Journal of Sustainable Development; Vol. 7, No. 5; 2014
ISSN 1913-9063 E-ISSN 1913-9071
Published by Canadian Center of Science and Education

Managing Climate Risks Using Seasonal Climate Forecast Information in Vhembe District in Limpopo Province, South Africa

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Received: June 3, 2014 Accepted: July 15, 2014 Online Published: September 14, 2014

doi:10.5539/jsd.v7n5p68 URL: http://dx.doi.org/10.5539/jsd.v7n5p68

Abstract

The majority of small – scale farmers in the Vhembe district have been experiencing extreme climatic risk, high climate variability and change for a very long time. The majority of these small –scale farmers are vulnerable to all types of climate risk due to their low adaptive capacity, lack of access to technology as a result of level of education, lack of financial resources and also among other things low level of resilience and high level of poverty amongst these farmers. However, the majority of these small – scale farmers in the Vhembe district use different adaptive strategies as a way of preserving assets for future livelihoods including: (a) Drought resistant varieties, (b) Crop diversification, (c) Plant crops that require less water, (d) Some of these small – scale farmers use local climate indicators to monitor climate risk, (e) Adjust fertilizer input, (f) Use rainwater harvesting techniques. Different institutions in the country including the South African Weather Services, and the Agricultural Research Council, and the Limpopo Provincial Department of Agriculture, issue and disseminate the seasonal forecasts information to different districts including the Vhembe. Most of the time, the information has been disseminated to end-users in simple ways, but the need to find more out more about end users' needs is still required.

Keywords: seasonal forecasting, climate risk, drought impacts, climate information, Limpopo Province

1. Introduction

Since 1994, the South African Weather Service (SAWS) has been actively involved in research around the seasonal time-scale of climate predictions (Klopper *et al*., 1998; Landman and Manson, 1999; Tennant, 1999; O'Brien *et al*., 2000), with the aim of providing the best possible information on future climate conditions so that the risk in economic and social decisions are reduced. Climate information, even if provided in a perfect forecast, has limited value if it cannot be understood and used by the recipient to support the decision-making process (Glantz, 1977; Chagnon, 1992; Osunade, 1994; Mutiso, 1997; Huber and Pedersen, 1998; Eakin, 2002; Roncoli *et al*., 1999; Finan & Nelson, 2001; Roncoli *et al*., 2001a; Roncoli *et al*., 2002a; Luseno *et al*., 2000). Most studies of the value of the seasonal forecast have been conducted in the developed world (Mjelde *et al*., 1988; Lyakhou, 1994; Mosley, 1994; Mason, 1996; Nicholls, 1996; Mjelde *et al*., 1997; Landman & Mason, 1999; Letson *et al*., 2001; Klopper & Landman, 2003, O'Brien & Vogel., 2003). This paper will add to the few studies conducted in the southern African region. Various mechanisms have been used by several organizations to disseminate climate forecast information by distributing fliers, newsletter, electronic and printing media, technical briefs etc.

Forecasts, moreover, need to be expressed in the language of the users, providing the communities with possible appropriate alternatives to current production methods (Price, 1995; Arctic Council, 1995; Blench, 1999; Stern and Easterling, 1999; Stricherz, 1999; Letson *et al*., 2001; Valdivia and Gillies., 2003; Easton, 2004b; Hansen *et al*., 2004; Ziervogel *et al*., 2004). Blench (1999) and Finan (1999), argue that these forecasts will probably be useful only to certain types of producers, as not all farmers can equally access or use the information. It also requires that trust and communication exist between users and providers of climate forecast (Finan, 1999).

Effective use of seasonal forecast information that is useful to farmers, however, is wider than just issuing a forecast and includes a process of examining the current needs, problems and context in which users operate. The use of forecasts, however, provides more than just information about the forecast. The highly variable nature of rainfall in southern Africa enhances the potential use and value of reliable and dependable seasonal forecasts in the decision-making processes of different sectors. The knowledge that rainfall is so variable imparts considerable inertia on the implementation of such a process that may also often require major shifts in policy and redirection of investments (Mjelde *et al*., 1996; Nicholls, 1996).

Using climate forecasts to better manage climate-sensitive sectors such as agriculture is a new frontier in climate-risk management, with potentially very significant implications for farmers (IRI, 2000). Seasonal climate forecasts also require further integration into agriculture management (Orlove & Tosteson, 1999; Wilbanks & Kates, 1999; Unganai, 2000; McGee, 2004; Ritchie *et al*., 2004).

Seasonal climate forecast information in farming communities is increasingly becoming an option to manage risk due to the variable environment in which farmers operate heightened by the increasing pressure of the cost of inputs such as seeds, fertilizer and herbicides (Nicholls, 1996). As a result of lower yields, some farmers are unable to recover financial costs due to high cost of inputs. Seasonal climate forecasts may thus help farmers to make more informed decisions for farm management based on the seasonal climate information. In order for the seasonal climate forecast to be useful to farmers, however, the information must be accurate, reliable and have meaning. The user must be able to understand and interpret the information. Various institutions such as SAWS, ARC, PDA and various academic institutions disseminate seasonal climate forecast information through different structures before the season starts in the form of an advisory. The objectives of this paper: (a) Understand how farmers in Vhembe district are managing climate risks from 1920 to present. (b) This paper seeks to understand how farmers in Limpopo Province are managing risk and mid-season dry spells during the growing season. (c) Analyse the impact of rainfall variability during the growing season in Vhembe district.

2. Study Area

According to Van Averbeke, 2013:18, Vhembe borders Zimbabwe in the north and Mozambique in the east. It incorporates the territories of two former homelands of Venda and Gazankulu. The Venda homeland was created for the Venda-speaking people. Gazankulu was the territory allocated to the Tsonga-speaking people, also known as the Shangaan. Culturally, the VhaVenda are closely associated with the Shona people of Zimbabwe, whilst the cultural roots of the Shangaan are in Mozambique.

