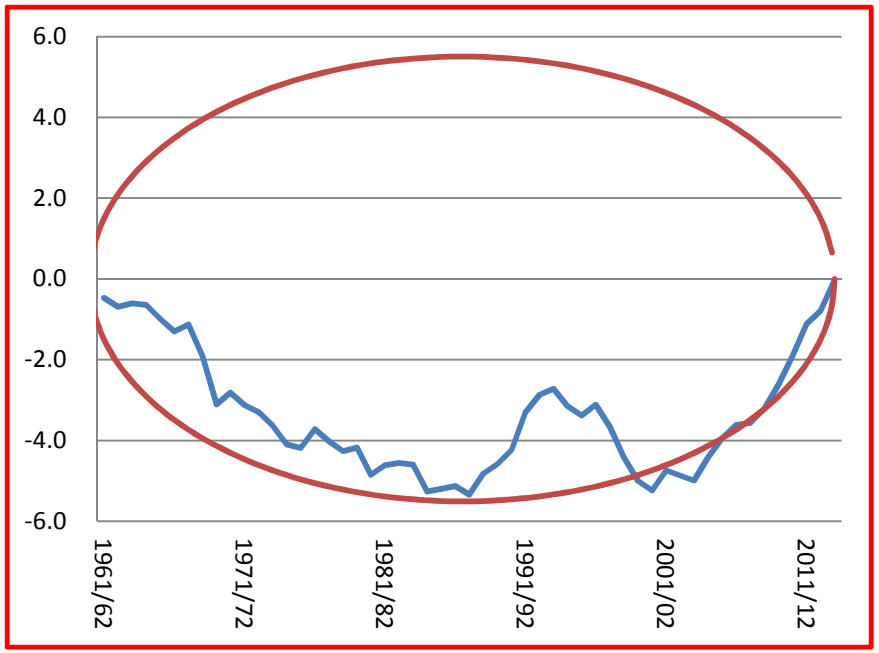
Statistical tests

Station	Rainfall		Minimum Temperature		Maximum Temperature	
Station	Intervention Year	T-test	Intervention Year	T-test	Intervention Year	T-test
Maun	1977/78	2.36**	1983/84	6.81**	1980/81	4.59**
Tshane	1977/78	1.277	1986/87	5.72**	1977/78	2.71**
Tsabong	1977/78	1.04	1996/97	5.54**	1988/89	1.62
Mahalapye	1980/81	0.61	1981/82	6.50**	1980/81	2.85**
Kasane	1977/78	2.97**	1991/92	7.079**	1998/99	2.66**
Gantsi	1977/78	0.63	1984/85	3.43**	1978/79	3.05**
Shakawe	1977/78	1.33	1990/91	2.64**	1980/81	0.68
SSKA	2000/01	0.70	1994/95	2.15*	1998/99	1.82
Lethakane	1999/00	1.333	2000/01	3.32**	2004/05	0.65
Jwaneng	1994/95	1.28	1994/95	3.01**	1999/00	0.38
Francistown	1980/81	0.36	1981/82	2.90**	1980/81	4.06**

