The relationship between crop yield, the SOI and rainfall data in the Ngqushwa local municipality, South Africa

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Abstract

The study determines the correlation *r* between crop yield and rainfall variability, and mean annual rainfall scores were compared with the mean crop yield for 30 years (1982 to 2011). The Pearson Correlation indicates that the rainfall for Grahamstown and Peddie are strongly correlated (r=0.63; P<0.01) with both lagged and unlagged SOI values showing a strong correlation for the prediction of rainfall trends. The study area has experienced several dry spells. The study recommends adaptation alternatives such as large-scale irrigation schemes and SOI aligned Information and Communications Technologies (ICT) interventions as tools for an integrated early warning system.

Keywords: *Rainfall, Crops, SOI, Variability, Correlation, Adaptive capacity, ICT, South Africa*

Introduction

In South Africa, crop production is crucially dependent on precipitation - even more so than on temperature (Province of the Eastern Cape, 2011). Historically, the Ngqushwa Local Municipality (NLM) has experienced numerous drought spells which have adversely affected crop-farming, leading to wide-spread agricultural field abandonment (Wenhold, 2007). This study focuses on the biophysical changes, including scientific analysis of the prevailing climatic regimes, particularly rainfall trends, as well the relationship between rainfall variability and crop yields for the small-scale and subsistence farmers in this rural locality.

Methodology

Rainfall data was collected from the South African Weather Services (SAWS). The monthly rainfall data from Grahamstown spans 112 years (1900-2011) while at Peddie the data are from 1900-1987 (88 years) and from King William's Town the data range from 1970-2011 (42 years). While Grahamstown is outside of the Ngqushwa Local Municiaplity jurisdiction, data from the Grahamstown rainfall station was utlilised to cater for the missing data from the other stations.

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Grahamstown's rainfall station is in relatively close proximity to the Ngqushwa rainfall station. To determine the correlation *r* between crop yield and rainfall variability, the mean annual rainfall scores were compared with the mean crop yield for 30 years (1982 to 2011). To analyse the long-term trend in inter-annual rainfall variability at the station for the individual recording period, the annual absolute deviation from mean annual rainfall (absolute deviation) was computed. The Southern Oscillation Index (SOI) values were also correlated with the rainfall data. To obtain qualitative data ten(10) focus groups were conducted with the small scale farmers.

Results

Figure 1 shows the Z-Scores for Crop Yield over 30 years. The Pearson's correlation coefficient between mean annual rainfall and estimated mean annual maize crop yield is 0.69 (**Figure 2**), which indicates a strong positive linear relationship between rainfall and crop yields. This co-efficient implies that 69% of crop yield is attributable to rainfall variability. The study area has experienced several dry spells over the 30 years.

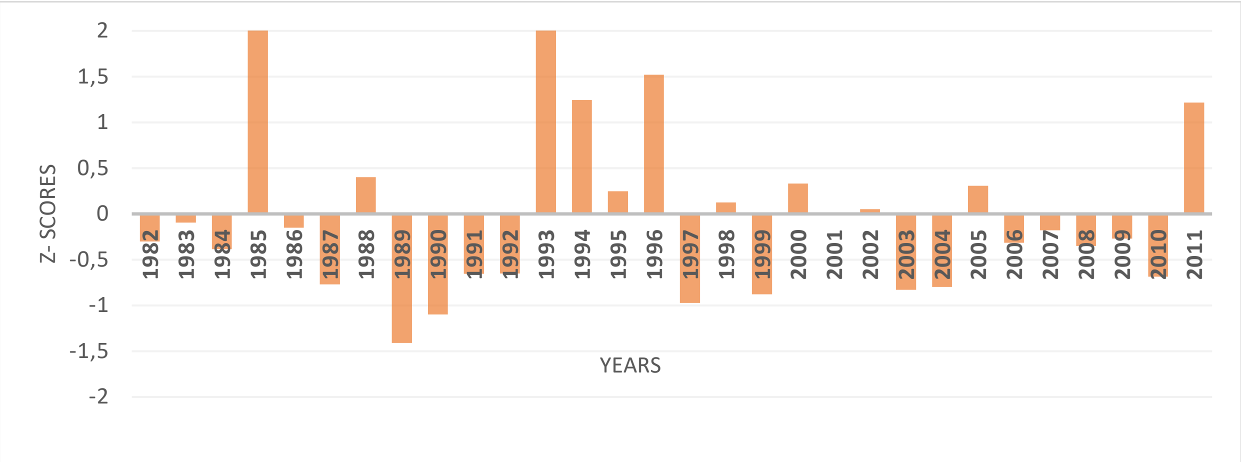

Figure 1: Z-Scores for 30 Year Crop Yield (1982 -2011)
(Source: Department of Agriculture- DoA)