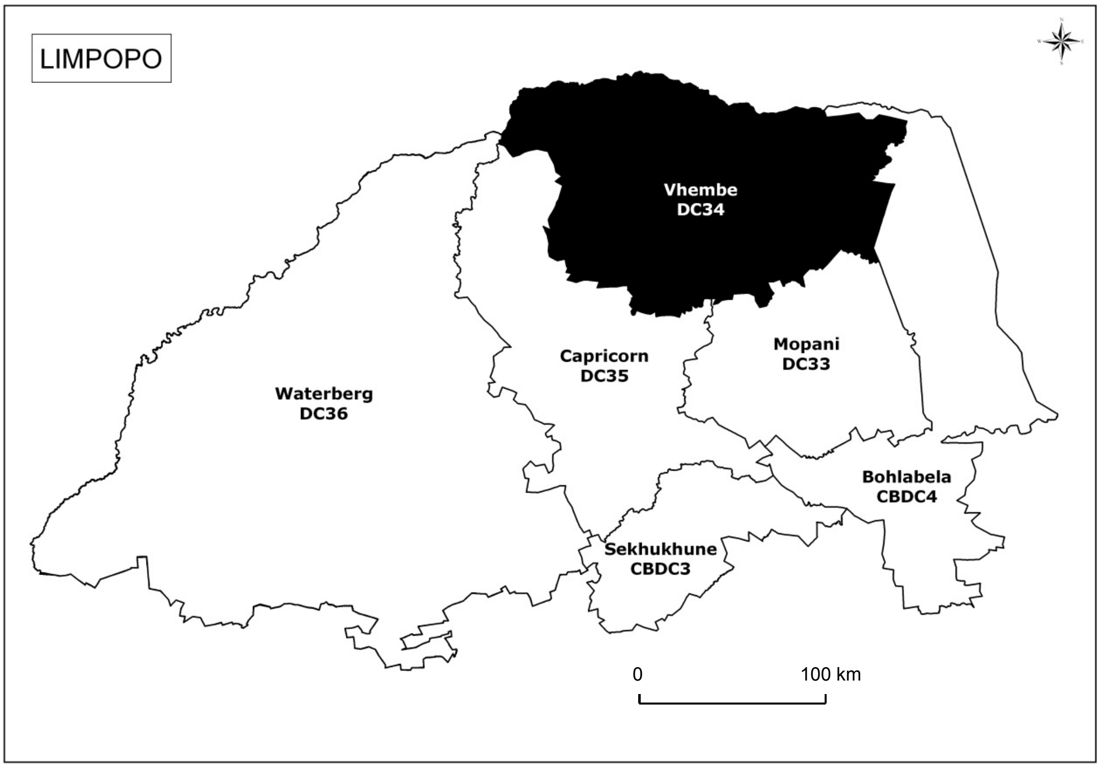

Figure 1. Location of the Vhembe district in the Limpopo Province

Source: Van Averbeke, 2013.

3. Materials and Methods

Two methods were used to analyze the results from this paper and this includes:

(a) Mean annual rainfall map:

The rainfall data downloaded from the AgroMet databank at the ARC-ISCW (South African Weather Service and ISCW weather stations) from 1920 – 1999 with a recording period of 10 years and more. Regression analysis and spatial modelling were utilized during the development of the surface.

(b) SPI time series:

Rainfall GIS surfaces, covering South Africa, have been produced from data within the ARC-ISCW Climate Databank. The databank holds historical data from the South African Weather Service and the ARC-ISCW. Monthly rainfall GIS surfaces are produced from the historical rainfall data over the period from 1920-2013. The rainfall surfaces are produced as follows:

(i) Rainfall data from between 1200 and 3000 mechanical and automatic stations are extracted.

(ii) The long-term average rainfall for a specific month is used as a trend surface for interpolation

(iii) Rainfall at a specific point is expressed as a percentage of the underlying rainfall trend surface

(iv) The rainfall percentage values for a specific ten-day period are interpolated using the inverse distance weight method.

The method results in a monthly rainfall surface that is true to the points where rainfall is recorded, but follows the climatology resulting from the influence of factors such as topography or distance from the ocean. The rainfall surfaces from 2003 onward are created through a combination of the abovementioned method and satellite rainfall estimates to supplement rainfall data over the South African plateau.

The resulting monthly rainfall surfaces are summarized to quaternary catchment (These are represented by +/- 1700 polygons in a GIS, covering the surface area of South Africa). For each catchment, the rainfall at monthly to 48-monthly time scale is transformed to Surface Precipitation Index (SPI) value for the catchment. The result is an SPI dataset for several time scales for each month since 1920. The SPI values can be used to study the time series of drought intensity classes by considering the traditional classification of the SPI ranges.

4. Results and Discussions

The high rainfall variability in Limpopo Province and some other parts of the country have led some farmers to use seasonal forecasts information for farm planning and decision making. Daily weather forecasts allow farmers to plan their daily activities. The daily weather forecast is provided by the SAWS through both the print and the electronic media and is published on line 24 hours.

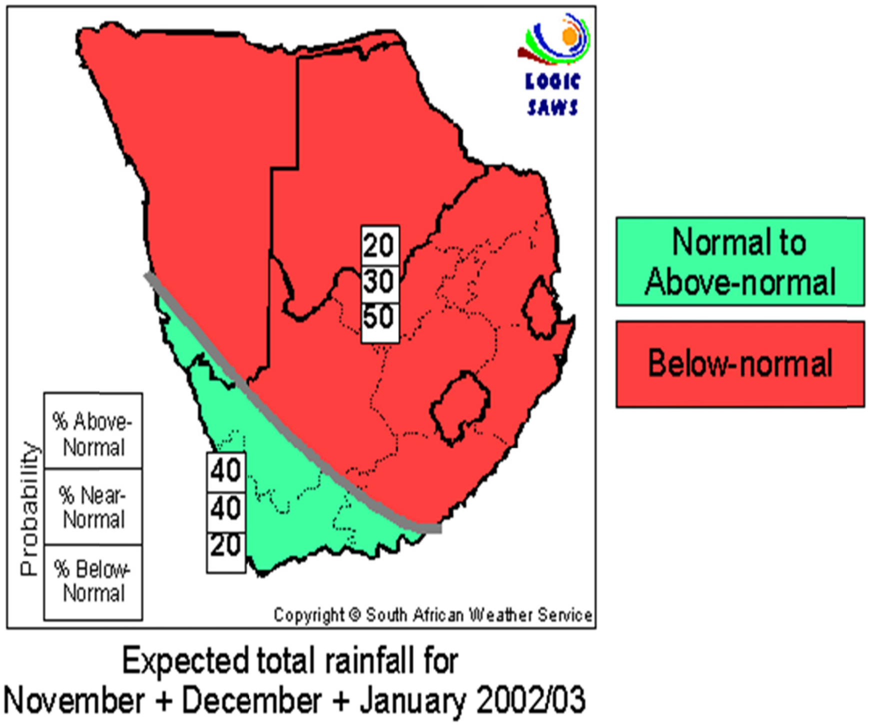

Figure 2. Seasonal climate forecast map for November, December and January 2002/2003

Source: SAWS, 2005.

Seasonal climate forecasts are issued as probabilistic outlooks for the future usually for a coverage period of three months and with a rather broad spatial coverage (Fig. 2). Conveying notions of ‘probabilistic’ information to a variety of users is not easy. It is important for users to understand that all seasonal forecast information or data are given as probabilities and not as deterministic. A probability forecast outlines how likely an event is likely to occur, as a percentage, and can assist farmers to be aware of the risks associated with weather and climate events. Seasonal climate forecasts are grouped into three categories of rainfall probability (a) above-normal (wet conditions), (b) near-normal (around average), (c) below-normal (dry conditions) (Fig. 2). The first category in the below normal, shows 50% probability of rainfall to be above-normal. The second category shows 30% probability for near-normal rainfall and the third category shows 20% probability for below-normal rainfall (Fig. 2).