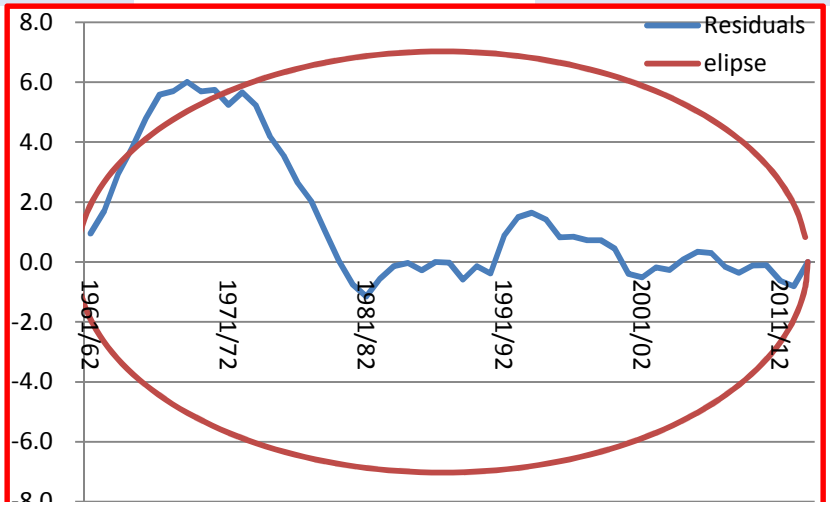
HOMOGENEITY TEST FOR RAINFALL AND MAX TEMP



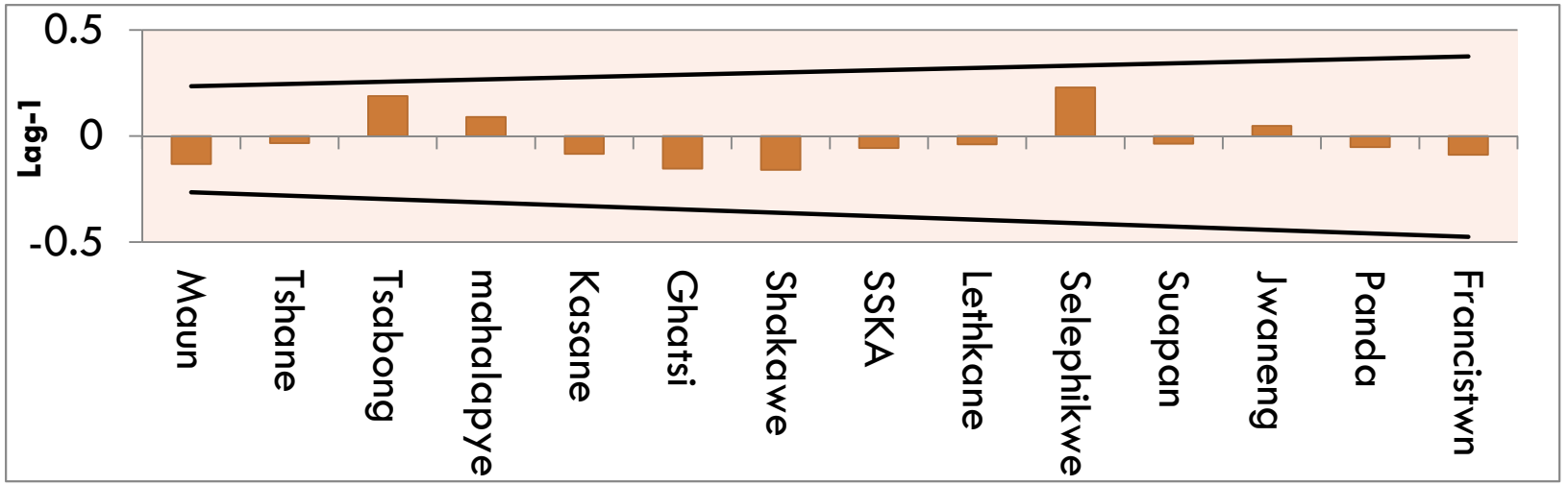
ANNUAL RAINFALL



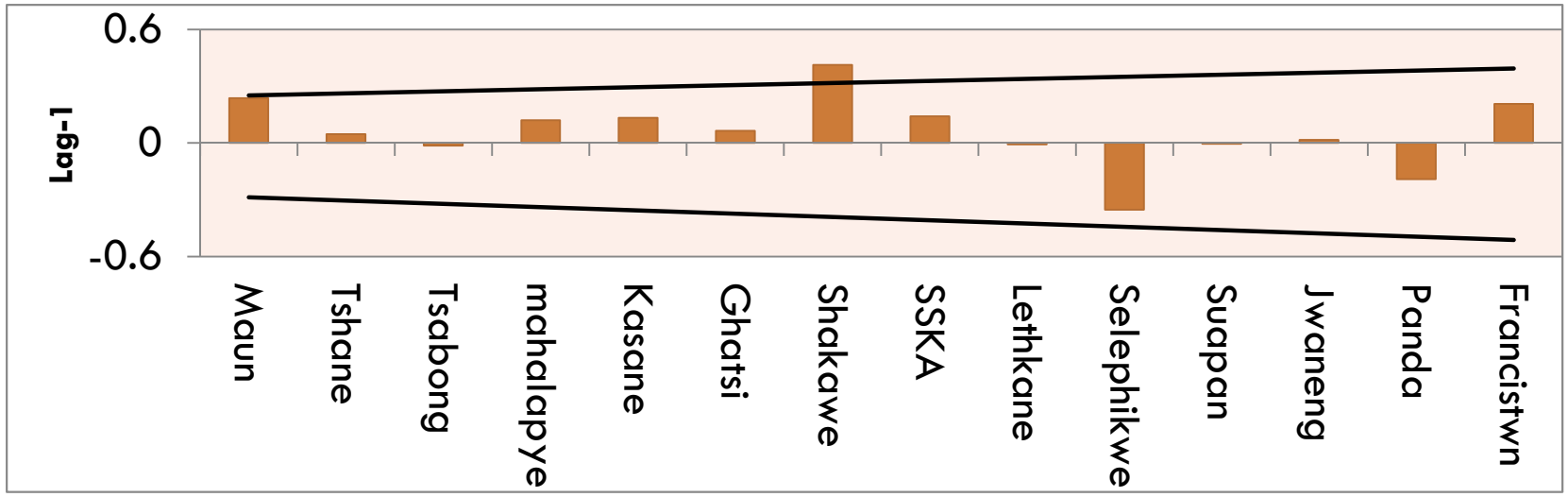
MEAN MAX MONTHLY TEMPERATURE



ANNUAL RAINFALL AND MAX TEMPERATURE R_1

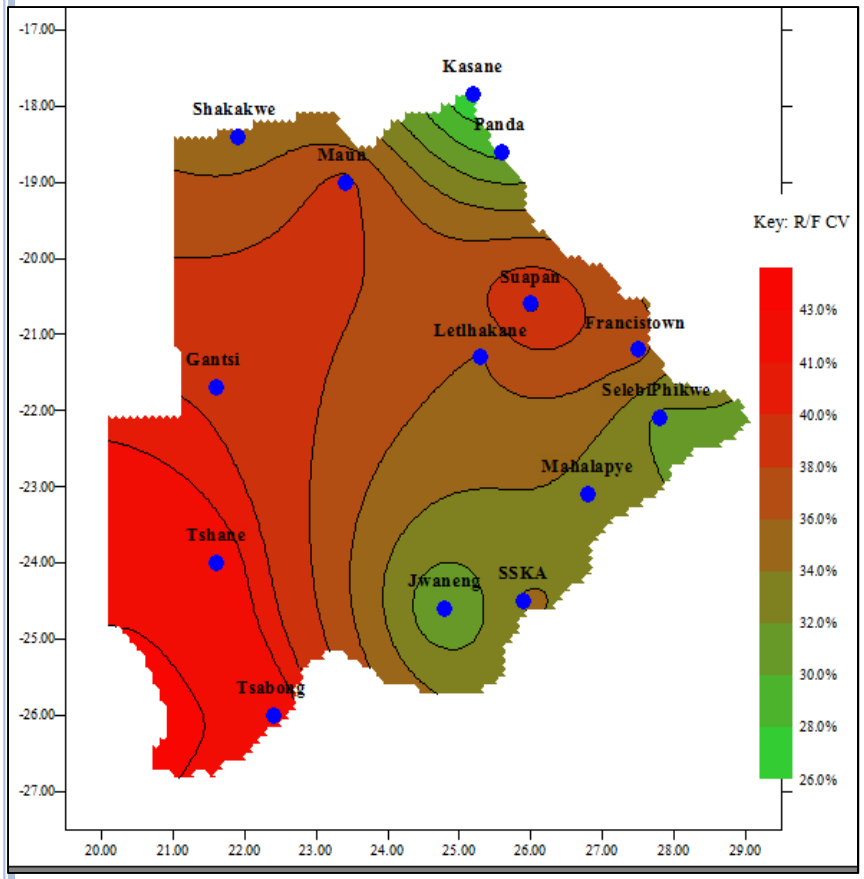


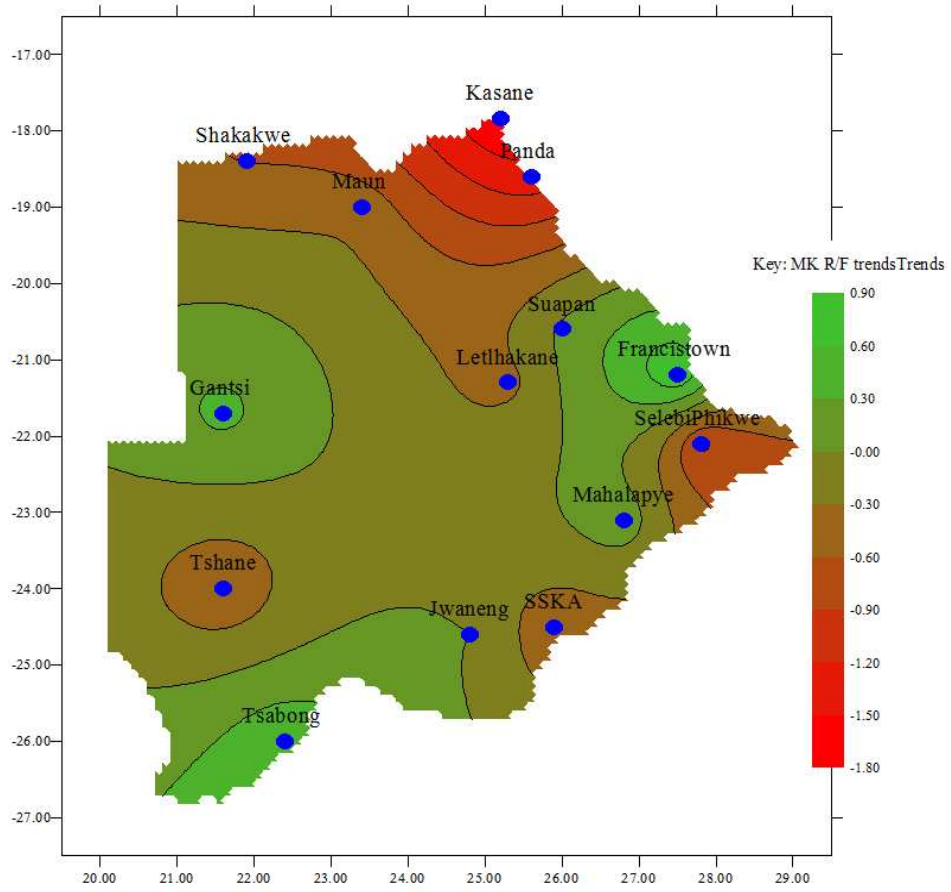
ANNUAL RAINFALL



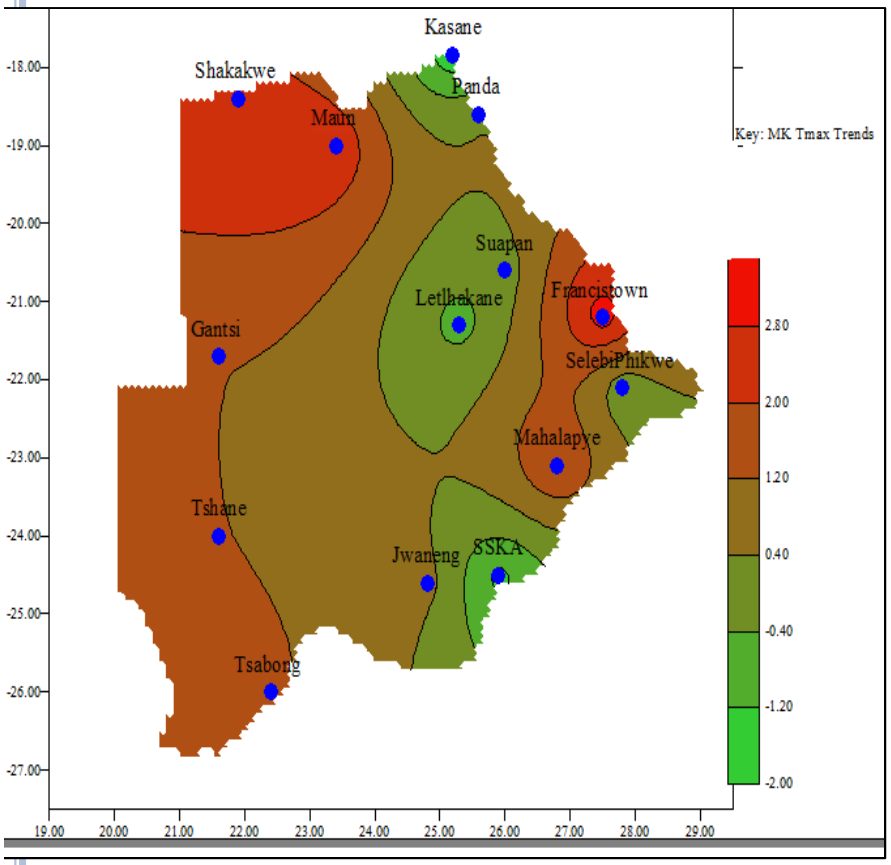
MEAN MAX MONTHLY TEMPERATURE

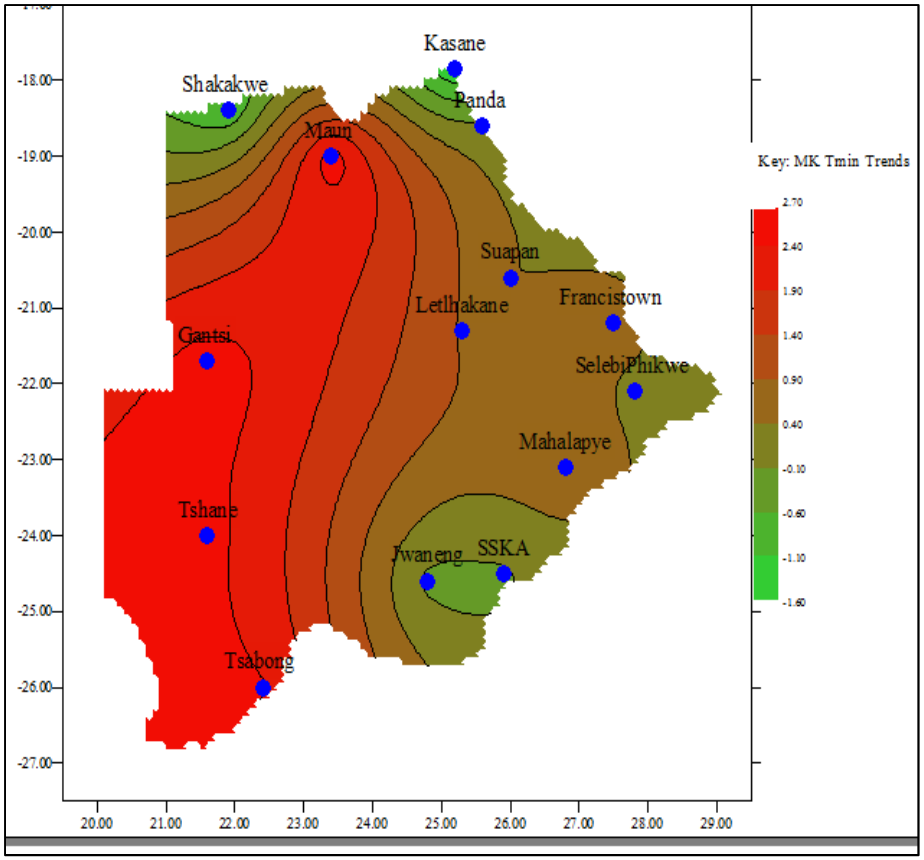
RAINFALL VARIABILITY AND TRENDS