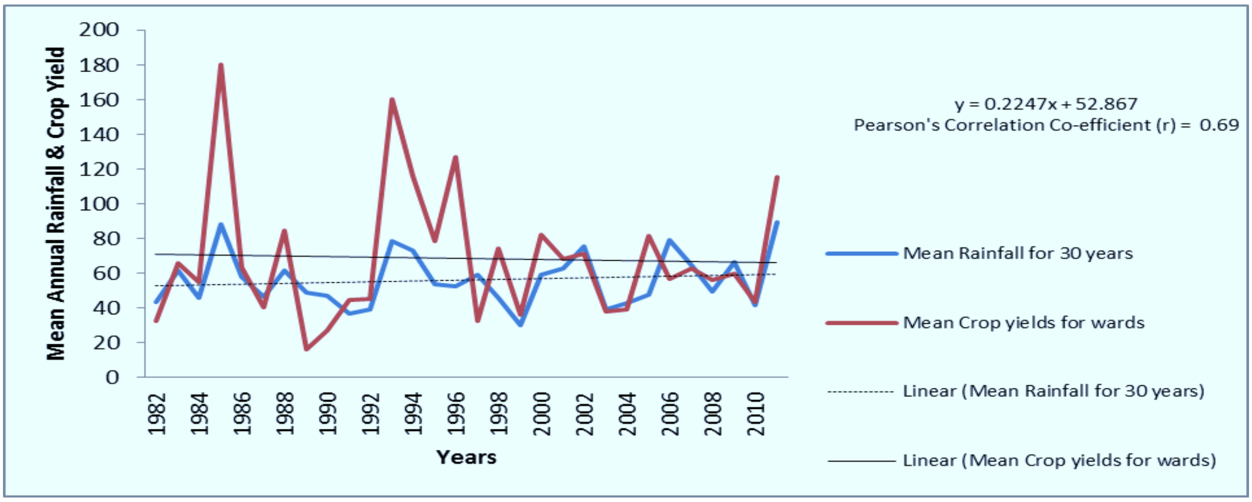

Figure 2: The 30-year Mean Annual Rainfall and Crop Yield Estimates
(Source: South African Weather Services (SAWS),DoA)

Even though both stations show an increase in precipitation concentration index (PCI) values from 1900, the increase is not statistically significant. To further test the changes in intra-annual rainfall the monthly rainfall linear trend for Grahamstown and Ngqushwa (Peddie) for the recording period were analysed (**Table 1**) and (**Table 2**). The Pearson Product Moment Correlation indicates that the rainfall of Grahamstown and Ngqushwa are strongly correlated at the 99% confidence level (r=0.63; P<0.01). From linear regression the absolute deviation around the mean has increased from 85mm to 170mm over the 112 years. Pearson's correlation coefficient between mean annual rainfall and mean annual maize crop yield is 0.69 - which indicates a strong positive linear relationship between rainfall and crop yields.

Table 1: Intra-Annual Rainfall and Monthly Linear Trends (Source: SAWS and DoA)

Month	Linear correlation (r)	Significance (P)
January	0.02	0.87
February	0.01	0.96
March	0.14	0.16
April	0.03	0.76
May	0.06	0.52
June	0.04	0.67
July	0.12	0.20
August	0.20	0.04
September	0.06	0.52
October	0.04	0.67
November	0.05	0.59
December	0.01	0.93

The SOI values (both lagged and unlagged) have both a strong correlation and a statistically signicant relationship with rainfall trends, as well as with the crop yield trends particularly during the spring rainfall months (J-A-S-O) (**Table 2**). Therefore, the values can be used to predict rainfall trends as well as crop yields (Hyden & Sekoli, 2000; Wang & Robetson, 2011; Cobon & Toobs, 2013; Gutierrez, 2017; Muza, 2017).