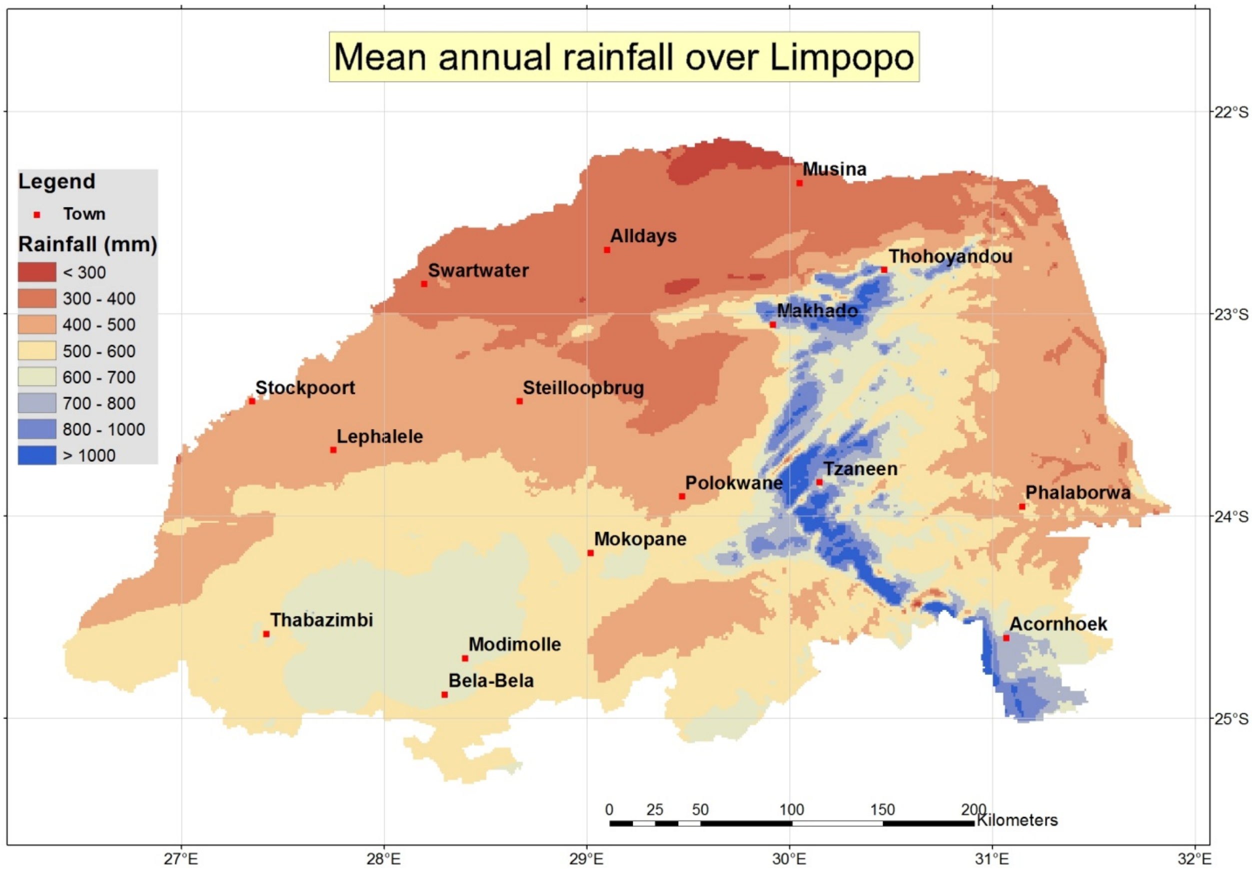

Figure 3. Mean annual rainfall map for Limpopo Province

Source: ARC-ISCW, 2014.

The average annual rainfall in the Vhembe district is 820 mm. The rainy season starts in October in most areas of the Limpopo Province especially in the Vhembe district. The rainfall pattern peaks in January-February months, and thus when floods are also expected (Fig. 3). Rainfall exceeds the potential evapotranspiration in months (December to March). It was also noted that the meteorological drought is the result of the negative deviation of rainfall from the mean and is normally the most common indicator for drought (Wilhite *et al.,* 2000; Wilhelmi & Wilhite, 2002). Limpopo Province has high climatic variability & change and therefore farmers need to have seasonal climate forecast information or projections in advance in order for them to be able to plan their farming calendar accordingly. Figure 3 shows that Makhado and Thohoyandou areas in the Vhembe district are located in micro- climatic areas. In the Vhembe district, for example, the highest average monthly amount of rainfall received is normally from November to March every year (Mpandeli, 2006). February usually records the highest rainfall of more than 184 mm. During the winter months, from May to August, climate is warm during the day with dry air prevailing. Temperature can drop sharply in the evenings. During the winter period, less than 20 mm of rainfall monthly is usually received in the Vhembe district with the average rainfall dropping to 8 mm during August in 2003 (Mpandeli, 2006). The majority of the farmers in Limpopo Province generally start planting their summer crops during September. The mean annual rainfall figures from Figure 3 indicate very low rainfall especially in areas such as Musina, Alldays and Swartwater, therefore the mean annual rainfall for these areas are less than 300 mm. In these areas such as Musina, Alldays and Swartwater farmers respond different to drought and extreme climatic events. According to Mpandeli, 2006, commercial farmers most of time have more wide choices during drought than subsistence and small –scale farmers. Due to the fact that the majority of the commercial farmers have strong financial back ups, they could easily switch their enterprise to a more safe environment or to an area where they will be able to cope and adapt easily and most of the commercial farmers had enough reserves their activities even if they are farming in new area. However, for subsistence and small – scale farmers, they have limited options due to the fact that these farmers do not have enough financial resources, they do not have collateral or security in case if they need loans from banks compared to the commercial farmers in the area.

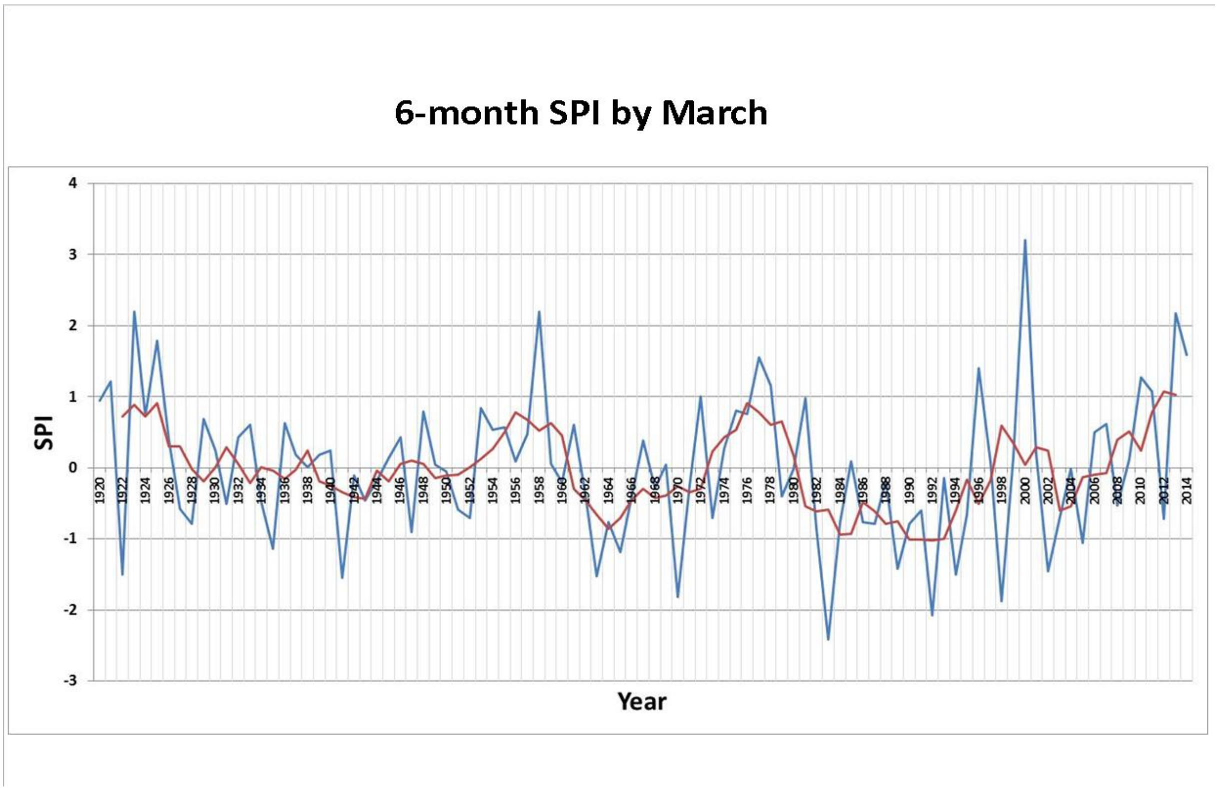

Figure 4. Shows the 6-month Surface Precipitation Index (SPI) for the quaternary catchment encompassing Musina from 1920 to 2014 in Vhembe district, Limpopo Province