TRENDS IN MAX AND MIN TEMP





DISCUSSION

- CV recorded over Botswana for the period of 1960/61 to 2012/13 was above 26 %, an indicator towards high climatic variability
- Step change year occurred between around1980/81 for most of the stations
- Min and max temp indicate a significant warming trend from South West to North
- The rainfall trends are decreasing mainly in the North with Kasane registering a drop of 3.3 mm/yr stretching west to Shakawe 0.6 mm/yr. However there was an increasing trend in rainfall recorded at Francistown (1.3 mm/yr) and Gantsi (0.5 mm/yr) though all non significant
- The results indicate spatial trends from Southwest to North eastern part of Botswana in agreement with findings of Batisani and Yarnal (2010), who suggested a rainfall gradient in the same direction.
- The lessons drawn from understanding the nature of meteorological variables over Botswana for a period of 1980/81 to 2012/13 can be applied to various social and economic spheres to support decision-making related to water resources planning and management

CONCLUSIONS

1. High rainfall variability of up to 43 % may be an indicator of higher aridity

2. Overall rainfall is decreasing over Botswana at a rate of 1mm/yr

3. Since both min and max temp are increasing, there is more likelihood of further reduction in rainfall which will further impact on crop production and general people's livelihood

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THANK YOU FOR LISTENING