Table 2: Correlation coefficient r with the relevant level of significance P between station summer rainfall and the mean SOI values for certain periods (Source: SAWS)

Rainfall period	Period of SOI values (non- lagged)	Grahamstown		Peddie	
November-March		r	P	r	P
	Nov+Dec+Jan	0.60	<0.01	0.41	<0.01
	Nov+Dec+Jan+Feb+Mar	0.22	0.02	0.40	<0.01
	Period of SOI values (lagged)				
	May+Jun+Jul+Aug+Sep	0.61	<0.01	0.35	<0.01
	Jun+Jul+Aug+Sep	0.41	<0.01	0.36	<0.01
	Jun+Jul+Aug+Sep+Oct	0.80	0.02	0.36	<0.01
	July+Aug+Sep	0.74	<0.01	0.35	<0.01
	Jul+Aug+Sep+Oct (J-A-S-O)	0.77	<0.01	0.35	<0.01

This correlated relationship is useful for determining the small-scale farmers' agricultural output, sustainable livelihoods, and viable food security. The challenge is that the study area has experienced several dry spells over the 30 years. One of the foremost applicable solutions under such circumstances is the use of irrigation systems (IS) which are known to be relatively sustainable and predicable sources of water resources in the face of extremely desiccating climate events (Roco et al., 2017). However, in the study area there is a dearth of irrigation systems (IS). To address the absence of the IS this study finds that the relationship between SOI values, rainfall events and crop yields can be translated into a user-friendly language/ communication system which can be achieved through the use of an integrated ICT system that incorporates the ubiquitously existing communication tools which include indigenous knowledge systems, cell phones and radios. Access to climate information is crucial to achieving lasting adaptive capacity (Zamasiya et al., 2017).

Qualitative data collection revealed that the approximately situated community radio stations were suitable platforms for communicating weather/climate forecasted events for the purpose of building resilient agricultural systems and adaptive livelihood practices. In addition, the small-scale farmers use cell-phones to communicate the climate news to their peer small-scale farmers. In small-scale farmer community fora, the currently known indigenous climate prediction information is communicated. Such information still needs to be achieved, stored and broadly disseminated. There is general acknowledgement and consensus that further studies on the integration of diverse data sources are pivotal to an inclusive climate information communication system that utilises both quantitative and qualitative data sources (Loewen & Kinshuk, 2012; Myeza & Kaya, 2016; Mafongoya & Ajayi, 2017). This study shows that there is a need for the relationship between SOI, crop yield and rainfall data to be synergistically analysed and disseminated to reflect a comprehensive approach towards the achievement of localised access to climate information, as opposed to the reliance on national, regional and global quantitative climate information.

Conclusions

This study shows that while the inter-annual and seasonal rainfall trends are highly variable, there is a strong correlation between SOI values (lagged and non-lagged), rainfall trends as well as with crop yields. Therefore, the relationship betwen SOI and rainfall trends is useful for the prediction of crop yields for the NLM small-scale/subsistence farmers. Small-scale farmers in rural communities depend on rainfed agriculture, but such reliance increases vulnerability and reduces resilience for their crops and further threatens their livelihoods (Akpalu et al., 2008, Ayanlade et al., 2009). The study confirms the causal link that the limited crop yileds experienced by the small-scale farmers are the consequence of the many dry spells which had visited the farmers in the 30 years under study. In order to build adaptive capacity, this study recommends the restoration of the Peddie/NLM weather station, as well as the erstwhile alternatives of the locality such as large-scale irrigation schemes (Muza, 2017) and (ICT) interventions as early warning systems, which would be coupled with SOI aligned forecasting. This study recommends that such ICT data should include the integration of indigenous climate prediction knowledge and that the data are translated into a language which is end-user friendly for the rural small-scale farmer. The findings of this study could compel policy–makers to up-scale rural sustainable development to include the restoration, development and implementation of multi-hazard early-warning systems.

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