Figure 4 shows the 6-month SPI for the quaternary catchment encompassing Musina from 1920 - 2014. Multi-year dry periods are indicated. The clustering of dry years exacerbates the effect of low rainfall. Figure 4 shows that the Musina area in the Vhembe district received significant Surface Precipitation Index for the following years 1924, 1958, 1977, 1986, 2000 and 2013. This area had more than 1.5 SPI above the mean. It was noted that the serious dry spells were experienced in the following years in the Musina area 1922, 1941, 1970, 1983 and 1992. The lowest year was 1983 with – 2.45 below the mean. During the dry spells in the Musina area, the majority of farmers lost large numbers of livestock, shortage of drinking water, low yields and shortage of seeds for subsequent cultivation (Mpandeli & Maponya, 2014). The driest periods in the Musina area was in 1983, the majority of farmers had to seek assistance from the South African government and most of these farmers were commercial farmers (Fig. 4). Low SPI values indicate drought conditions, high values indicate very wet conditions.

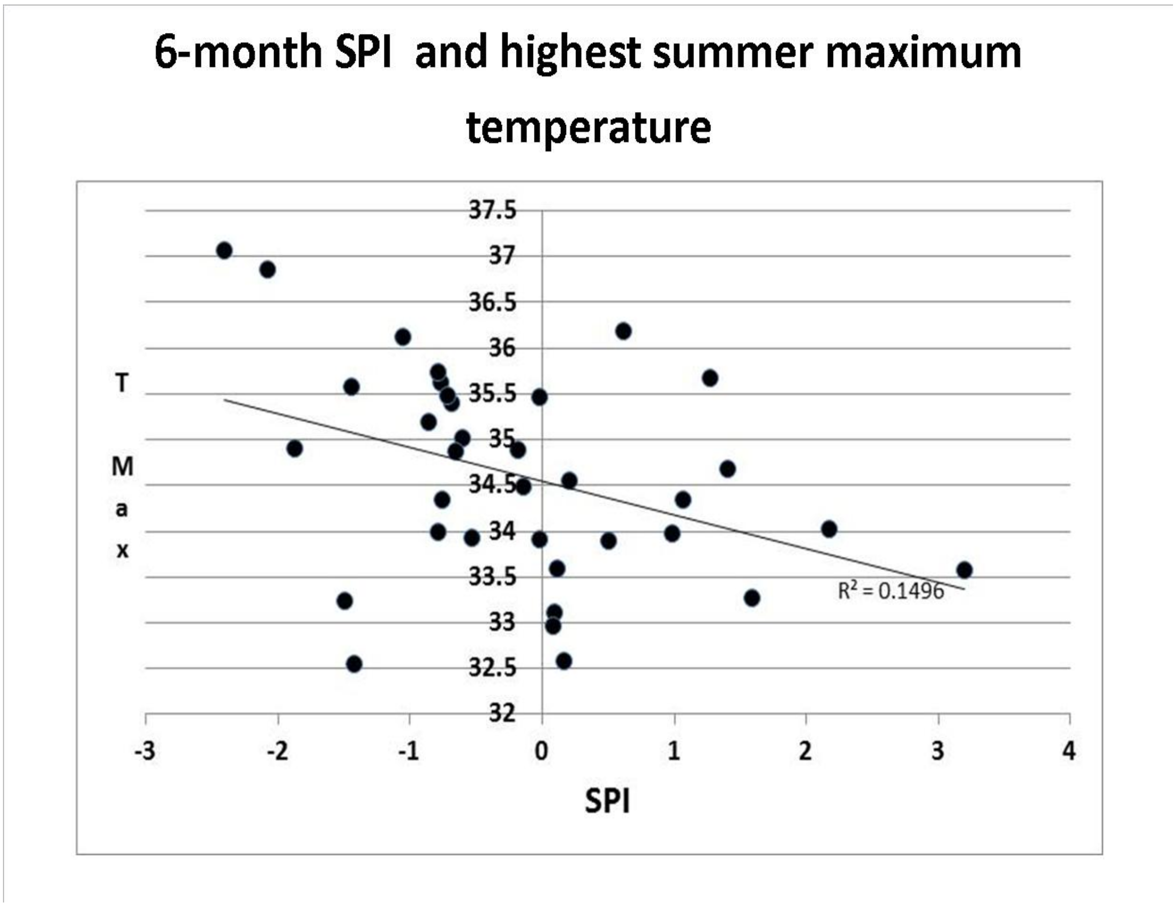

Figure 5. Shows the highest summer maximum temperature in Vhembe district, Limpopo Province

Fig. 5 shows the SPI and TMax since 1980 shows the inverse relationship between summer rainfall (6-month SPI) and the highest maximum temperatures during the summer – showing that during dry years, higher temperatures increase the negative impact of low rainfall through increased potential evapotranspiration.

Vhembe district sometimes experiences extremes in temperatures. When the temperature is high, there is also a high probability of evaporation during that particular period (Fig. 5). Temperatures, for example, can reach more than 35°C during summer. According to Mpandeli, 2006, the average monthly maximum temperature most of the time can reach more than 35°C especially during summer (Mpandeli, 2006). Occasional frosts that may occur from early June to mid-August are a feature in the area from 1995 to 2003. During the winter months cold fronts normally occur, and these conditions can damage crops and livestock. It is important to note that farmers in the Vhembe district have always apply different coping and climate change adaptation strategies in order to increase production during drought periods including: (a) Adjust fertilizer inputs, (b) Practice crop diversification, (c) Food preservation (d) Adopt destocking during uncertainty periods. Drought, for example, has also been a recurrent phenomenon occurring in the 1960s, 1980s, 1990s, 2002 and 2003 (Tyson and Dyer, 1978; Vogel *et al*., 2000; Adger et al., 2002; Kihupi *et al*., 2003, Mpandeli, 2006). Drought frequently adversely affects agricultural production in various provinces including Limpopo, Free State and Northern Cape (e.g. *Sowetan*, 2003).

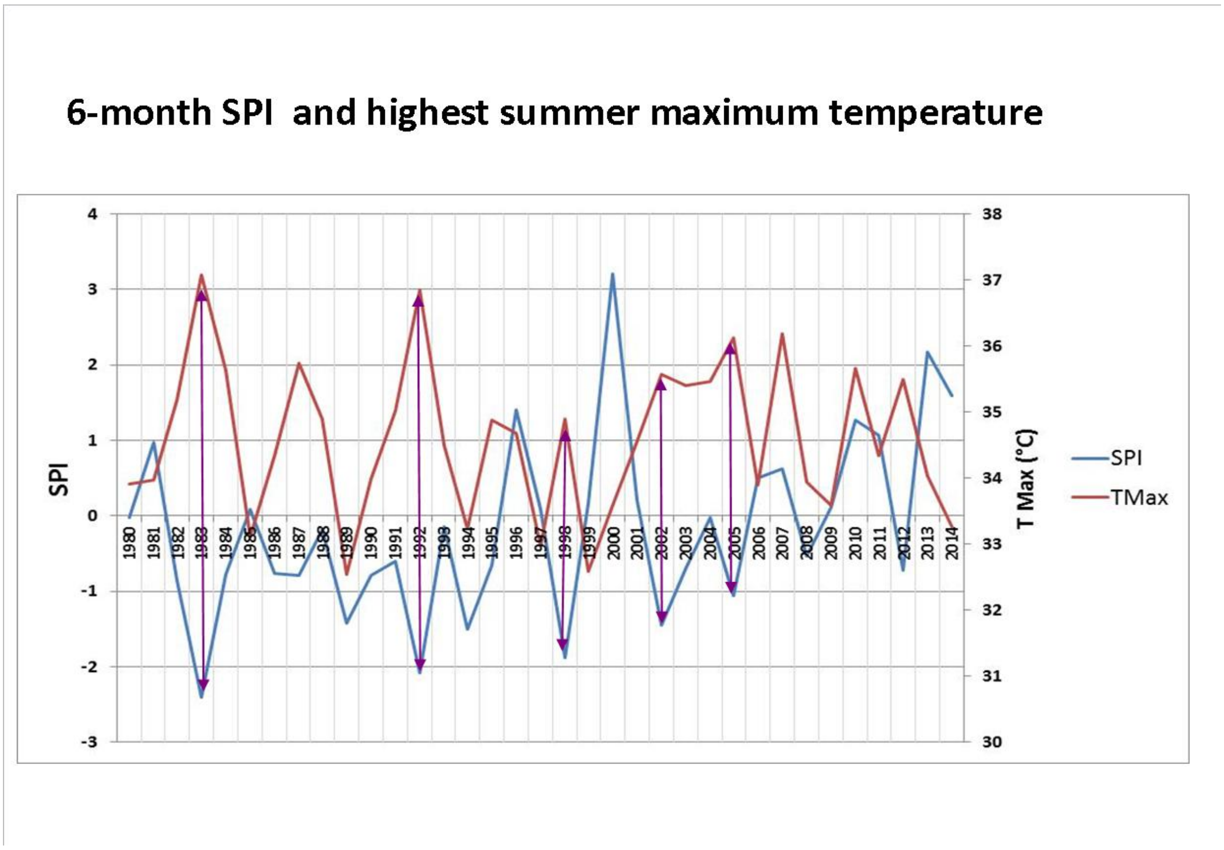

Figure 6. Shows the surface precipitation index and highest summer maximum temperature from 1980 to 2014 in Vhembe district, Limpopo Province

Figure 6 shows that the SPI and TMax since 1980 shows the inverse relationship between summer rainfall (6-month SPI) and the highest maximum temperatures during the summer – showing that during dry years, higher temperatures increase the negative impact of low rainfall through increased potential evapotranspiration. Vhembe district sometimes experiences extremes in temperatures. When the temperature is high, there is also a high probability of evaporation during that particular period (Fig. 6). Temperatures, for example, can reach more than 35°C during summer. The average yearly maximum temperature from 1980 to 2014 during summer was 37°C. The figure 6 shows that the highest maximum temperature was experienced in 1983, 1992, 2005 and 2007. Farmers in this area need to come up with varies coping and climate change adaptation strategies including: (a) Use of drought resistance seeds, (b) Use early matured crop varieties, (c) Practice crop diversification system (e) Changing farming practices, (f) Use seasonal climate forecasting etc. According to Sivakumar, 2000, climate information is very useful because it assists farmers to be able to plan their agricultural calendar accordingly. For example, if farmers can access climate information in advance on issue such as advisory, early warning on drought, farmers can able to counteract any threats posed by drought impacts on time as long as the information is reliable, accurate and also simply to interpret & understand. Problems and constraints that might come as result of climate change include high temperatures, decreased precipitation, incidence of fungal crop diseases such as army worm, destruction of habitats, environmental degradation and extinction of plants and animal species (Matarira et al., 2004). Climate information, including seasonal climate forecasts, has been heralded as a promising tool for early-warning systems and agricultural risk management in Southern Africa (Vogel, 2000; Vogel et al., 2000).

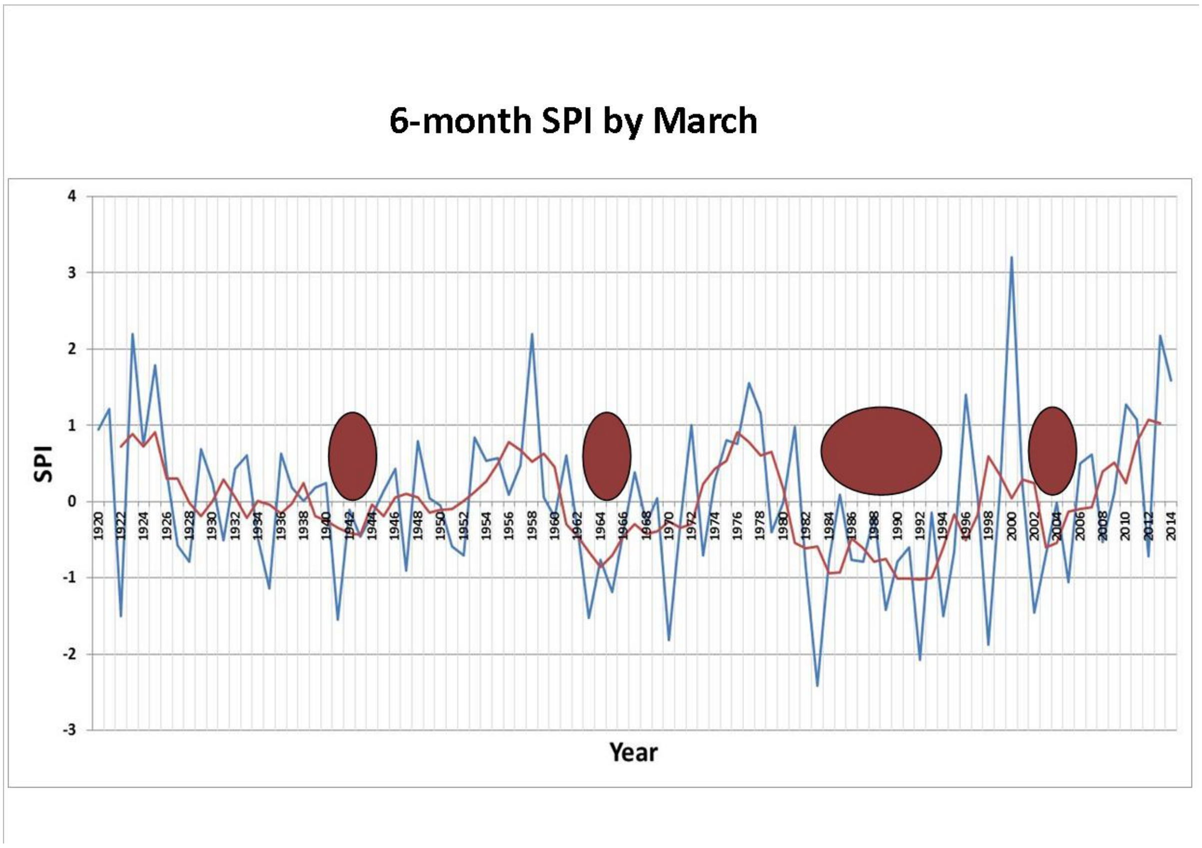

Figure 7. Shows the surface precipitation index from 1920 to 2014 in Vhembe district, Limpopo Province

The climate of the Limpopo Province as indicated previously is usually hot and is characterised by hot summers and dry winters. Rainfall can vary markedly over time (Fig. 7). The highest annual average rainfall recorded in 2000, for example, was 1612 mm (Mpandeli, 2006). According to Mpandeli, 2006, heavy rain in the year 2000, resulted in flooding, loss of properties, loss of human life and loss of agricultural production. The lowest average annual rainfall recorded was 438 mm in 1992. Limpopo Province has been characterised by low rainfall and recurrent drought problems especially in 1981/84, 1988/89, 1991/92 and in the 2004 and these hinder agricultural production in the province. The majority of farmers in 1992 lost high volumes of crops and livestock due to shortages of water and because of drought problems during that year (Mpandeli, 2006).

4.1 Living with Drought in the Vhembe District

According to Mpandeli and Maponya, 2014, Limpopo Province is characterised by high climatic variability. This is a serious problem in Limpopo Province considering the fact that the province is in a semi-arid area with low, unreliable rainfall. The rainfall distribution pattern, for example, in the Vhembe district is characterised by wet and dry periods depending on the geographical location. In the Vhembe district high rainfall is usually experienced in the Tshakhuma and Levubu areas. Most of the rainfall received in the Vhembe district is in the form of thunderstorms and showers, and this makes rainfall in the district vary considerably (Mpandeli & Maponya, 2014). The impact of lower rainfall has negative effects on the agricultural sector, low rainfall resulting in decreases in agricultural activities, loss of livestock, shortage of drinking water, low yields and shortage of seeds for subsequent cultivation (Mpandeli & Maponya, 2014).

4.2 Vegetation Characteristics and Drought Impacts in the Vhembe district

In the Limpopo Province, the condition of the vegetation is a major concern for livestock farmers. Limpopo Province is characterised by different kinds of veld types, the kind of veld type differs especially in the morphology, palatability and the nutritive value. Sweet veld grass is found around the Thohoyandou area in the Vhembe district and the sweet veld grows in frost-free and low-lying areas (Acocks, 1998). Sourveld grows mostly in the Tshakhuma area; these types of grass usually grow in a high rainfall area.

The quality and status of vegetation can be severely impacted by drought periods. One way to monitor the condition of the vegetation is to use the Normalised Difference Vegetation Index (NDVI). A relationship between rainfall and vegetation status exists, usually expressed as an index the NDVI. This index generally shows the presence and absence of green vegetation (Fig. 8). Since green vegetation reflects more infrared radiation than visible radiation, the higher the value of NDVI, the higher the vegetation activity. An example of the relationship between periods of drought and vegetation can be observed in Fig. 8.

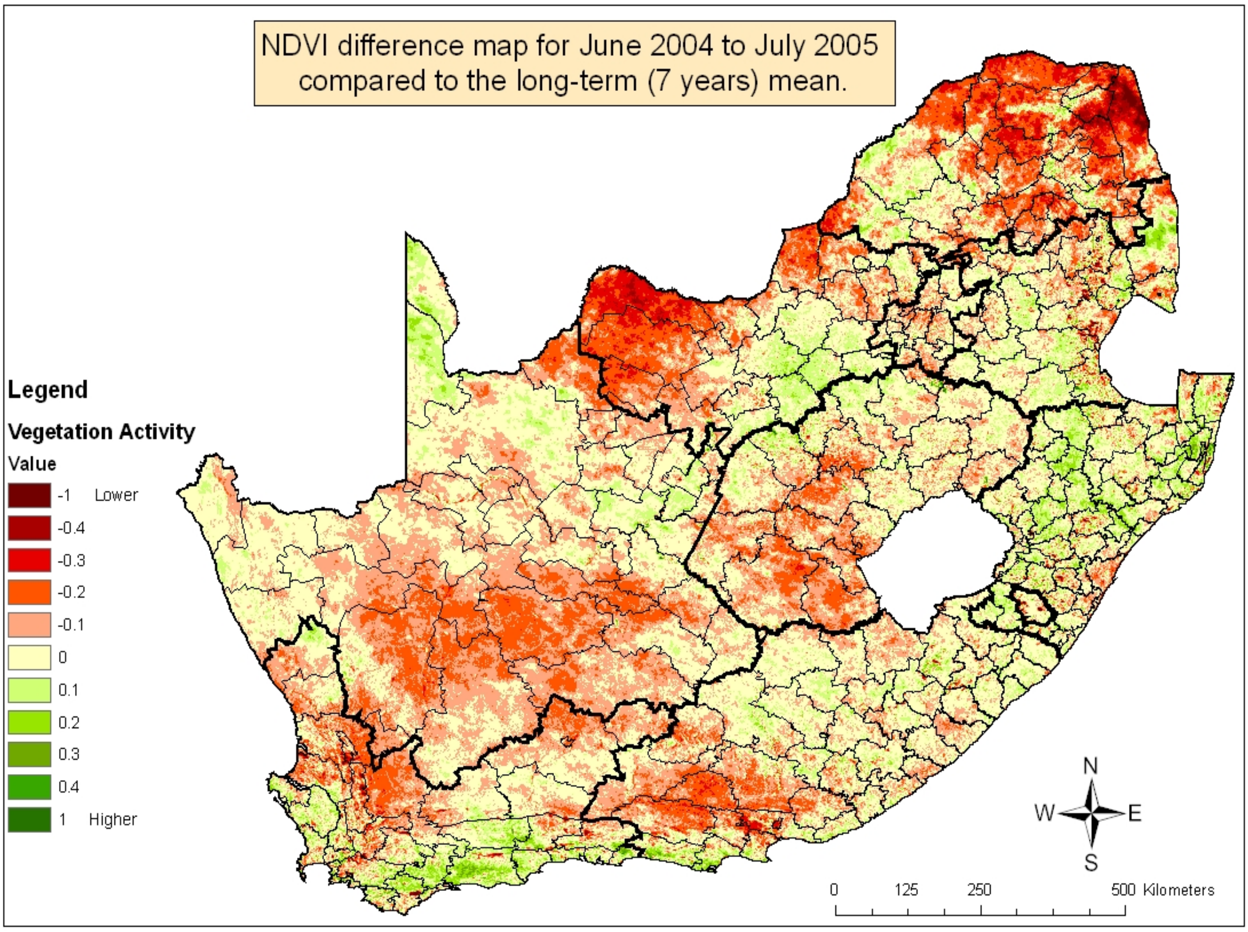

Figure 8. Normalised difference vegetation index map for June 2004 to July 2005, compared to the long-term mean for seven years

Source, ARC-ISCW, 2005.

NDVI can thus be displayed and interpreted spatially over time. For example, from Fig. 8, one can infer that the rainfall distribution was very low in Limpopo Province compared to other parts of the country for the period June 2004 to July 2005. The red colour in most parts of Limpopo Province shows that the vegetation activity was lower than normal over this period. The green colour shows that there was higher vegetation than normal. In areas where the green colour dominates, there was good rainfall distribution (Fig. 8).

The combination of these factors, for example low rainfall, poor vegetation condition and a range of other constraints, heightened during droughts, unfortunately produces a range of additional stressors for farmers in the area. Poor vegetation usually means poor grazing and therefore poor cattle condition. This can further translate into loss of livelihoods as poor cattle often receive poor market prices.

Older farmers in the Vhembe district indicated that drought has been a recurring process since the 1950s and this it was confirmed by results from figure 6. Some farmers stated that in 1992 they had severe drought problems resulting in a shortage of grazing and crop failures in many parts of the district (Bakali, pers. comm., 2004). Livestock was slaughtered and farmers had to sell their livestock at prices as low as R5 per unit. The drought impacts in 1992 increased farming debt and affected food exports in the province (Koch, pers. comm., 2005 and Mpandeli, 2006). According to Mpandeli, 2006, farmers in the Vhembe district farmers describe drought based on the following factors such as food and feed shortages, low rainfall, decrease in water availability, dying vegetation and animals etc. These factors were also highlighted by O' Farrell et al., 2009. Accroding to O' Farrell et al., 2009 farmers described drought in terms of the way it affected the agricultural systems.

5. Conclusions and Recommendations

There are several issues that emerge in this paper: (i) The majority of farmers are using seasonal climate in order to make decisions in their farming business. The majority of these small –scale farmers are beginning to use seasonal forecast information in order to manage climatic risk. Both small – scale and commercial farmers are using seasonal forecast information in order: (a) Prepare a seasonal calendar for agricultural activities, (b) Make informed decisions for farm planning management and decision- making, and, (c) Some of the farmers are using seasonal forecast information as a tool to manage risk due to the variable environment in which they operate. It was noted, however, that in order to make a seasonal forecast useful to farmers it must be, accurate, reliable and have meaning.

Farmers have used a variety of information sources to help themselves to manage climate risk. These farmers, for example, have been exposed to scientific climate forecasting with some starting to use the information as a guide during the decision-making process. The rainfall distribution patterns in the Vhembe district various from area to area and small –scale farmers are using various coping and climate change adaptation strategies including: (a) Crop diversification, (b) Early planting strategies, (c) Plant crops that require less water, (d) Some farmers use local climate indicators, for example cloud formation as part of the decision making tool, (e) Changing farming practices. If small – scale farmers in the Vhembe district are planning to obtain higher yields they should use several climate change adaptation strategies in order to have good agricultural production and be able to sustain their livelihoods. The fact that these small – scale farmers are situated in a semi –arid area with high climatic variability and poor rainfall distribution makes farming very difficult to manage.

Acknowledgements

The author of this paper wishes to thanks the Agricultural Research Council – Institute for Soil, Climate and Water (ARC – ISCW) for verifying the data.

References

Adger, W. N., Huq, S., Brown, K., Conway, D., & Hulme, M. (2002). Adaptation to climate change: Setting the Agenda for Development Policy and Research. *Progress in Development Studies, 3*(3), 179-195. http://dx.doi.org/10.1191/1464993403ps060oa

Arctic Leaders Summit Declaration. (1995). The Declaration on its establishment recognized 'the traditional knowledge". *Arctic Council Press release*. Ottawa, Canada.

Bakali, agricultural scientist, personal communication, 2004.

Blench, R. (1999, November 25). Seasonal Climate Forecasting: Who can use it and how it should be disseminated? *Natural Resource Perspectives,* (47). Retrieved from http://www.oneworld.org/odi/nrp/47.html

Chagnon, S. A. (1992). *Gender and Migration in the Developing countries.* London: Belhaven Press.

Eakin, H. (2002). Seasonal climate forecasting and the relevance of local knowledge. *Physical Geography, 20*, 447-460.

Easton, P. (2004). West African languages: medium and message. In: Indigenous knowledge: local pathways to global development. *The World Bank*, 64-167.

Finan, T. J, & Nelson, D. R. (2001). Making rain, making roads, making do: public and private adaptations to drought in Ceará, Northeast Brazil. *Climate Research, 19*, 97-108. http://dx.doi.org/10.3354/cr019097

Finan, T. J. (1999). Drought and Demagognemy: A Political Ecology of Climate Variability in Northeast Brazil, *Workshop Proceedings from Public Philosophy, Environment, and Social Justice*: October, 21-22, 1999, *Carnegie Council on Ethics and International Affairs*. New York, USA.

Glantz, M. H. (1977). The value of long-range weather forecasting for the West African Sahel. *Bulletin of the American Meteorological Society, 58*, 150-158. http://dx.doi.org/10.1175/1520-0477(1977)058<0150:TVOALR>2.0.CO;2

Hansen, J. W., Marx, S., & Weber, E. (2004). The role of climate perceptions, expectations and forecasts in farmer decision making: the Argentine Pampas and South Florida. *International Research Institute for Climate Predictions Technical Report,* 04-01, Palisades, New York.

Huber, T., & Pedersen, P. (1998). Meteorological knowledge and environmental ideas in traditional and modern societies: the case of Tibet. *Journal of the Royal Anthropological Institute, 3*, 577-598. http://dx.doi.org/10.2307/3034768

IRI (International Research Institute for Climate Prediction). (2000). *Proceedings of a conference held on 20 July 1992 at IDS, Sussex, UK.* Retrieved June 14, 2000, from http://iri.Ucsd.Edu/forecast/sup/index.html

Kihupi, N., Kingamkono, R., Dihenga, H., Kingamkono, M., & Rwamugira, W. (2003). Integrating indigenous knowledge and climate forecasts in Tanzania. In Vogel C., & O'Brien K. (Eds.), *Coping with climate variability: the use of seasonal climate forecasts in Southern Africa* (pp. 155-169). Ashgate, Burlington, Vermont.

Klopper, E., & Landman, W. A. (2003). A simple approach for combining seasonal forecasts for southern Africa. *Meteorological Applications, 10*, 319-327. http://dx.doi.org/10.1017/S1350482703001014

Klopper, E., Landman, W. A., & Van Heerden, J. (1998). The predictability of seasonal maximum temperature in South Africa. *International Journal Climatology, 18*, 741-758. http://dx.doi.org/10.1002/(SICI)1097-0088(19980615)18:7<741::AID-JOC279>3.0.CO;2-B

Koch, agricultural project manager, personal communication, 2005.

Landman, W. A., & Manson, S. J. (1999). Change in the association between Indian Ocean sea-surface temperature and summer rainfall over South Africa and Namibia. *International Journal Climatology, 19*, 1477-1492. http://dx.doi.org/10.1002/(SICI)1097-0088(19991115)19:13<1477::AID-JOC432>3.0.CO;2-W

Letson, D., Llovet, I., Podestá, G. P., Royce, F., Brescia, V., Lema, D., & Parellada, G. (2001). User perspectives of climate forecasts: crop producers in Pergamino, Argentina. *Climate Research, 19*, 57-67. http://dx.doi.org/10.3354/cr019057

Luseno, W. K., McPeak, J. G., Barrett, C. B., Little, P. D., & Gebru, G. (2000). Assessing the value of climate forecast information for pastoralists: Evidence from Southern Ethiopia and Northern Kenya. *World Development, 31*, 1477-1494. http://dx.doi.org/10.1016/S0305-750X(03)00113-X

Lyakhou, A. A. (1994). Analysis of economic benefits of short term, medium term and long term forecast. WMO/TD-No 630, Geneva, 278-280.

Mason, B. J. (1996, November). The role of meteorology in the national economy. *Weather document*, 382-393.

Matarira, C. H., Makadho, J. C., & Mukahanana-Sangarwe, M. (2004). *Vulnerability and Adaptation of Maize Production to Climate change in Zimbabwe.* Government of the Republic of Zimbabwe, Ministry of Environment and Tourism. Harare.

McGee, R. (2004). Unpacking policy: actors, knowledge and spaces. In Brock K., McGee R., & Gaventa J. (Eds.), *Unpacking policy: knowledge, actors, and spaces in poverty reduction in Uganda and Nigeria* (pp. 1-26). Fountain Publishers, Kampala.

Mjelde, J. W., Sonka, S. T., Dixon, B. L., & Lamb, P. J. (1988). Valuing Forecast Characteristics in a Dynamic Agricultural Production System. *American Journal of Agricultural Economics, 70*, 674-684. http://dx.doi.org/10.2307/1241506

Mjelde, J. W., Thompson, T. N., Nixon, C. J., & Lamb, P. J. (1997). Utilising a farm-level decision model to help prioritise future climate prediction research needs. *Meteorology Applied Journal, 4*, 161-170. http://dx.doi.org/10.1017/S1350482797000418

Mosley, M. P. (1994). Economic and social benefits of climatological information and services. *A review of existing assessments*. WCASP-38, WMO/TD, 78, 38.

Mpandeli, N. S. (2006). *Coping with climate variability in Limpopo Province*. Unpublished PhD thesis, University of Witwatersrand.

Mpandeli, N. S., & Maponya, P. I. (2014). Constraints and challenges facing the small scale farmers in Limpopo Province. *Journal of Agricultural Science, 6*(4). http://dx.doi.org/10.5539/jas.v6n4p135

Mutiso, S. K. (1997). Indigenous knowledge in drought and famine forecasting in Machakos District, Kenya. In Adams W. M., & Slikkerveer L. J. (Eds.), *Indigenous knowledge and change in African agriculture, Ames IA* (pp. 67-86). Center for Indigenous Knowledge for Agriculture and Rural Development.

Nicholls, J. M. (1996). Economic and social effects of climatological information and services. *Are view of existing assessments*, WOASP-38, WMO/TD: 78, 38.

O' Farrell, P., Anderson, P., Milton, S., & Dean, W. (2009). Human response and response to drought in the arid zone: lessons from southern Africa. *South African Journal of Science, 105*(1-2), 34 -39.

O'Brien, K., & Vogel, C. (2003). A future for forecasts? In Vogel C., & O'Brien K. (Eds.), *Coping with climate variability: the use of seasonal climate forecasts in Southern Africa* (pp. 197-211). Ashgate, Burlington, Vermont.

Orlove, B., & Tosteson, J. (1999). The application of seasonal to interannual climate forecasts based on EL Nino-Southern Oscillation (ENSO) events: *Lesson from Australia, Brazil, Ethiopia, Peru and Zimbabwe:WP 99-3. Institute of International Studies,* University of California, Berkeley.

Osunade, M. A. A. (1994). Indigenous Climate Knowledge and Agricultural Practices in South-western Nigeria. *Malayasian Journal of Tropical Geography, 1*, 21-28.

Ritchie, J. W., Zammit, C., & Beal, C. (2004). Can seasonal forecasting assist in catchment water management decision-making? *A case study of the Border Rivers catchment in Australia. Agriculture, Ecosystem, and Environment, 104*, 553-565. http://dx.doi.org/10.1016/j.agee.2004.01.029

Roncoli, C. S., Bahadio, S., & Boena, S. (1999). *The role of rainfall information in farmers decisions: Ethnographic research in the Central Plateau (Burkina Faso), Technical Report 1, Climate Forecasting and Agricultural Resources Project*, University of Georgia, Athens.

Roncoli, C., Ingram, K., & Kirshen, P. (2001). The costs and risks of coping: Household impacts and farmer responses to drought in Burkina Faso. *Climate Resources, 19*(2), 119-132. http://dx.doi.org/10.3354/cr019119

Roncoli, C., Ingram, K., Kirshen, P., & Jost, C. (2001). Modernity meets marginality: Impacts of seasonal rainfall forecasts on rural livelihoods in Burkina Faso, *Paper presented at the Society for Applied Anthropology Meetings*, Merida, Mexico, March.

Roncoli, C., Ingram, K., Kirshen, P., & Jost, C. (2004). Meteorological meanings: understandings of seasonal rainfall forecasts by farmers of Burkina Faso. In Strauss S., & Orlove B. (Eds.), *Weather, climate and culture, Berg, Oxford* (pp. 181-202).

Sivakumar, M. V. K. (2000). Climate prediction and agriculture. Proceedings of START/WMO International Workshop, Geneva, Switzerland, 27–29 September 1999. International START Secretariat, Washington, DC.

Sowetan. (2003). Drought takes its toll in Limpopo Province. 5 May 2003, *Sowetan, Gauteng*, 23.

Stern, P., & Easterling, W. (Eds). (1999). *Making Climate Forecasts Matter: Panel on the Human Dimensions of Seasonal- to- Interannual Climate Variability. Committee on the Human Dimensions of Global Change. Commission of Behavioural and Social Sciences and Education.* National Research Council. National Academy Press, Washington, D. C.

Stricherz, V. (1999). Long-Term Forecast Cold Give Nations Tools to Survive Climate Change. Retrieved from http://www.euralert.org/releases/ww-/fno11999.html

Tennant, W. J. (1999). Numerical forecasting of monthly climate in Southern Africa. *International Journal of Climatology, 19*, 1319-1336. http://dx.doi.org/10.1002/(SICI)1097-0088(199910)19:12<1319::AID-JOC381>3.0.CO;2-9

Tyson, P. D., & Dyer, T. G. J. (1978). The predicted above-normal rainfall of the seventies and the likelihood of droughts in the eighties in South Africa. *South African Journal of Science, 74*, 372-377.

Unganai, L. S. (2000). Application of long range rainfall forecasts in agricultural management: a review of Africa's experience. *Proceedings of the International Forum on Climate Prediction, Agriculture and Development, International Research Institute for Climate Prediction.*

Valdivia, C., & Gilles, J. L. (2003). Coping and adapting to climate variability in the Andes: strategies and local knowledge, *Paper presented at the Open Meeting of the Global Environmental Change Research Community*, Montreal, Canada, 16-18 October 2003.

Van Averbeke, W. (2013). Improving Plot Holder Livelihood and Scheme Productivity on Smallholder Canal Irrigation Schemes in the Vhembe District of Limpopo Province.

Vogel C. (2000). Usable science: an assessment of long-term seasonal forecasts among farmers in rural areas of South Africa. *South African Geographical Journal, 82*, 107-116. http://dx.doi.org/10.1080/03736245.2000.9713700

Vogel, C., Laing, M., & Munnik, C. (2000). Drought in South Africa. In Wilhite, D. (Ed.), *Drought Volume 1, A Global Assessment, Routledge Hazards and Disasters Series* (pp. 348-366). London.

Wilbanks, T. J., & Kates R. W. (1999). Global change in local places: How scales matters. *Climate Change, 43*(3), 601-628. http://dx.doi.org/10.1023/A:1005418924748

Wilhelmi, O. V., & Wilhite, D. A. (2002). Assessing Vulnerability to Agricultural Drought: A Nebraska Case Study. *Natural Hazards,* (25), 37-58. http://dx.doi.org/10.1023/A:1013388814894

Wilhite, D. (2000). Drought as a natural hazard: Concepts and definitions. Drought Volume 1: A Global Assessment. In D. A. Wilhite (Ed.), *Routledge Hazards and Disasters Series* (Vol. 1, pp. 3-18). Routledge.

Wilhite, D. (2000). *Drought Preparedness in the sub-Saharan Africa context* (Vol. I & II). London: Routledge.

Ziervogel, G., Bithell, M., Washington, R., & Downing, T. E. (2004). Agent-based social simulation: A method for assessing the impact of seasonal climate forecast application among smallholder farmers. *Agricultural Systems, 83*, 1-26. http://dx.doi.org/10.1016/j.agsy.2004.02.009